Advanced Nuclear Frontiers Webinar Series

ADVANCED NUCLEAR 101

UNDERSTANDING THE BASICS OF ADVANCED NUCLEAR TECHNOLOGY AND WHAT IT MEANS FOR WYOMING

MONDAY, DECEMBER 13, 2021
12:00 - 2:00 PM

REGISTER:
WWW.UWYO.EDU/SER/EVENTS

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Presented By The Wyoming Energy Authority
in collaboration with the University of Wyoming School of Energy Resources

WYOMING ENERGY AUTHORITY

UNIVERSITY OF WYOMING | School of Energy Resources

For questions or more information email Christine Reed at christine.reed@uwyo.edu

December, 2021

Dr. Steven Aumeier
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Idaho National Laboratory

Advanced Nuclear Energy – Perspectives for Wyoming Stakeholder Consideration

Idaho National Laboratory

Overview

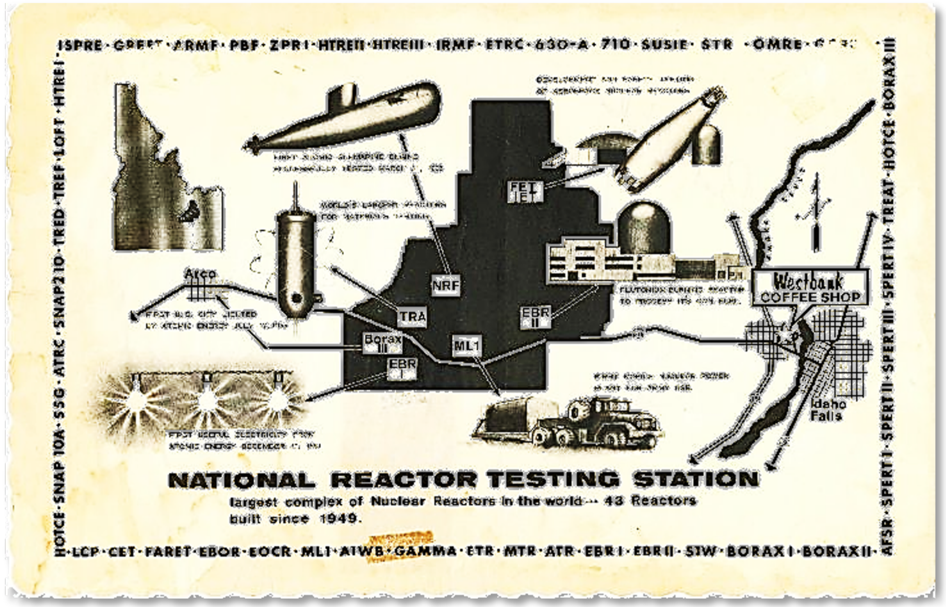
- Yesterday, today and tomorrow – Perspective on fundamental differences in deployment environments and markets
- Why the different technologies now? What's new, and what's not.
- The role of the national laboratories v. industry
- Economic potential in a net-zero world
- Questions that might be considered

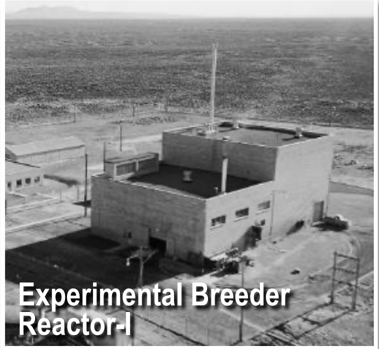
At the beginning of the age of commercial nuclear energy 65 years ago	Today	Our future. 2040 and beyond
Global population 2.8 B	Global population 7.8 B	Global population exceeding 9 B
Nuclear technology is new and novel; First commercial power plant at Shippingport, PA comes on-line	444 reactors, 31 countries, 388 Gwe, 11% of global generations, $2.6 T / 2-decade global market	Asymmetric global growth in baseload commercial nuclear energy; markets expand as nuclear powers more industry and non-baseload operations
130 quads global primary energy consumption; angst about American energy supply security	540 quads global primary energy consumption, angst about climate security and energy distribution	800 quads global primary energy consumption
U.S. per capita GDP $3 K (current USD)	U.S. per capita GDP $58 K (current USD)	U.S. per capita GDP > $90 K (current USD)

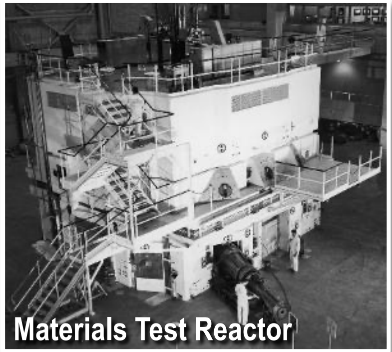
From a New Invention to a Mature Global Market –
The Evolution of Civilian Nuclear Energy

Nuclear Power was pioneered by the United States at Idaho National Laboratory

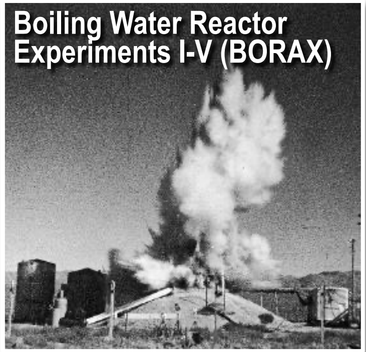
- First nuclear power plant
- First U.S. city to be powered by nuclear energy
- First submarine reactor tested
- First mobile nuclear power plant for the Army
- Demonstration of self-sustaining fuel cycle
- Basis for LWR reactor safety
- Aircraft and aerospace reactor testing
- Materials testing reactors

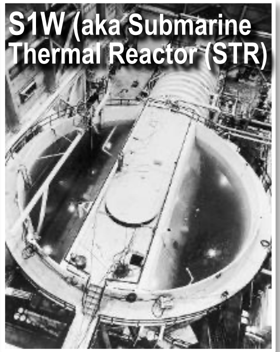


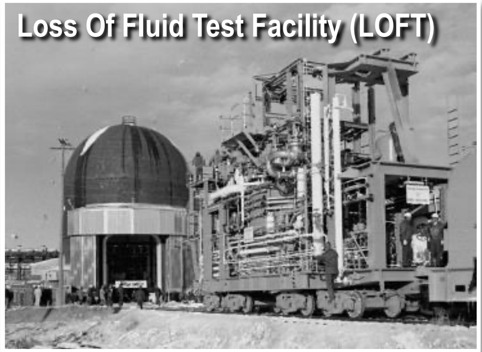

Experimental Breeder Reactor-I


Materials Test Reactor


Special Power Excursion Reactor Tests I though IV (SPERT)


Boiling Water Reactor Experiments I-V (BORAX)


S1W (aka Submarine Thermal Reactor (STR)


Loss Of Fluid Test Facility (LOFT)

Advanced Reactors Are Trending Smaller, Integrated, and Modular – Why?

- Versatile applications due to range of sizes and ability to integrate with future energy needs
- Reduced cost by enabling factory fabrication, size to market need, etc
- Ability to modularize creates intriguing economics
  - Not all small reactors are modular, but no big reactor is ……
  - Capital / cash flow timing
  - Match generation to load
- Based on decades of research and development at DOE national laboratories

SIZES

SMALL

1 MW to 20 MW

Micro-reactors

Can fit on a flatbed truck. Mobile. Deployable.

MEDIUM

20 MW to 300 MW

Small Modular Reactors

Factory-built. Can be scaled up by adding more units.

LARGE

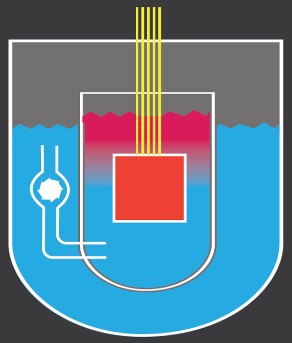
300 MW to 1,000 + MW

Full-size Reactors

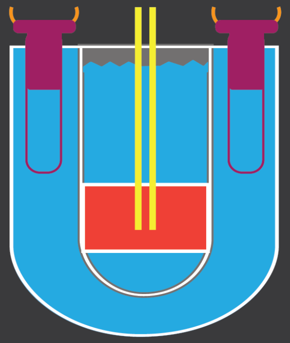
Can provide reliable, emissions-free baseload power

Advanced Reactors Supported by the U.S. Department of Energy

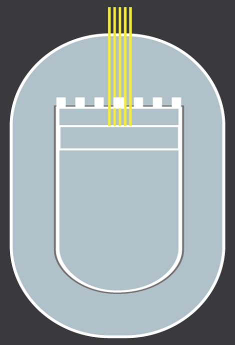
TYPES



MOLTEN SALT REACTORS – Use molten fluoride or chloride salts as a coolant. Online fuel processing. Can re-use and consume spent fuel from other reactors.



LIQUID METAL FAST REACTORS - Use liquid metal (sodium or lead) as a coolant. Operate at higher temperatures and lower pressures. Can re-use and consume spent fuel from other reactors.



GAS-COOLED REACTORS – Use flowing gas as a coolant. Operate at high temperatures to efficiently produce heat for electric and non-electric applications.

Why Size Matters, and Why This Evolution ?

- Large size pursued principally for efficiencies of scale and to match rapidly growing electric markets
  - Larger the better

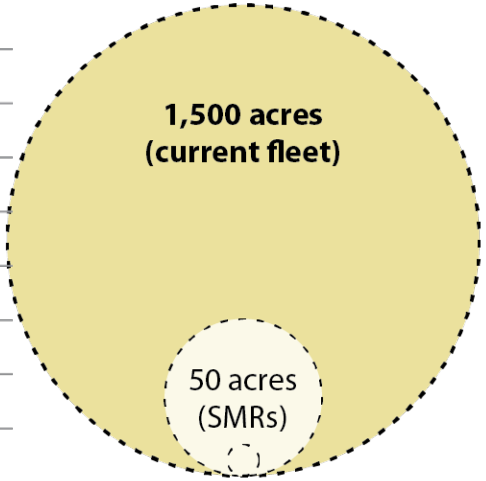
- Implications:
  - Significant for safety systems: System pressure, decay heat removal, reactor control mechanisms
  - NOT modular – generally each a unique massive construction project
  - Construction complexity (capital at risk, financing costs, etc)
  - Mismatch in market (load) and generation size as economies mature (growth rate) = underutilized capital

- Many markets will require smaller increments of power to match load
  - Grid
  - Industrial applications

Existing (large) nuclear reactors

Number in operation:	**95 in U.S.**
Timeframe:	**Built in the 1950s-1980s**
Products:	**Electricity**
Megawatts:	**1,000+ megawatts**
Customers:	**Large utilities**
Emergency zone:	**10 miles**
Construction:	**Custom built on site**
Scalability:	**Difficult due to size and cost**

Footprint



Less than an Acre
(Micro Reactors)

Applications:
Baseload electricity; 24/7

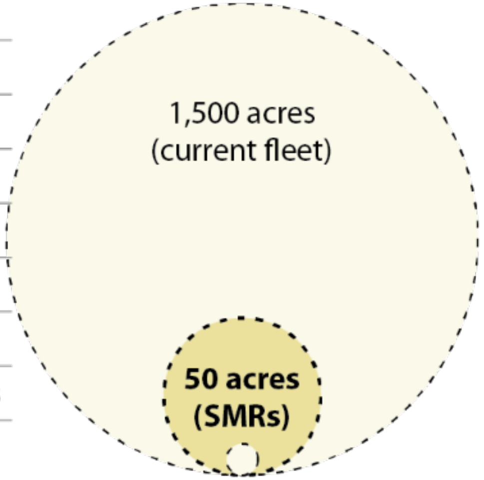
Coming soon: Hydrogen production

Did you know? In November 2018, the Union of Concerned Scientist recommended that federal and state governments adopt policies to preserve the low-carbon electricity the current fleet of nuclear reactors provides.

Slide courtesy of Kortny Rolston-Duce

Small modular reactors

Number in operation:	**None***
Timeframe:	**First reactors expected by 2029**
Products:	**Electricity, heat, and steam**
Megawatts:	**60-300 megawatts per module**
Customers:	**Large utilities; municipalities; industry**
Emergency zone:	**.19 miles**
Construction:	**Factory built; assembled on site**
Scalability:	**Reactor modules added as demand increases**



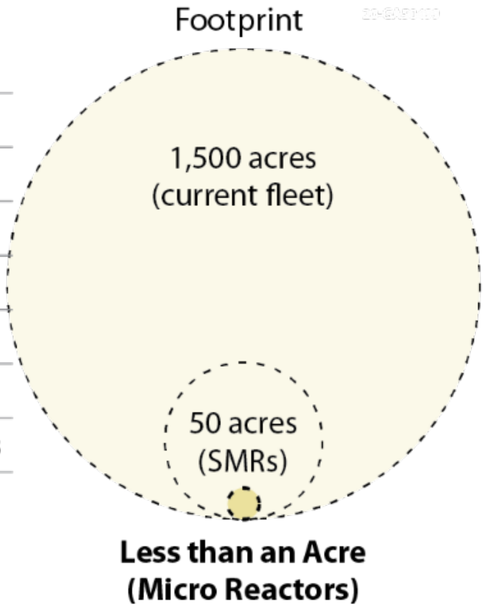
Applications:
Baseload electricity, industrial heat, industrial processes such as hydrogen production

**NuScale SMR has completed NRC design approval with plan to start operation on INL site in 2029*

Slide courtesy of Kortny Rolston-Duce

Microreactors

Number in operation:	**None**
Timeframe:	**First reactors expected by 2025**
Products:	**Electricity, heat, and steam**
Megawatts:	**20 megawatts or less**
Customers:	**Military; municipalities; industry**
Emergency zone:	**Less than 1 acre**
Construction:	**Factory built; assembled on site**
Scalability:	**Reactor modules added as demand increases**



Applications:
Power for remote locations, maritime shipping, military installations, mining, space missions, desalination, disaster relief

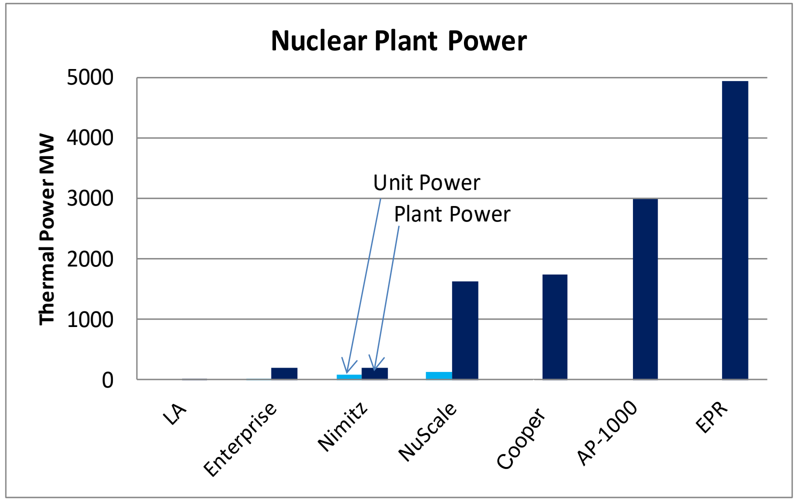
Sen. Lisa Murkowski, R-Alaska, April 4, 2019 Op-Ed in the Anchorage Daily News.

