

FUELS FOR THE FUTURE

AUGUST 2023, TODD ALLEN, PROFESSOR & SENIOR FELLOW



FASTEST PATH TO ZERO
UNIVERSITY OF MICHIGAN

CONTEXT



WHAT DO WE WANT IN OUR FUTURE?



VS.



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

- Clean
- Affordable
- Resilient
- Equitable

Innovation: Not Limitation

ENERGY REIMAGINED

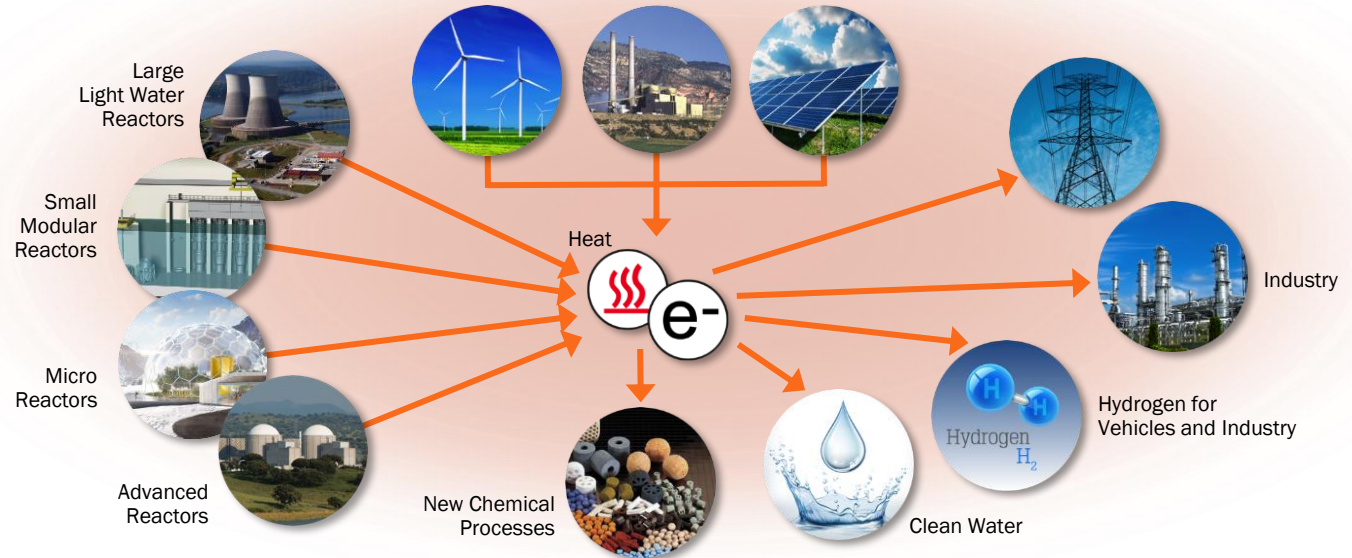
Maximizing energy utilization, generator profitability, and grid reliability and resilience through novel systems integration and process design

Today
Electricity-only focus



Potential Future Energy System

Integrated grid system that leverages contributions from nuclear fission beyond electricity sector



Flexible Generators ❖ Advanced Processes ❖ Revolutionary Design

EXISTING COMMERCIAL NUCLEAR REACTORS



Applications:
Baseload electricity; 24/7

Number in operation: **98 in U.S.**

Timeframe: **Built in the 1950s-1980s**

Products: **Electricity**

Megawatts: **1,000+ megawatts**

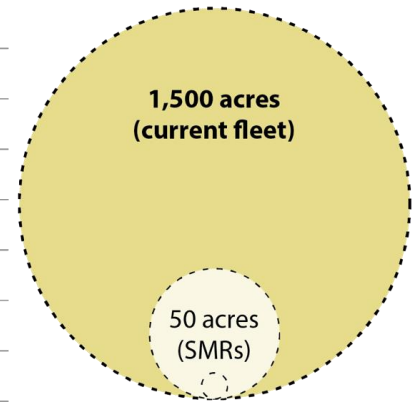
Customers: **Large utilities**

Emergency zone: **10 miles**

Construction: **Custom built on site**

Scalability: **Difficult due to size and cost**

Footprint