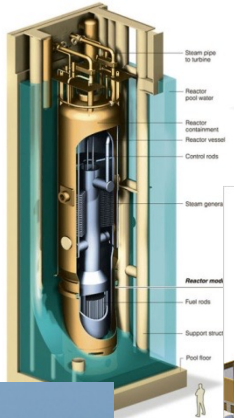
Improvements in nuclear technology "are enabling the emergence of so-called "microreactors" that could be a perfect fit throughout our state. As the name suggests, these smaller reactors can be right-sized for dozens of Alaska communities and will have off-grid capability that could solve the challenge of providing clean, affordable energy in our remote areas."

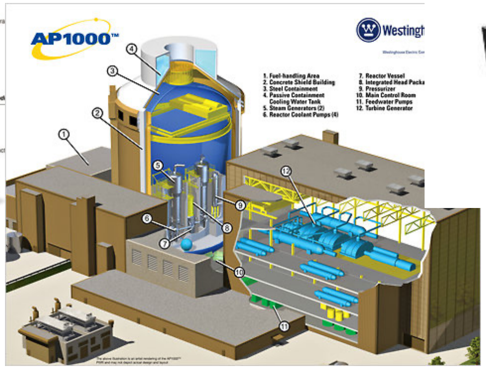
Slide courtesy of Kortny Rolston-Duce

Sample of the Evolution of Power (Size)

- Shippingport – 72 MWe
- Cooper BWR, 800MWe
- Westinghouse AP-1000, 1000MWe
- European Pressurized Reactor, 1650MWe
- NuScale Reactor 12 x 60MW, 720MWe
- Natrium – 345 MWe
- Los Angeles Class Submarine -26 MW
- Enterprise Class Aircraft Carrier 8x
- Nimitz Class Aircraft Carrier 2x97MW, 194MW
- eVinci – 1-5 MWe (plus heat)







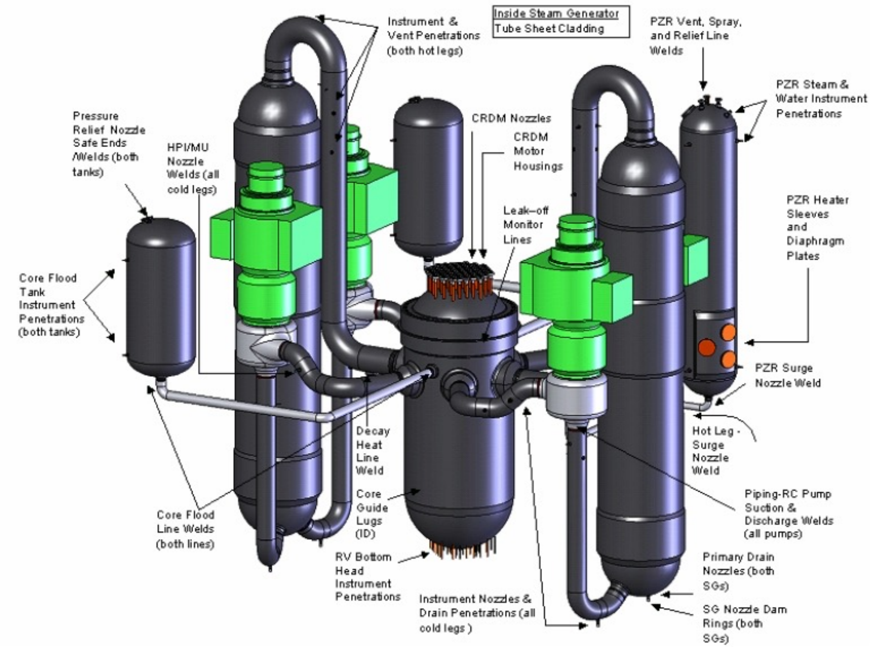
Westinghouse e-Vinci

Slide courtesy of George Griffith

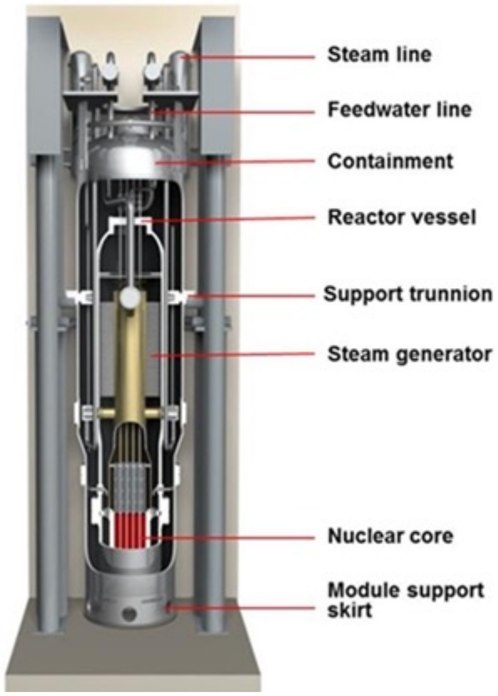
Integrated Small Reactor – Simplification for Safety

SMR reactor and full primary system in one vessel

Simplified systems
Fewer Failure Modes



Typical PWR Reactor



IPWR Reactors

Slide courtesy of George Griffith

Advanced Reactors and Passive Safety – The Important Role of Demonstrations

- Many decades of experience in demonstrating advanced technologies
  - Similar to approaches in other industries- Develop, demonstrate, improve

- Experimental Breeder Reactor – 2: A Case Study
  - Sodium cooled fast reactor
  - Operated very successfully for 30 years
  - Demonstrated power production, plant operations, and ”inherent safety” of this class of technology
    - Most aggressive accident scenarios tested: Loss of coolant flow and loss of heat sink

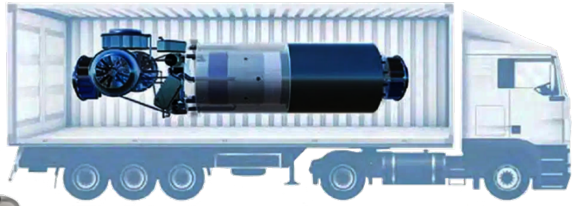
- Lean on this knowledge base

EBR-II, a sodium cooled fast reactor, demonstrated inherent safety in 1986 and operated successfully and effectively for 30 years

1) Demonstrated natural circulation
2) Loss of flow without shutdown
3) Loss of heat sink without shutdown

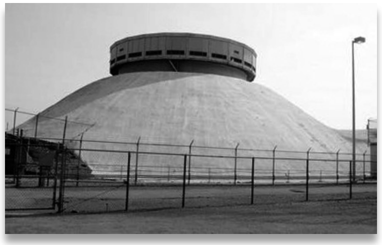
Nuclear Reactor Demonstration Timeline

MARVEL
DOE
2022-2023

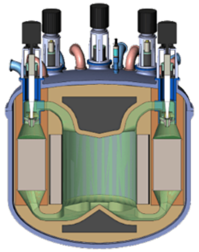


Project Pele Microreactor
DoD
2023-2024

DOME Test Bed
NRIC
2023-2024

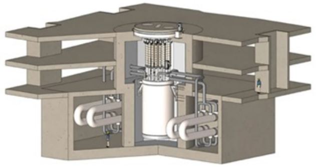


LOTUS Test Bed
NRIC
2024



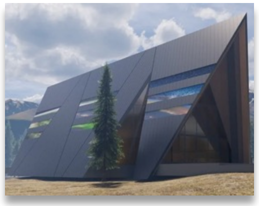
MCRE
Southern Co. & TerraPower
2025

TerraPower
Southern Company



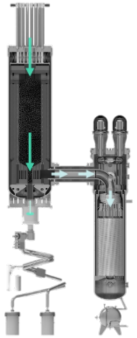
Hermes
Kairos
2026

Kairos Power



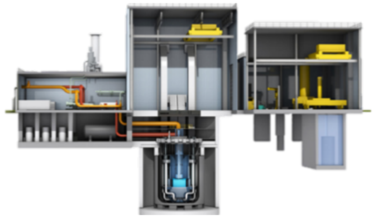
Aurora
Oklo Inc.
TBD

OKLO



Xe-100
X-energy
2027

energy



Natrium Reactor
TerraPower & General Electric
2028

TerraPower
GE HITACHI

SMR
UAMPS &
NuScale
2029

UAMPS
NUSCALE Power for all humankind

2030

NRIC National Reactor Innovation Center

Meeting the Needs of a World of 9 B People: The Broader Potential for Economic Value and Climate Impact

- In the model of the past, nuclear energy touches a very small share of global energy
  - Projections that electricity accounts for ~25% of 800 quad energy demand in 2040
  - Nuclear accounts for 10%-15% of electricity in the 2040 scenario
  - Baseload electricity is ~40% of electricity market (U.S.)
- What if?
  - Innovation allowed lower cost, easier to operate plants *(advanced SMR, microreactors, etc.)*?
  - Innovation allowed integration into broader energy economy– decarbonize hard to address industry
  - Innovation introduced game-changing embedded nuclear-industrial process designs and "smart reactors"?
  - Smaller scale, niche markets, affordable – key tool to achieve net-zero economy

Conceptual Functional Layout for Quantum Battery - MIT

Value chain (what one produces with the energy) is likely much larger than supply chain (stuff that goes into a plant)

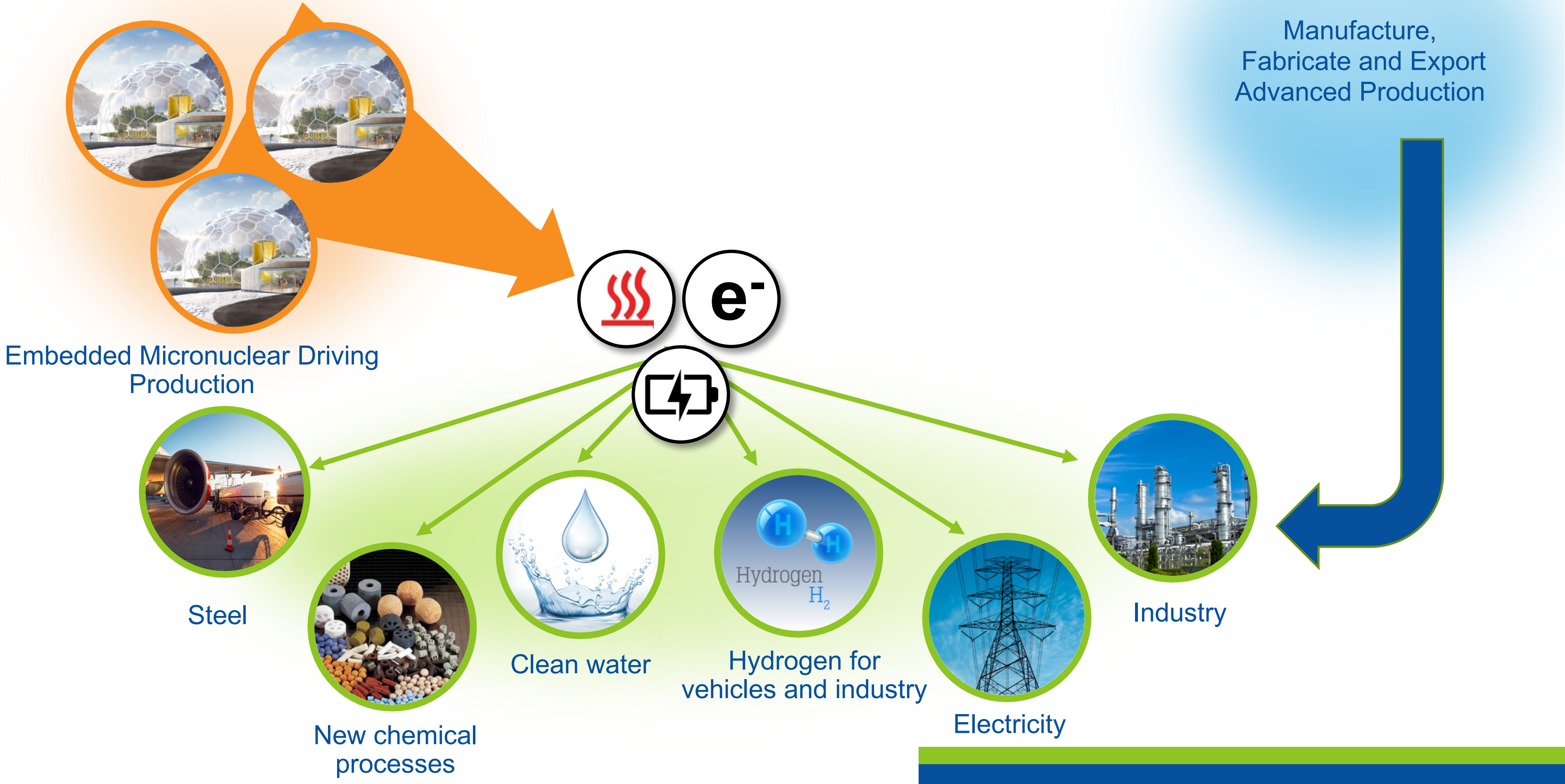
Transforming the Economic Paradigm in Wyoming ?

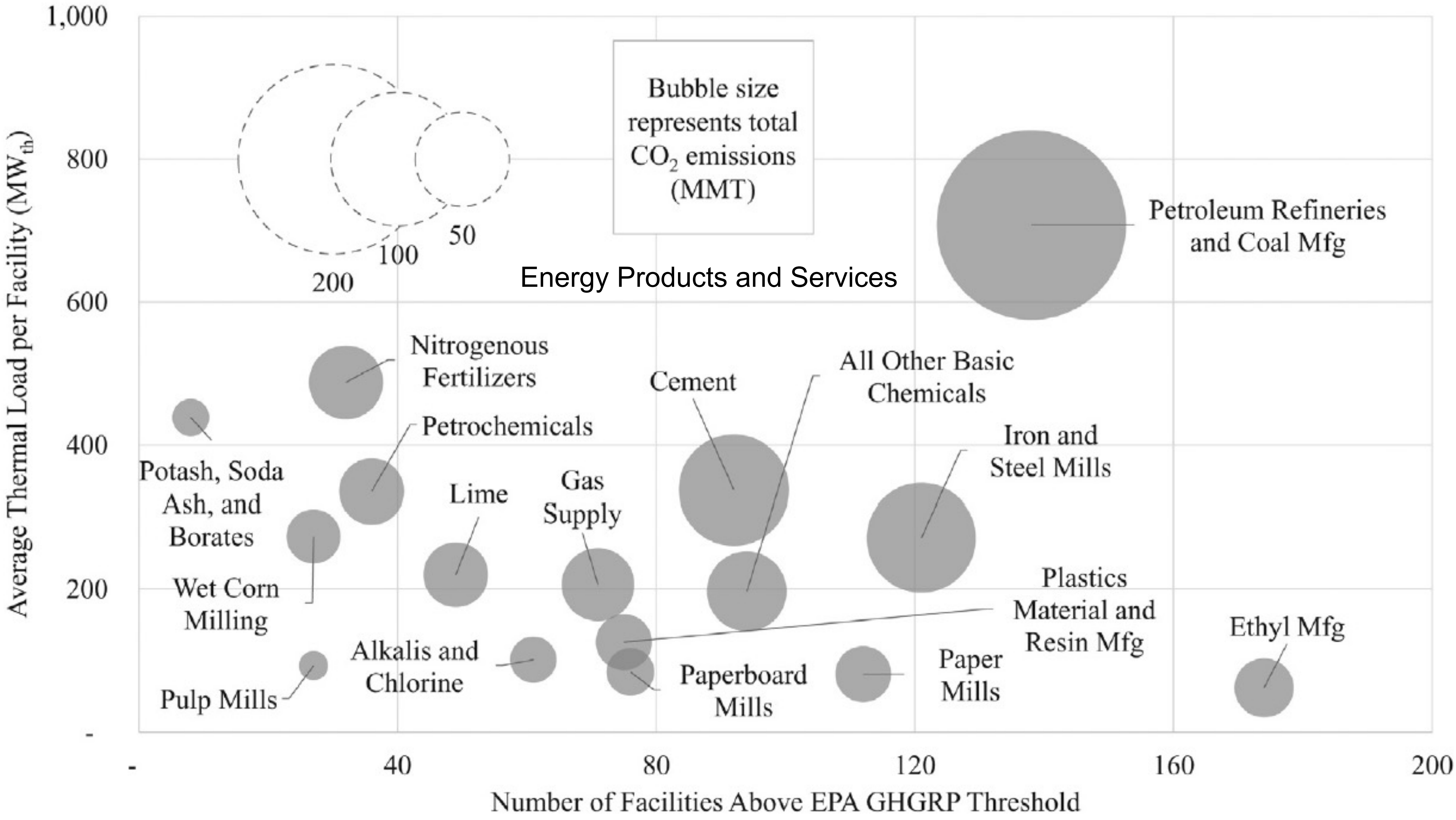
Today

Electricity and
Commodity only focus

Future

Power source embedded in advanced industrial production





1,000
800
600
400
200
-
Average Thermal Load per Facility (MW_{th})
Bubble size represents total CO_2 emissions (MMT)
200
100
50
Energy Products and Services
Petroleum Refineries and Coal Mfg
Nitrogenous Fertilizers
Potash, Soda Ash, and Borates
Petrochemicals
Cement
All Other Basic Chemicals
Iron and Steel Mills
Lime
Gas Supply
Wet Corn Milling
Plastics Material and Resin Mfg
Ethyl Mfg
Alkalis and Chlorine
Pulp Mills
Paperboard Mills
Paper Mills
-
40
80
120
160
200
Number of Facilities Above EPA GHGRP Threshold

Question, Plan, Engage-

- Rely on and engage with your university and your energy authority
- Regulatory oversight: Air, water, land, cultural, utilities
- Operations excellence
- Jobs, supply chain, value chain – what's the reality?
- Broader value ala engaging global markets
- Build partnerships for talent development, process learning, manufacturing, etc
- Fuel cycle – short / long term plan
- Consider facts – esp demonstrations past and future: What can be learned? What can be leveraged?

Other Slides of Possible Interest

The Nuclear Regulatory Commission Licenses Commercial Power Reactors

- All commercial power reactors operate under NRC licenses
  - Originally issues for 40 years
  - Subsequent licenses extended to 60 and 80
- Two current licensing approaches
  - 10 CFR 50 – Construction licenses followed by Operating License
  - 10 CFR 52 – Design approval/Combined Construction and Operating License
  - 10 CFR 53 – Technology inclusive regulatory framework under development
- Recent/current experience
  - NuScale SMR – 10 CFR 52 – 42 months for design approval
  - Oklo Aurora Microreactor – 10 CFR 52 - 36 month planned review period

Embedding clean energy in advanced industrial production - Moving to higher-value products

Commodities produced with NG

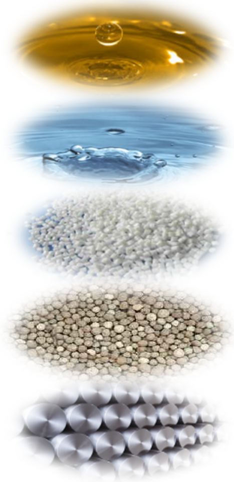
Synthetic Fuels & Lubes

Primary Chemicals

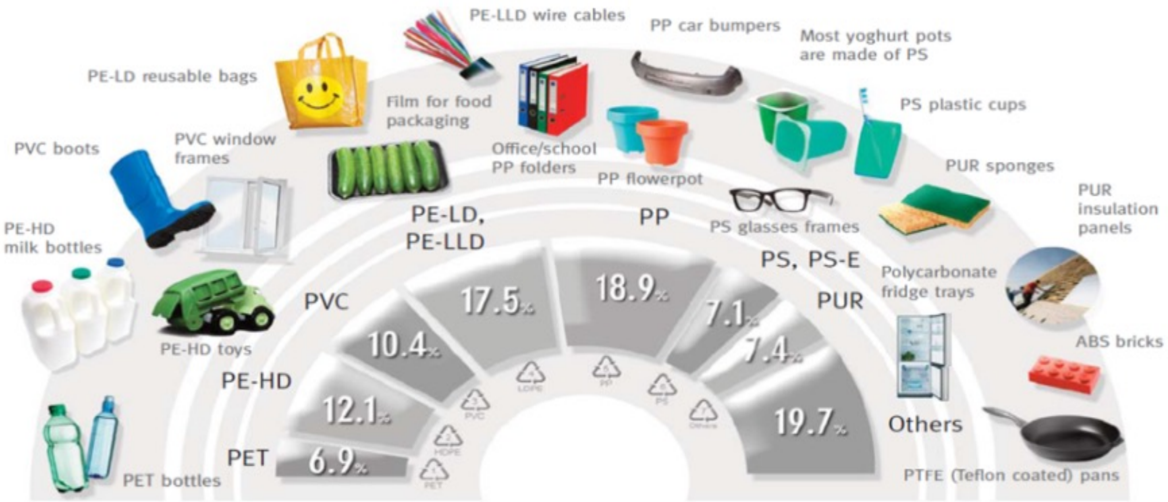
Plastics & Resins

Fertilizers

Primary Metals



Plastics Market: 50% growth projected by 2040



Acetic Acid	Acetone	Acrylonitrile
Ammonia	Base oils-lubes	Butadiene
Ethyl Alcohol	Ethylene	Ethylene Glycol
Formic Acid	Hydrogen	Isocynates
Melamine	Methanol	Oxo-Alcohols
Polyethylene	Polypropylene	Polyvinyl Chloride

Chemical commodities produced from NG

- H_2 for FCV, fertilizers, and oil refining
- Heat and electricity for alkane activation and dehydrogenation for plastics and resins
- Syngas for methanol and direct reduced iron

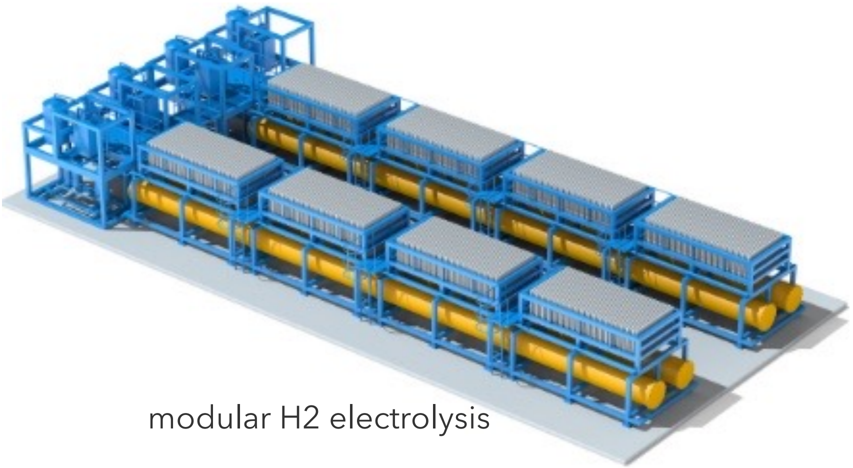
An Opportunity for Wyoming Economic Transformation

Imagine If ……

- New System architecture
  - Address some of these challenges
  - NOT a one size fits all ….. Some applications and needs will not scale
  - Industrial applications, adaptive communities, mission-critical loads, growing markets, etc
- Embedded systems for advanced production – it goes like this:
  - Embed energy modules in/with industrial processes (or other loads) – advanced nuclear + advanced production
  - Incremental provisioning of energy – match load requirements at a given time with incremental modules of energy (think batteries, Lego approach, etc)
  - Optimizes investment "stack" / cash flows, de-risk, localized approach, de-emphasize massive capital projects
  - Focus on non-commodity (or specialty commodity) production
  - Trade efficiencies of size for economies and resilience of numbers
  - Shift energy provisioning from large capital projects to advanced manufacturing / ultra-modularity
  - A slightly different take on microgrids, and its not built on SMR
- How is this different than CHP, collocated energy, etc?
  - Incremental provisioning, operational plug and play nature of nuclear battery
  - Industrial application architecture-centric

Applications?

- Modular production
  - Industrial precursors (H2)
  - Fertilizers
  - Iron ore reduction and steel processing
  - Mineral processing
- Critical loads
  - Flood control / pumps, desalination, key microgrids,
  - Transport charging stations, etc
- The steel example (Freda et al)
  - Initial results show strong economics
  - Very favorable debt / return timing
  - Applicable for new, modular mills



modular H2 electrolysis

fleet charging stations

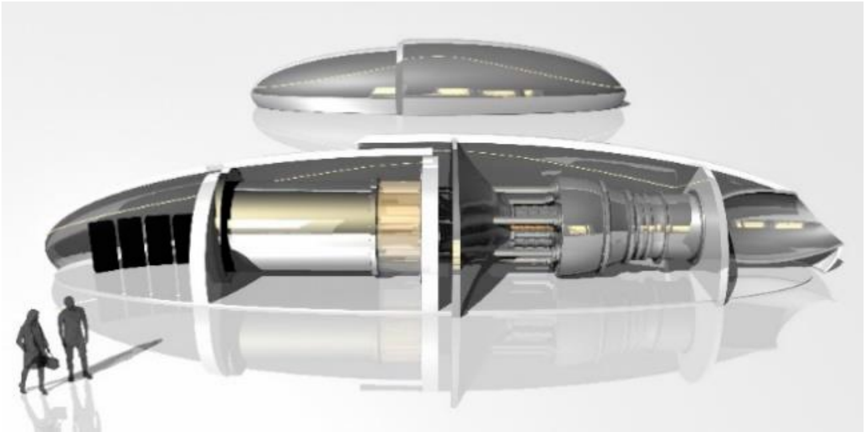
modular metals and ceramics

modular data centers

Technologies and Layout

- Microreactors are the key, but –
  - ”Fission battery” or “quantum battery” approach
  - Plug and play
  - Extended core life, practical to remove / replace modules
  - Secure intelligent monitoring and control
  - Possible new business model – fleet operation remotely, energy as leased service

MIT Conceptual Functional Layout



MIT Conceptualized NB w/ integrated gas turbine

Westinghouse e-Vinci

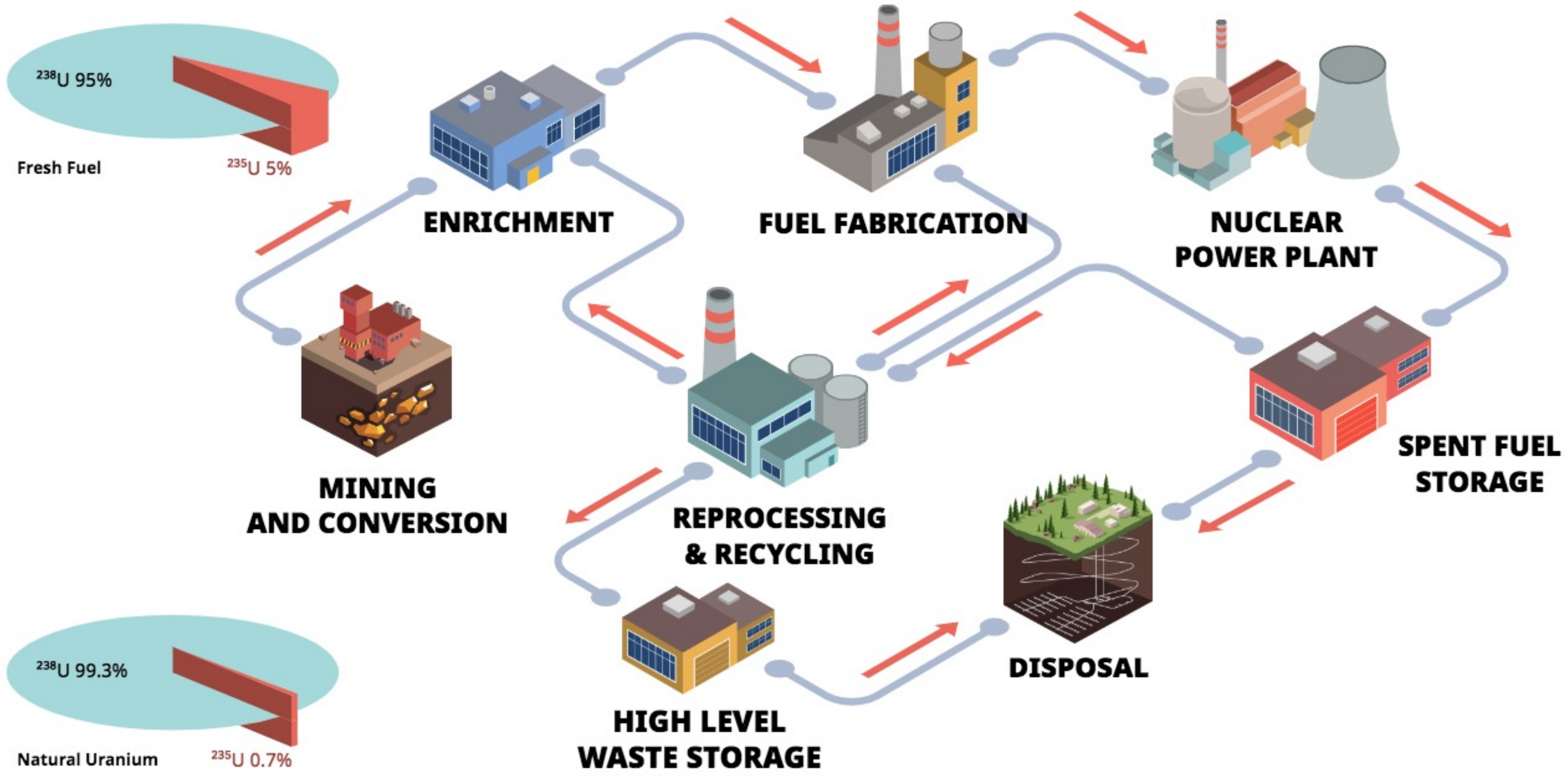
December 2021
University of Wyoming, Advanced Nuclear 101 Webinar

Presenter: Josh Jarrell, Ph.D.
Manager, Used Fuel Management Department,
Idaho National Laboratory

Nuclear Fuel Cycle: An Overview

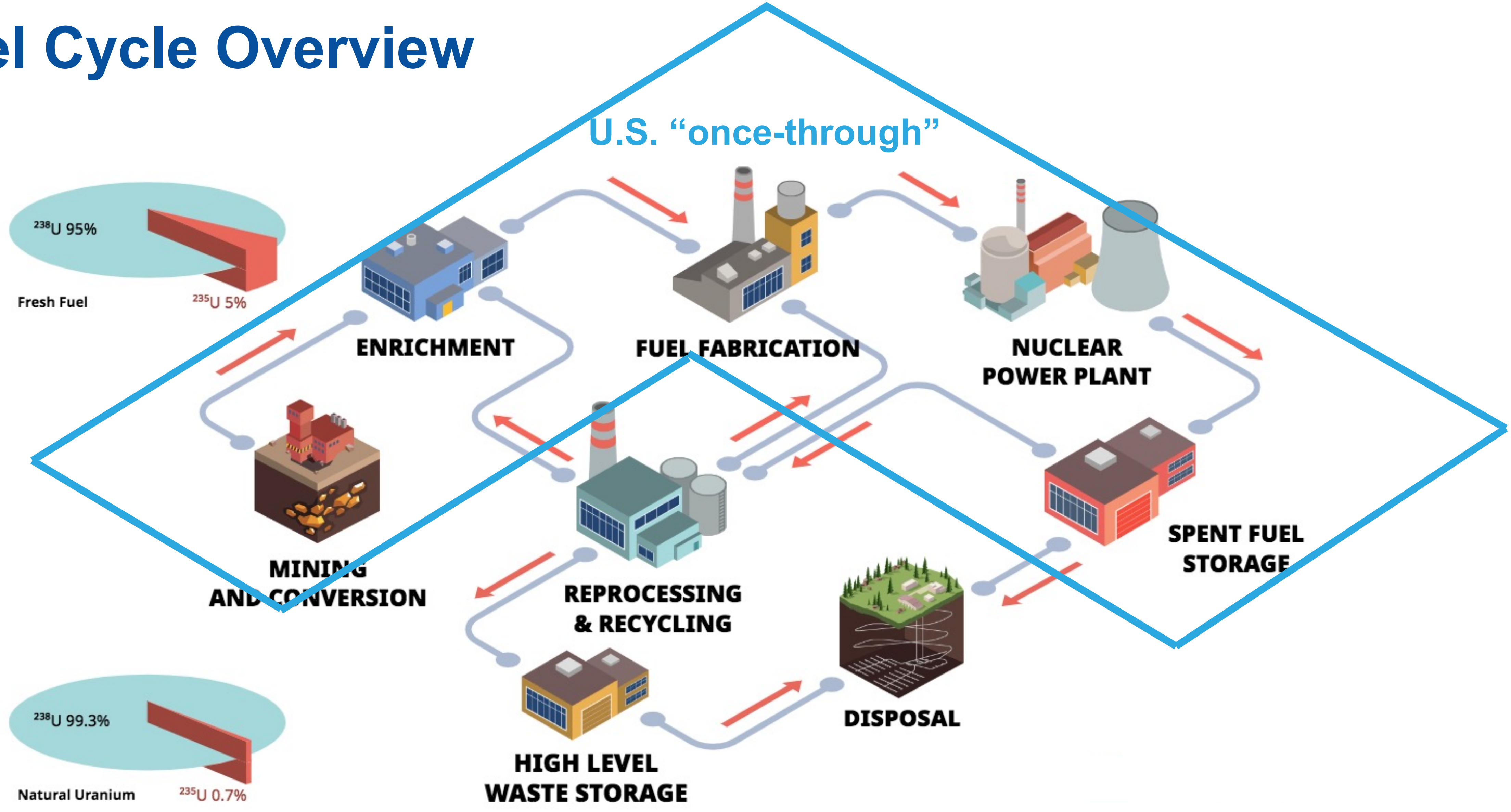
Idaho National Laboratory

Fuel Cycle Overview



Source: International Atomic Energy Agency, Spent Fuel and Radioactive Waste Management, Decommissioning and Environmental Remediation e-learning curriculum, Module SFM1: Policy and Strategy for Spent Fuel Management (elearning.iaea.org – requires free IAEA Nucleus account)

Fuel Cycle Overview



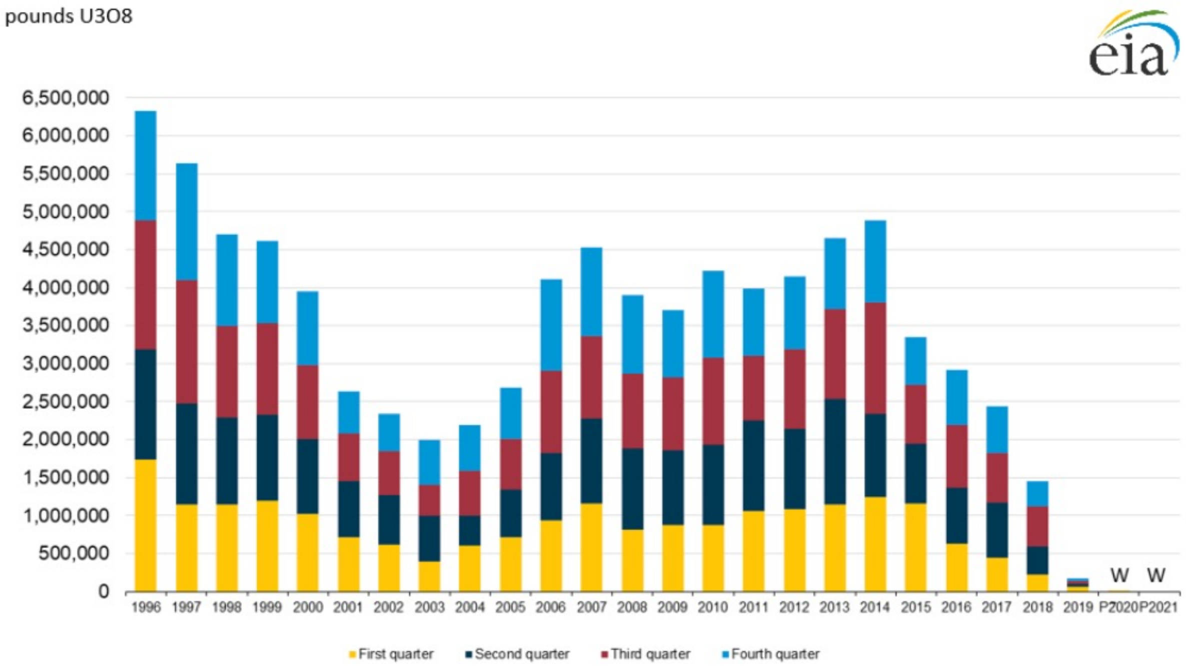
Source: International Atomic Energy Agency, Spent Fuel and Radioactive Waste Management, Decommissioning and Environmental Remediation e-learning curriculum, Module SFM1: Policy and Strategy for Spent Fuel Management (elearning.iaea.org – requires free IAEA Nucleus account)

Uranium Mining and Milling

- Three types of mining
  - Open Pit
  - Underground
  - In-situ Leach
- Milling required for Open Pit and Underground mining to concentrate uranium
- After mining/milling, uranium is a uranium oxide
- Dramatic reduction in US uranium production over the past 5 years

Rabbit Lake Uranium Mine, Canada
Source: Saskatchewan Schools

Figure 1. Uranium concentrate production in the United States, 1996 to second-quarter 2021

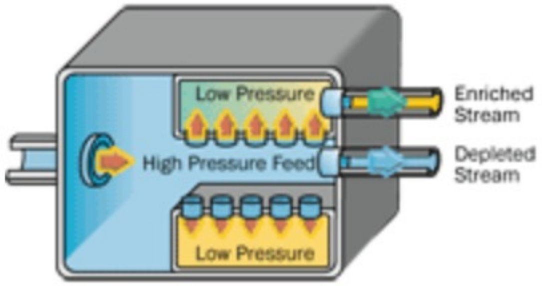


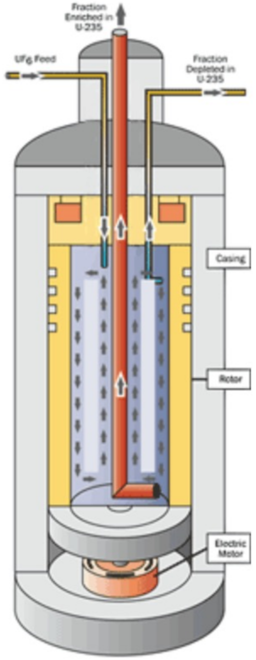
Source: https://www.eia.gov/uranium/production/quarterly/

https://www.eia.gov/uranium/production/annual/pdf/dupr2020.pdf
https://geoinfo.nmt.edu/resources/uranium/mining.html

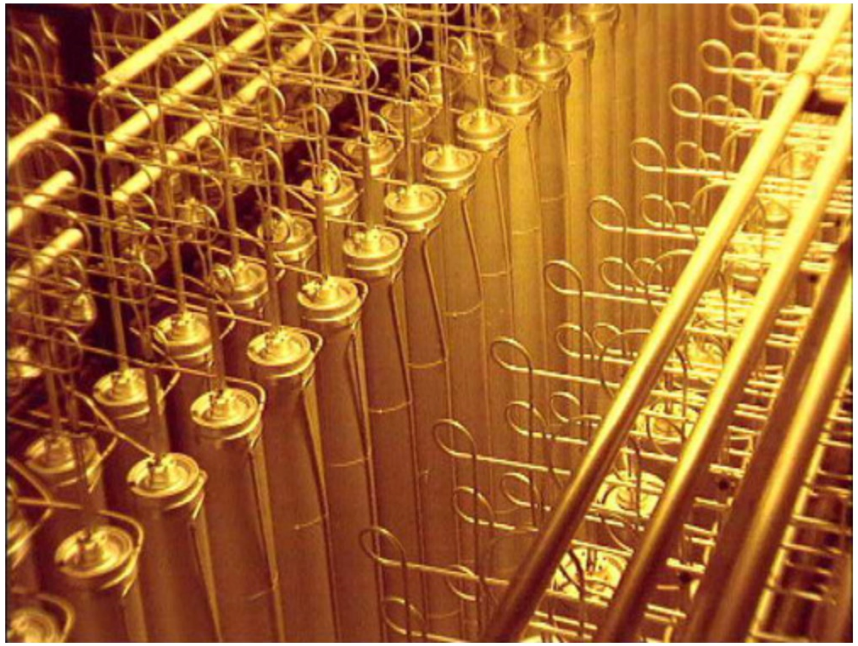
Uranium Enrichment

- Need to raise Uranium-235 from ~0.7% to ~5% of the total uranium
- Enriching U-235 is done via two proven* methods
  - Centrifuge
  - Diffusion
- Both require the uranium to be in the form of UF_6 (i.e., gas)
  - Conversion from oxide to fluoride





Source: https://www.nrc.gov/materials/fuel-cycle-fac/ur-enrichment.html

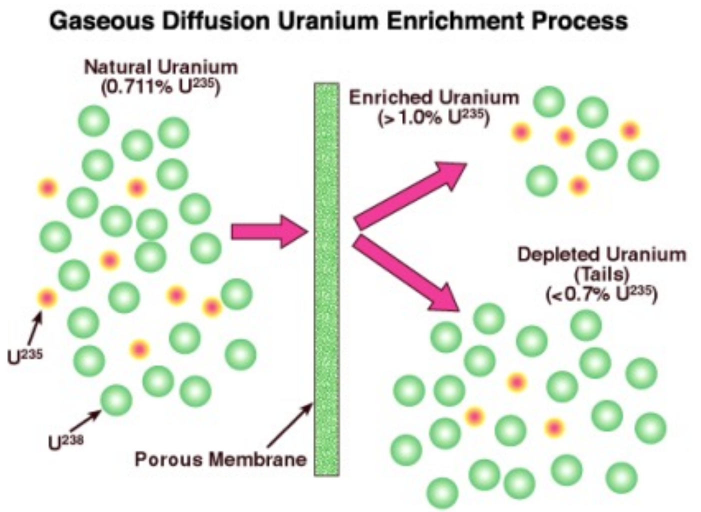


A bank of centrifuges at a Urenco plant

Source; https://world-nuclear.org/information-library/nuclear-fuel-cycle/conversion-enrichment-and-fabrication/uranium-enrichment.aspx

*Laser enrichment facility was licensed by NRC, but never constructed

Commercial US Enrichment Facilities



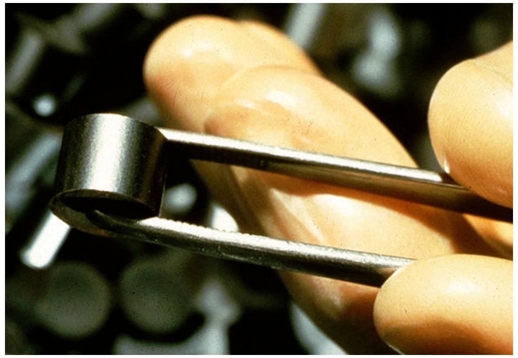
The uranium enrichment process increases the concentration of U^{235} to the amount needed for use in reactor fuel.

- No active diffusion plants
  - Paducah, Kentucky
  - Piketon, Ohio
  - Oak Ridge, Tennessee
- URENCO - Eunice, NM
  - Started operations in 2010
  - Stated desire to move forward with higher enrichment (HALEU) program (2019)
- American Centrifuge Operating (ACO) - Piketon, Ohio
  - CENTRUS subsidiary
  - DOE support for high assay uranium (greater than 5% U-235 but less than 20% U-235)
    - 3 year and $115M cost-shared contract (2019 – 2022)
  - Expected to start production in 2022 (NRC license approved in Summer 2021)

Source: https://www.nrc.gov/materials/fuel-cycle-fac/ur-enrichment.html
https://www.urenco.com/global-operations/uusa
https://www.nrc.gov/materials/fuel-cycle-fac/uranium-enrichment.pdf
https://world-nuclear-news.org/Articles/Urenco-USA-announces-HALEU-activities
https://www.world-nuclear-news.org/Articles/Centrus-receives-licence-for-HALEU-production

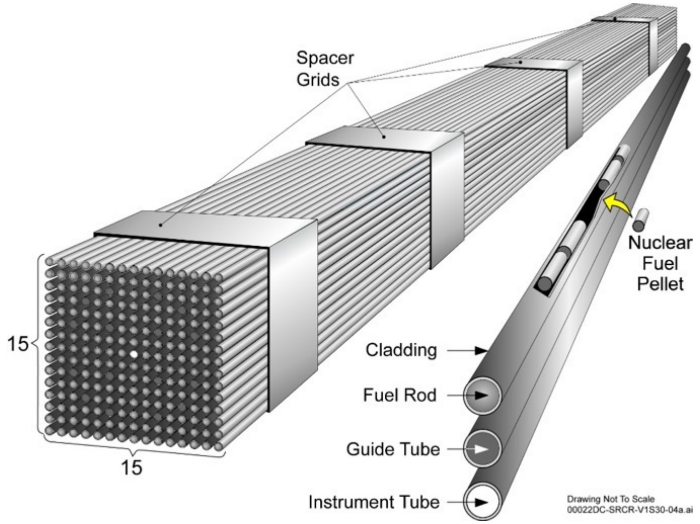
Fuel Fabrication

- After enrichment and deconversion back to an oxide, fuel fabrication can begin
- Fuel conditioning (i.e., ensure usable feed material)
- Fuel formation (i.e., place fuel in final form)
- Fuel encapsulation (i.e., place fuel in cladding)
- Three active fuel fabrication plants for commercial fuel
  - Global Nuclear Fuel-Americas (Wilmington, NC)
  - Westinghouse (Columbia, SC)
  - Framatome (Richland, WA)
- Two non-commercial fabrication plants (higher enrichment)
  - Nuclear Fuel Services (Erwin, TN)
  - BWXT (Lynchburg, VA)

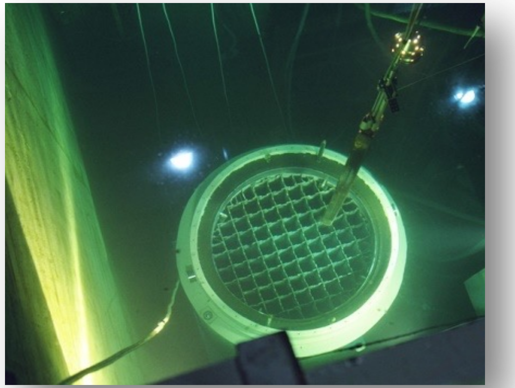


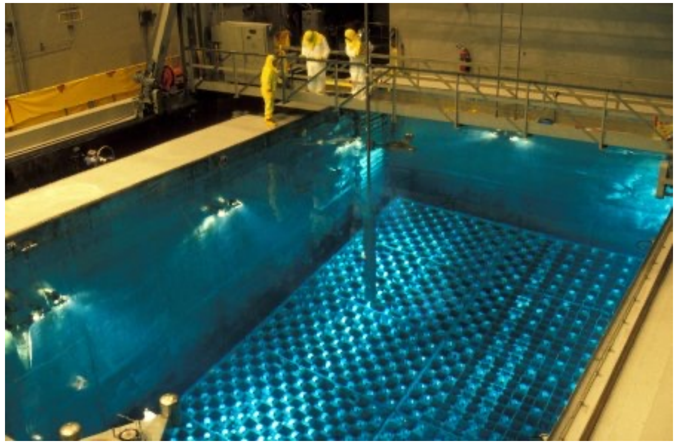
https://www.nrc.gov/materials/fuel-cycle-fac/fuel-fab.html

Current At-Reactor Spent Fuel Management Practices



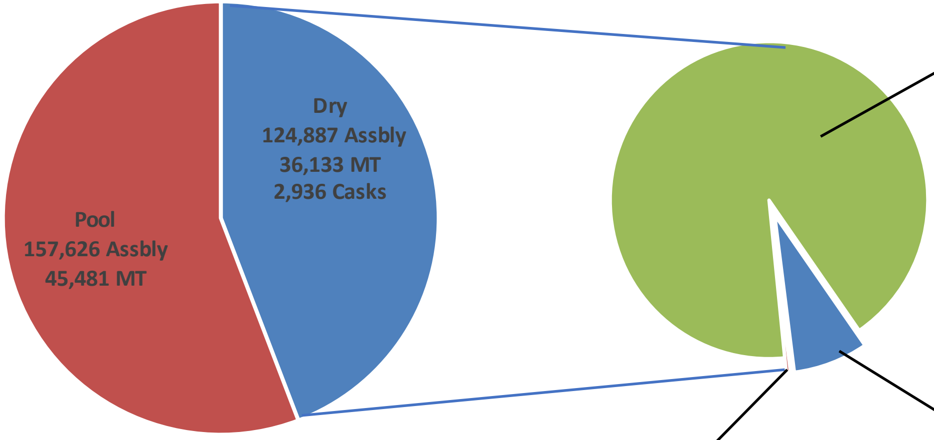
- All current commercial reactors are light water reactors (LWRs)
  - LWRs are fueled by enriched uranium (UO_2) fuel (assemblies) with zirconium cladding
- After ~5 years in reactor, it is declared spent nuclear fuel (SNF)
  - No longer useful in the current LWR
- The spent fuel is then moved into spent fuel pools (“wet storage”)
  - Pool storage provides cooling and shielding of radiation
- To allow continued operations, utilities have implemented dry storage
  - Each site generally loads a few storage casks every other year





There are thousands of dry storage canisters across the US

Inventory as of Jan. 1, 2019



2,700 Welded Metal Canisters In Vented Concrete Overpacks 113,572 Assemblies, 92% of Dry

Transnuclear (37%)
Holtec (44%)
NAC (17%)

12 Welded Metal Canisters in Transport Overpacks 866 Assemblies, 0.4% of Dry

224 Bare Fuel Casks 10,442 Assemblies, 7.6% of Dry

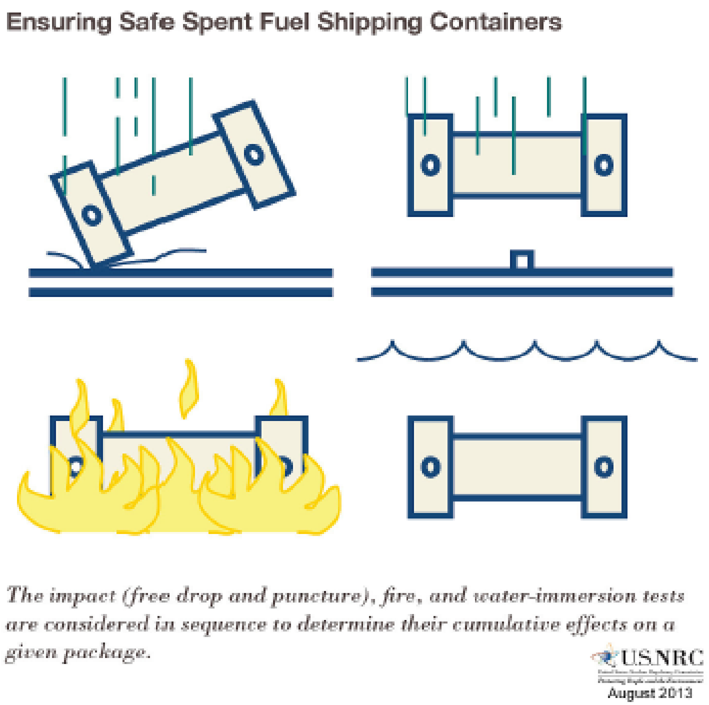
- *Majority is in Large Welded Canisters*
- *Current dry storage inventory is diverse*
- *Trend toward higher capacities*

Holtec Hi-Star 100

Transnuclear TN-32

Transportation Packages are designed to withstand severe transportation accidents

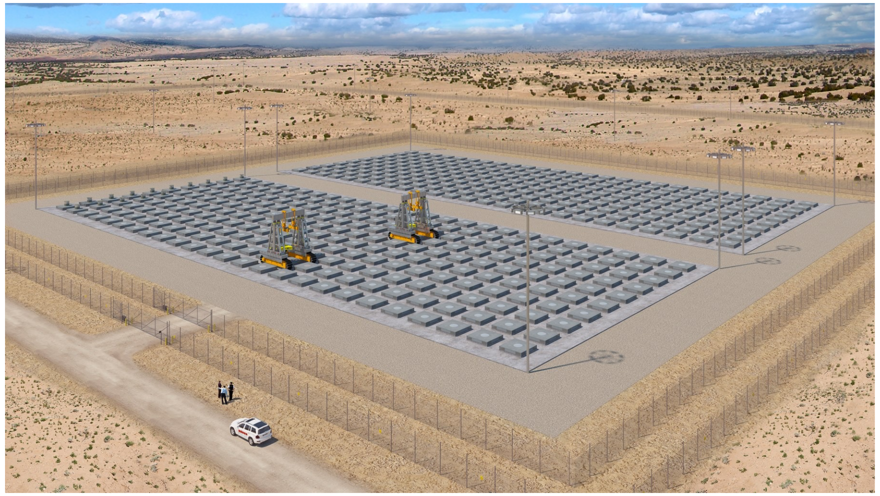
- It is impossible to completely prevent all transportation accidents
- Packages must meet stringent NRC/DOT regulations
- Packages certified for shipment of SNF and other highly radioactive materials must show ability to contain all contents in severe accidents
  - Accident conditions in sequence include:
    - 30 foot (9 m) drop onto unyielding surface
    - 40 inch (1 m) drop onto steel bar designed to puncture cask
    - 30 minutes engulfed in fire at 1475 F (800 C)
    - Immersion under 3 feet (0.9 m) of water
- At least 25,400 (and probably more the 44,400) shipments of SNF have been made worldwide since 1962



Away-from reactor, consolidated interim storage facilities have also been moving forward

- Eddy-Lea Energy Alliance and Holtec International (NM)
  - https://holtecinternational.com/communications-and-outreach/faqs/
- Interim Storage Partners (Waste Control Specialists and Orano USA) (TX)
  - https://interimstoragepartners.com/
- Political opposition in both NM and TX
- Goal is to eventually move the spent fuel to a repository
- Outside of these private initiatives, DOE has recently released a request for information for consent-based siting process
  - Comments due March 2022
  - https://www.energy.gov/articles/doe-restarts-consent-based-siting-program-spent-nuclear-fuel-requests-input-interim

Source: Interim Storage Partners
https://interimstoragepartners.com/wp-content/uploads/2015/12/renderedphoto-e1528223157924.jpg



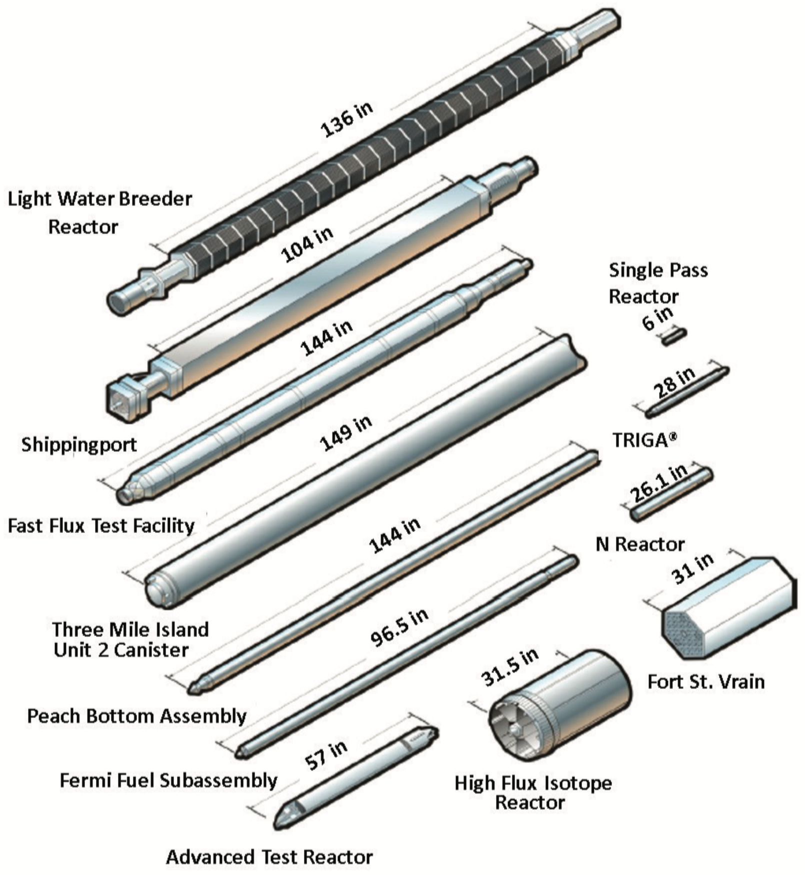
Source: Holtec International
https://holtecinternational.com/products-and-services/hi-store-cis/

International consensus is that deep geologic disposal is a robust and necessary solution for permanent isolation of spent fuel and other long-lived radioactive wastes

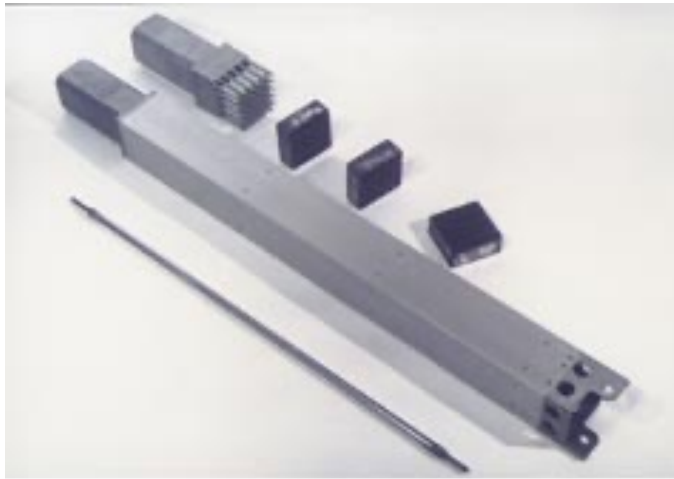
- WIPP (Waste Isolation Pilot Plant) was successfully developed and is in operation
- DOE and many in the scientific community concluded that Yucca Mountain was ready to license
  - No “negative” safety findings in the NRC review of the Yucca Mountain license application
- Finland has received a license to construct a geologic repository from their regulator (crystalline)
- Sweden has submitted a license application for construction of a geologic repository (crystalline)
- Mature safety assessments indicate that clay sites are also suitable (France)

Advanced reactors have different spent fuel management challenges (and opportunities)

- Advanced (i.e., non-light-water) reactors are different than current light water reactors
  - (generally) more efficient and smaller than current fleet
  - “walk-away-safe”
  - Different fuels (generally higher uranium enrichment)
- Spent fuel will be made of different materials (graphite, metals, etc.)
  - But may have “value” left after operations
  - Similar historic spent fuel management experience exists
- In the future, could lead to a “closed” fuel cycle (i.e., reprocessing/recycling)
  - Spent fuel storage and disposal still needed

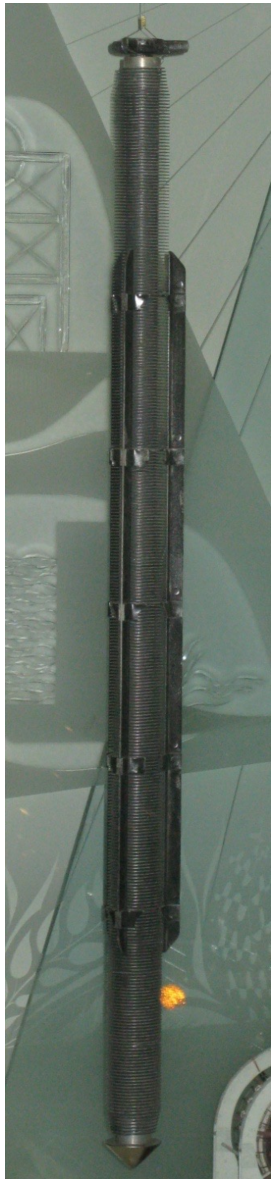


Fuel Images



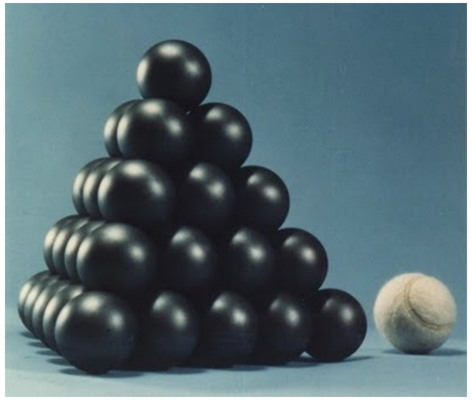
TRIGA (~15" fuel length)

CANDU (~20" in length)



MAGNOX (~40" in length)

BWR



Pebble Bed - HTGR

Prismatic Block - HTGR

Questions?

- 8 Dry storage casks (CPP-2707)
  - TN-REG and TN-BRP not pictured

21ST CENTURY NUCLEAR ENERGY

NOVEMBER 2021, TODD ALLEN, PROFESSOR & SENIOR FELLOW

FASTEST PATH TO ZERO
UNIVERSITY OF MICHIGAN

WHAT DO WE VALUE?

VS.

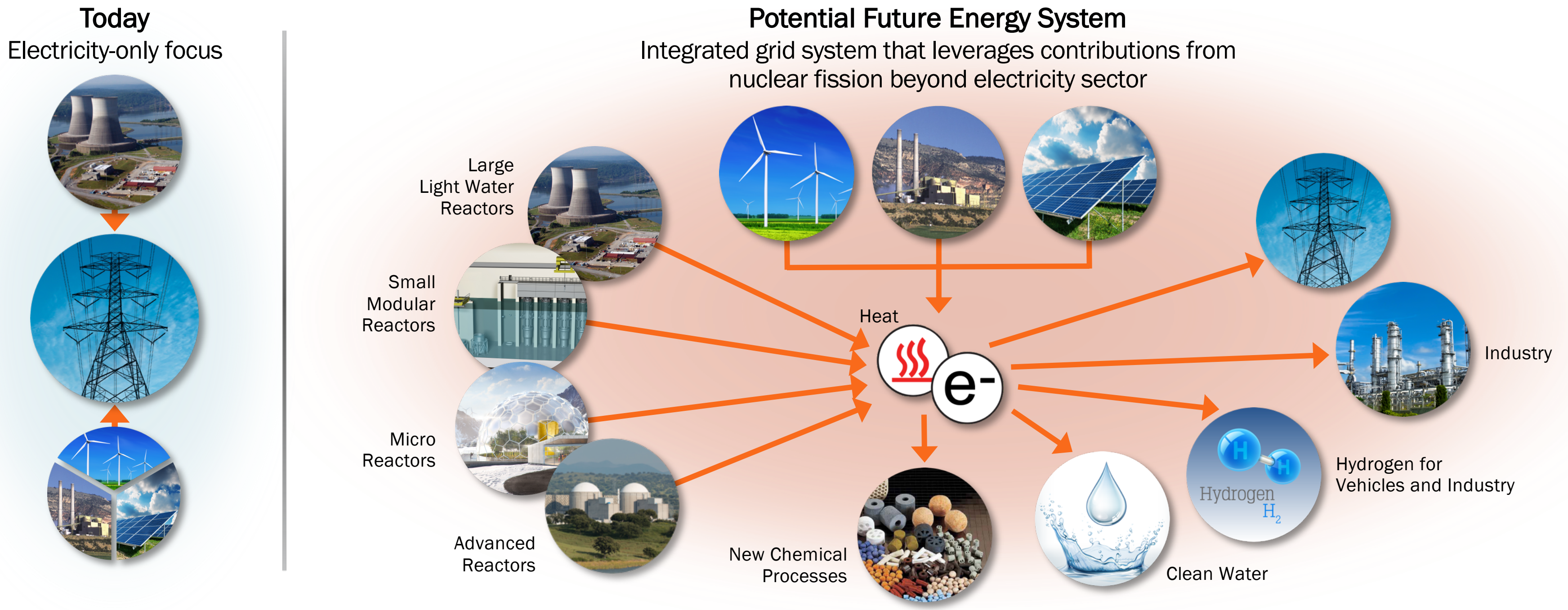
- Water purification
- Sanitation
- Irrigation
- Heating & air conditioning
- Vaccinations
- Pharmaceuticals
- Homes

Energy is Key

- Clean
- Affordable
- Resilient
- Equitable

ENERGY REIMAGINED

Maximizing energy utilization, generator profitability, and grid reliability and resilience through novel systems integration and process design



Flexible Generators ❖ Advanced Processes ❖ Revolutionary Design

Courtesy Shannon Bragg-Sitton, Ph.D., Idaho National Laboratory

THE EMISSIONS REDUCTION IMPERATIVE


Supply chains + Add to myFT

Blue chips act to cut supply chain greenhouse gas emissions

Rolls-Royce, Nestlé and Panasonic among larger companies taking action

Michael Pooler JANUARY 29, 2018 2

…mpanies taking serious action to tackle greenhouse gas …y chains has doubled, according to research by an …

…luding Rolls-Royce, Nestlé and Panasonic were among …d with taking an "industry-leading" approach on the …profit that collected data on behalf of 99 of the world's …nisations.


THE WALL STREET JOURNAL.

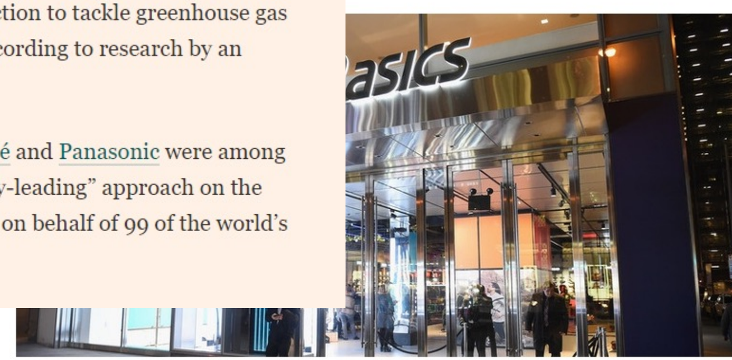
Home World U.S. Politics Economy Business Tech Markets Opinion Life & Arts Real Estate WSJ. Magazine

BUSINESS | LOGISTICS REPORT | WSJ LOGISTICS REPORT

Levi's Plans to Slash Emissions in Global Supply Chain by 2025

The apparel giant aims to reduce greenhouse gas emissions at a sprawling set of factories and mills in 39 countries, sta… suppliers

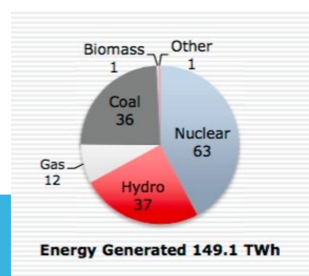
Levi's will start its effort to cut greenhouse gas emissions through energy-efficiency programs at factories run by vendors in the first tier of its supply chain, such as this supplier facility in Mexico. PHOTO: PHOTO COURTESY OF LEVI STRAUSS & CO.

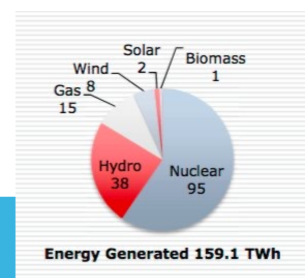


BRIEF

Asics plans to cut 55% of its supply chain carbon emissions

Ontario Transition from Coal

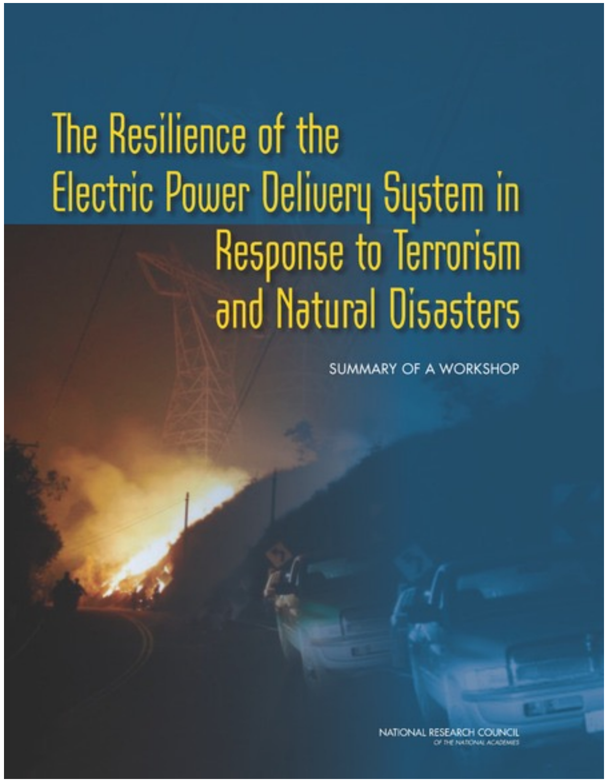




THE RESILIENCE IMPERATIVE

Houston, 22 December 2016 (Argus)-The North American Electric Reliability Corporation (NERC) wants to make sure utilities, power grid operators and federal and state policymakers understand the:

- Increased risk that reliance on a single fuel presents to dependable electric service.
- Firm transportation and dual-fuel capability may be needed to reduce widespread reliability problems.



A Call to Action:

A Canadian Roadmap for Small Modular Reactors

SUMMARY OF KEY FINDINGS

THE JOBS & SUPPLY CHAIN IMPERATIVE

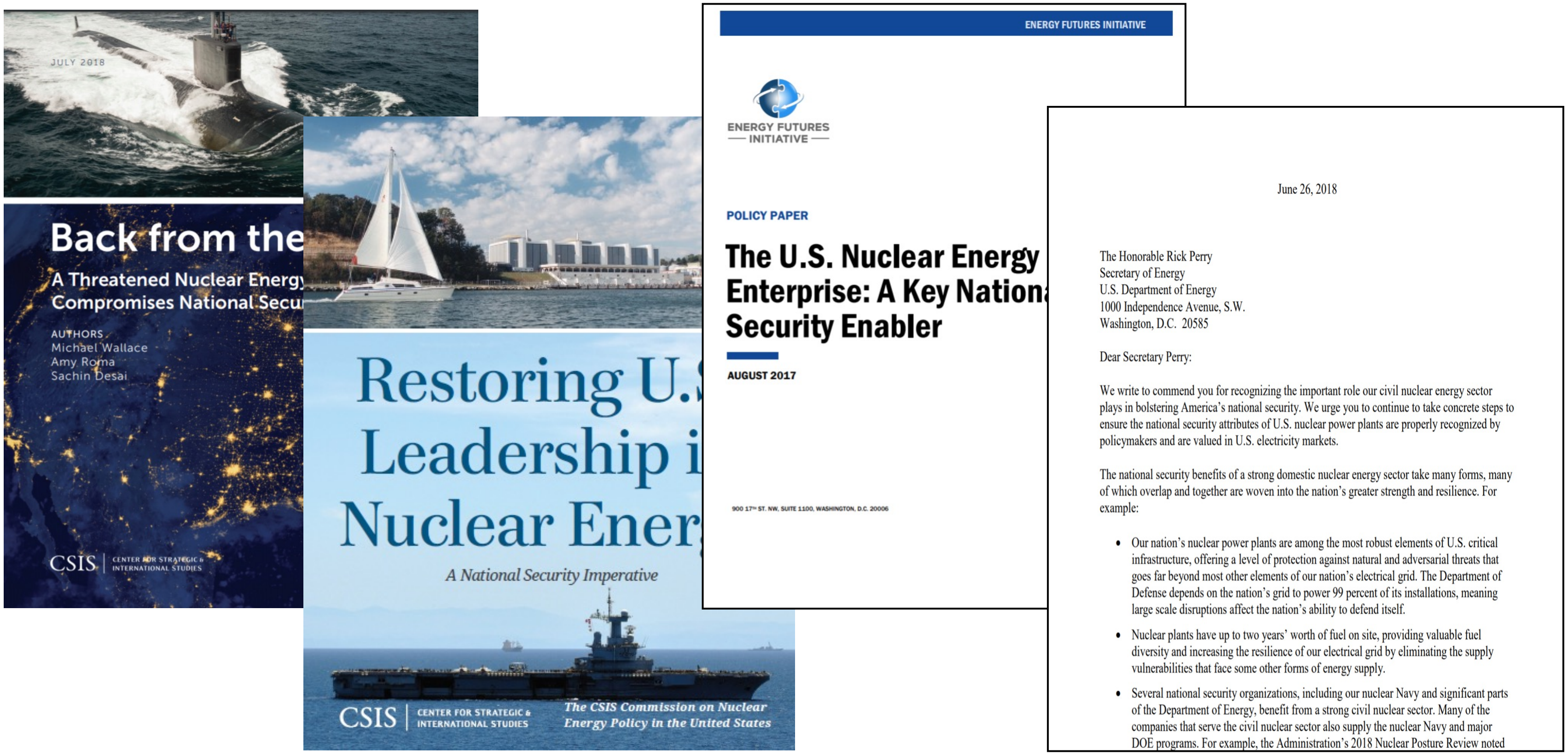
£1 trillion international new-build and decommissioning market over the next 10 years

The WNA estimates that the value of global investment in new reactor build will be of the order US$1.5 trillion (£0.93 trillion), with significant international procurement expected to be approximately US$530bn (£330bn), US$40bn (£25bn) per year through 2025.

> "We need to be clear where we own the value, understand our value proposition in nuclear and where the supply chain can improve competitiveness."
>
> **CEO, Manufacturing organisation**

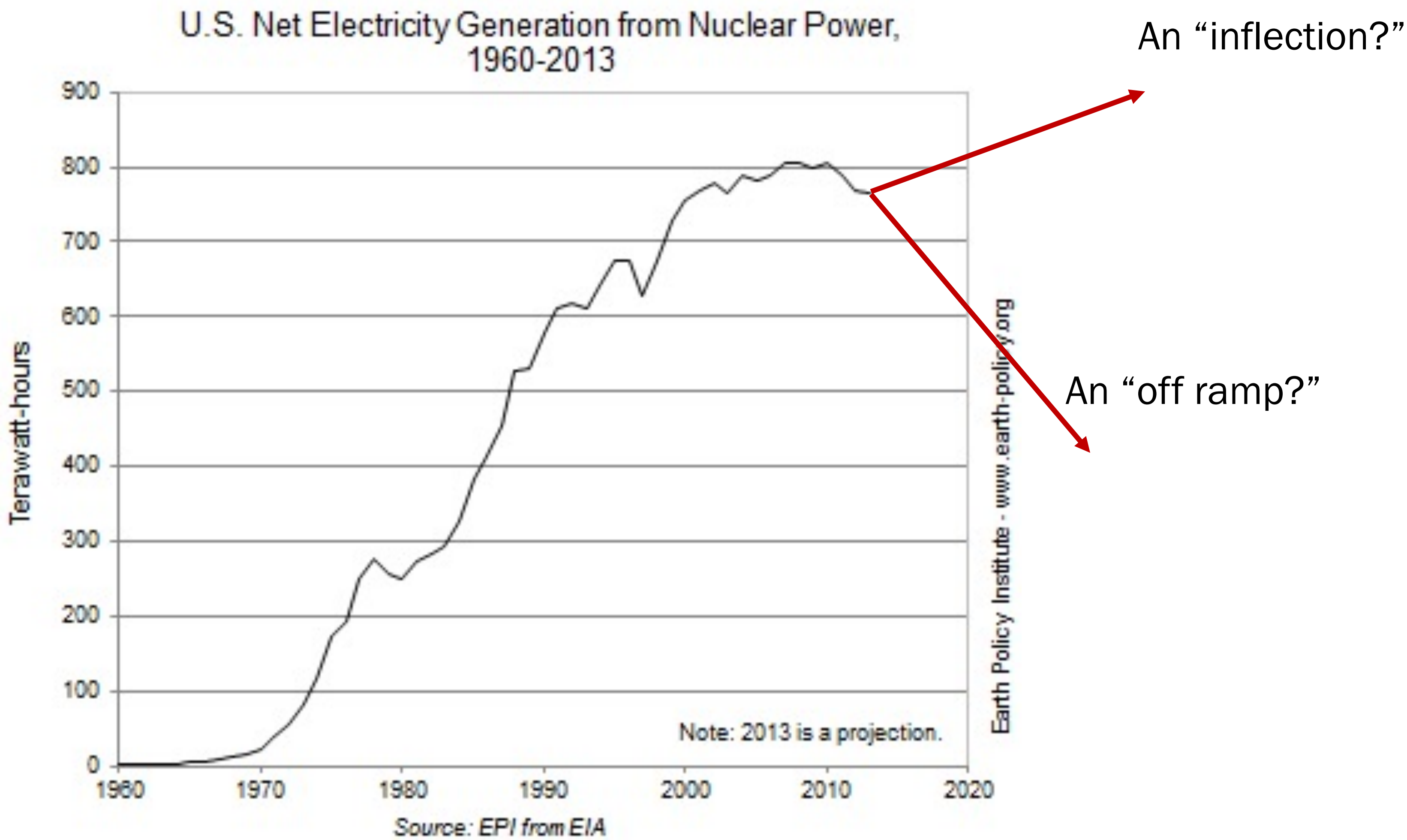
Ernst & Young LLP, "Creating confident investors and competitive advantage for the UK nuclear supply chain" November 2017

THE NATIONAL & INTERNATIONAL SECURITY IMPERATIVE



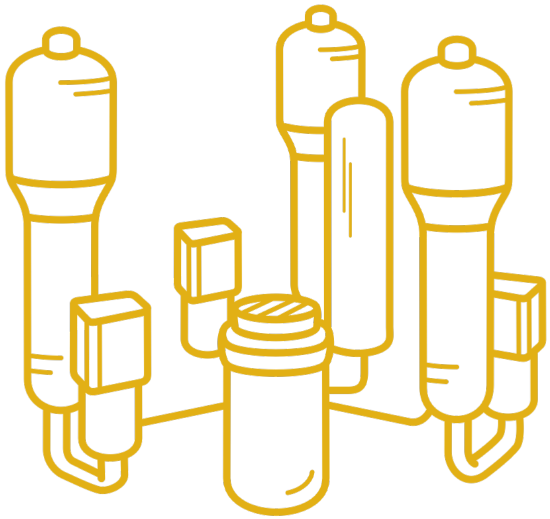
PRAGUE (Reuters, 14 Nov 2018) - Czech Prime Minister Andrej Babis said on Wednesday geopolitics should be a factor when the NATO and EU member country decides future nuclear power investments as the country mulls whether to build new reactors.

TRAJECTORY OF COMMERCIAL NUCLEAR ENERGY



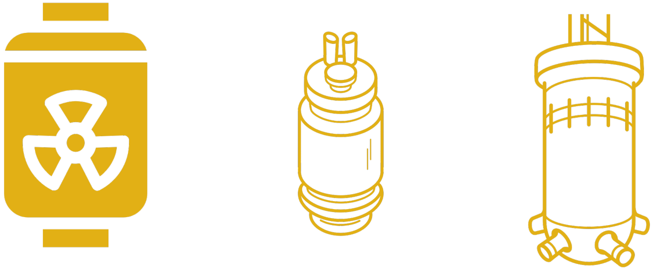
http://www.earth-policy.org/plan_b_updates/2013/update116

SOCIAL LICENSE



Prevailing design paradigm

Gigawatt scale light water reactors as grid scale sources of power



Emerging design paradigm

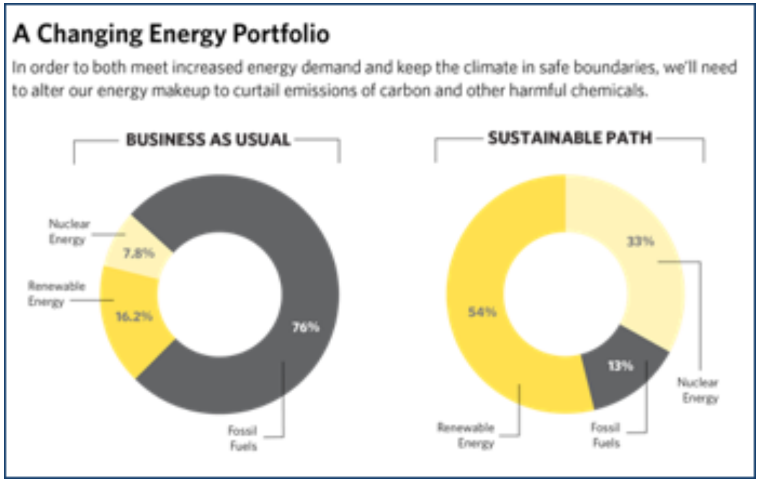
Small modular, micro, and nano reactors as off-the-grid, distributed, community-scale sources of power

Courtesy Aditi Verma, Ph.D., University of Michigan

ADVANCED NUCLEAR CONCEPTS-BY BUSINESS FUNCTION

- **Product**
  - Electricity (grid or dedicated)
  - Heat
  - Both
- **Size**
  - GW
  - MW
  - W
- **Examples**
  - Coal replacement
  - Dedicated to an industrial heat and/or power customer
  - Micro-reactor in a remote location, possibly transportable
  - Micro-reactor in an urban/suburban setting (defense base, EV charging)

NUCLEAR ENERGY INFLECTION POINT?



Source: The Nature Conservancy, The Science of Sustainability, 2018

Google

Moving toward 24x7 Carbon-Free Energy at Google Data Centers: Progress and Insights

Introduction

In recent years, Google has become the world's largest corporate buyer of renewable energy. In 2017 alone, we purchased more than seven billion kilowatt-hours of electricity (roughly as much as is used yearly by the state of Rhode Island[1]) from solar and wind farms that were built specifically for Google. This enabled us to match 100% of our annual electricity consumption through direct purchases of renewable energy; we are the first company of our size to do so.

Reaching our 100% renewable energy purchasing goal was an important milestone, and we will continue to increase our purchases of renewable energy as our operations grow. However, it is also just the beginning. It represents a head start toward achieving a much greater, longer-term challenge: **sourcing carbon-free energy for our operations on a 24x7 basis.**

Meeting this challenge requires sourcing enough carbon-free energy to match our electricity consumption *in all places, at all times.* Such an approach looks markedly different from the status quo, which, despite our large-scale procurement of renewables, still involves carbon-based power. Each Google facility is connected to its regional power grid just like any other electricity consumer; the power mix in each region usually includes some carbon-free resources (e.g. wind, solar, hydro, nuclear), but *also* carbon-based resources like coal, natural gas, and oil. Accordingly, we rely on those carbon-based resources — particularly when wind speeds or sunlight fade, and also in places where there is limited access to carbon-free energy. Carbon-free or not, around-the-clock electricity is the fuel that enables us to continuously deliver Google search results, YouTube video plays, Google Cloud Platform services, and much more without interruption.

OCTOBER 2018

The Nuclear Power Dilemma

Declining Profits, Plant Closures, and the Threat of Rising Carbon Emissions

Steve Clemmer
Jeremy Richardson
Sandra Sattler
Dave Lochbaum

November 2018

Union of Concerned Scientists

It's Time for Environmentalists and the Energy Industry to Work Together (Time Magazine, October 12, 2018)

MacArthur Foundation

Exelon

NICE Future
Nuclear Innovation: Clean Energy Future

CHOICES AND VALUES

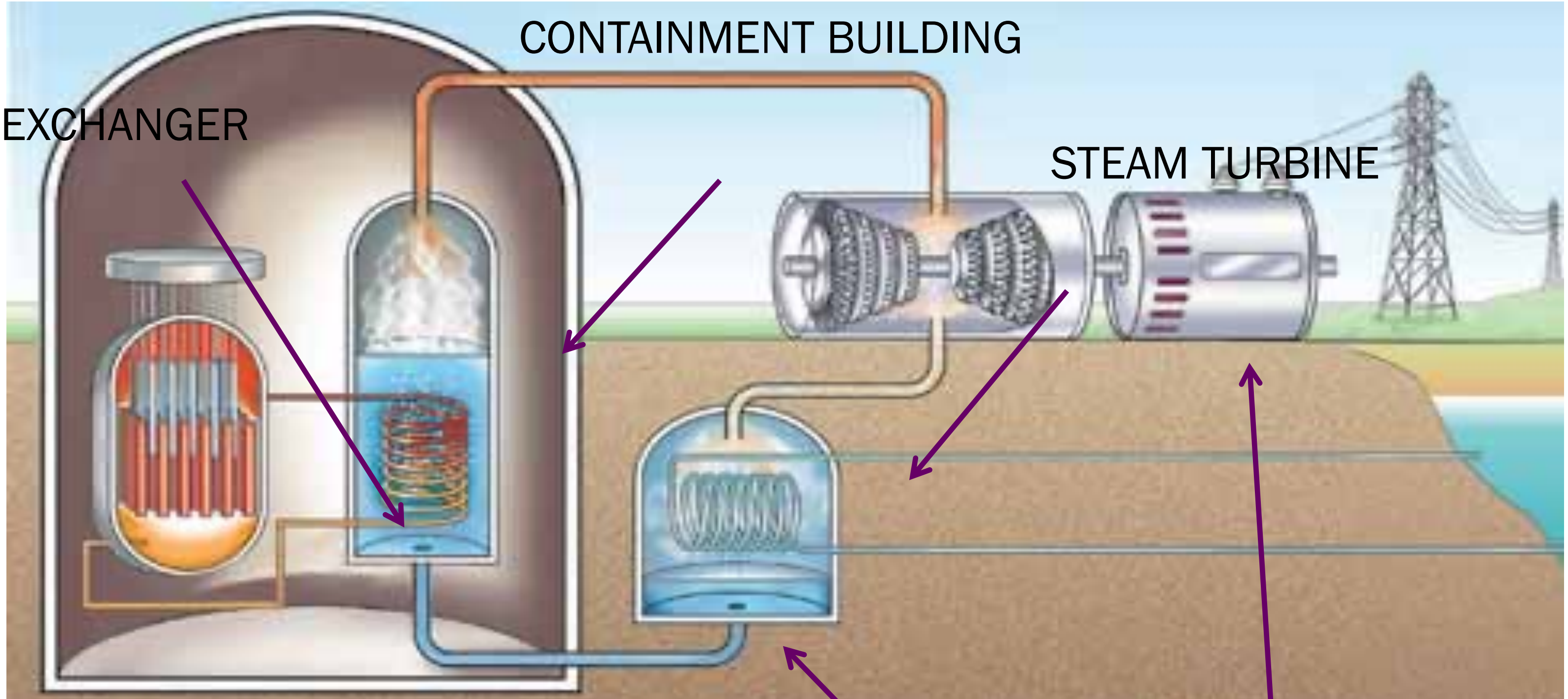
Reactor designers are envisioning a large number of new applications for nuclear technology.

Communities are in a position to envision a large number of deployment scenarios for their nuclear technology

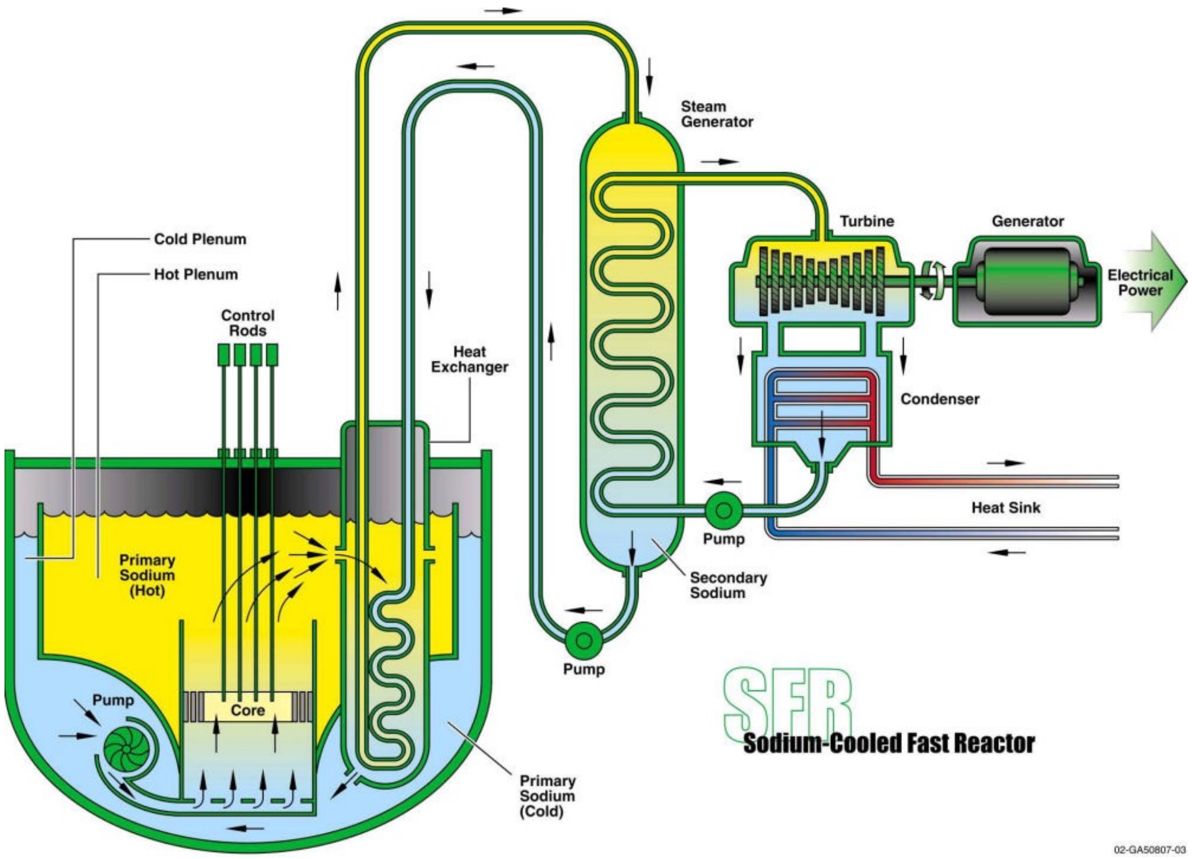
Lead rather than React! Build rather than Maintain!

A LIGHT WATER REACTOR NUCLEAR POWER PLANT

1000MWe, Roughly 600 jobs (plus 3x indirect jobs multiplier)



SODIUM COOLED FAST REACTOR



NATRIUM
345MWe

When a town loses its economic center

By Saqib Rahim | 10/23/2017 06:27 AM EST

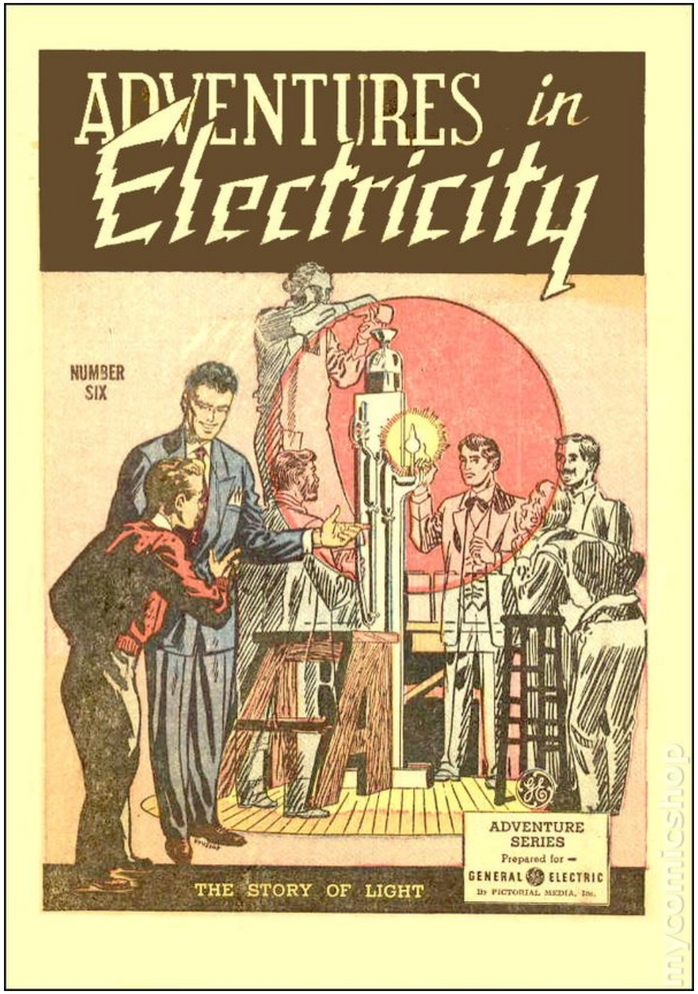
The Vermont Yankee nuclear plant, formerly operated by Entergy Corp., shut down in 2014. Nuclear Regulatory Commission/Wikipedia

POSSIBILITIES

Create options that align with local values

- *Co-located businesses that optimally use the energy (water, hydrogen, low temp heat for agriculture, district heating)*
- *Training Centers (As a first deployer, become the leading-edge trainer)*
- *Supply chain opportunities*
- *Spin off technologies*

SYNERGY


ADVENTURES in Electricity
NUMBER SIX
ADVENTURE SERIES
Prepared for
GENERAL ELECTRIC
By PICTORIAL MEDIA, Inc.
THE STORY OF LIGHT
mycomicshop


More Time
FOR
BETTER LIVING
MADE IN CANADA
GENERAL ELECTRIC
APPLIANCES
Prepare your Meals .. Help you Entertain .. Do your Housework
.. and SAVE MONEY
You'll marvel how quickly you can do your housework with the aid of General Electric Appliances. Every day, they will give more time for relaxation, at less cost.
It's so exciting to cook a complete dinner automatically on a Hotpoint Hi-Speed Range—and you'll enjoy electric cooking that is clean, cool, fast and thrifty. Besides, the G-E Refrigerator will protect your perishables—save on food bills.
In your laundry, a General Electric Washer and Ironer will do all the hard work of the weekly wash—make the clothes look fresher and last longer—and reduce laundry bills to the minimum. A G-E Cleaner speeds up housework.
Decide now to see the many General Electric Appliances on display at leading electrical, department and hardware stores. Easy terms to suit your budget.
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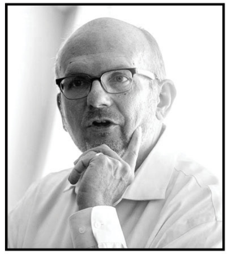
WEBINAR PANEL DISCUSSION



THURSDAY, DECEMBER 16, 2021
10:00 - 11:30 AM

Register Here: http://www.uwyo.edu/ser/events/event-registration2.html

FEATURING:

CCUS Background and Wyoming CarbonSAFE Project Update
Dr. Fred McLaughlin, University of Wyoming School of Energy Resources

Pore Space Leasing: Private and Federal Issues
Kris Koski, Esq., Long, Reimer, Winegar, Beppler, LLP

Leasing on State Lands
Tyler Seno, Wyoming Office of State Lands & Investments

Class VI Permitting: Resources, Guidance and Approach
Lily Barkau, Wyoming Department of Environmental Quality

CCUS Financing
Kipp Coddington, Esq., University of Wyoming School of Energy Resources

Moderated by Scott Quillinan, University of Wyoming School of Energy Resources

CO_2 Carbon Capture, Utilization & Storage Development in Wyoming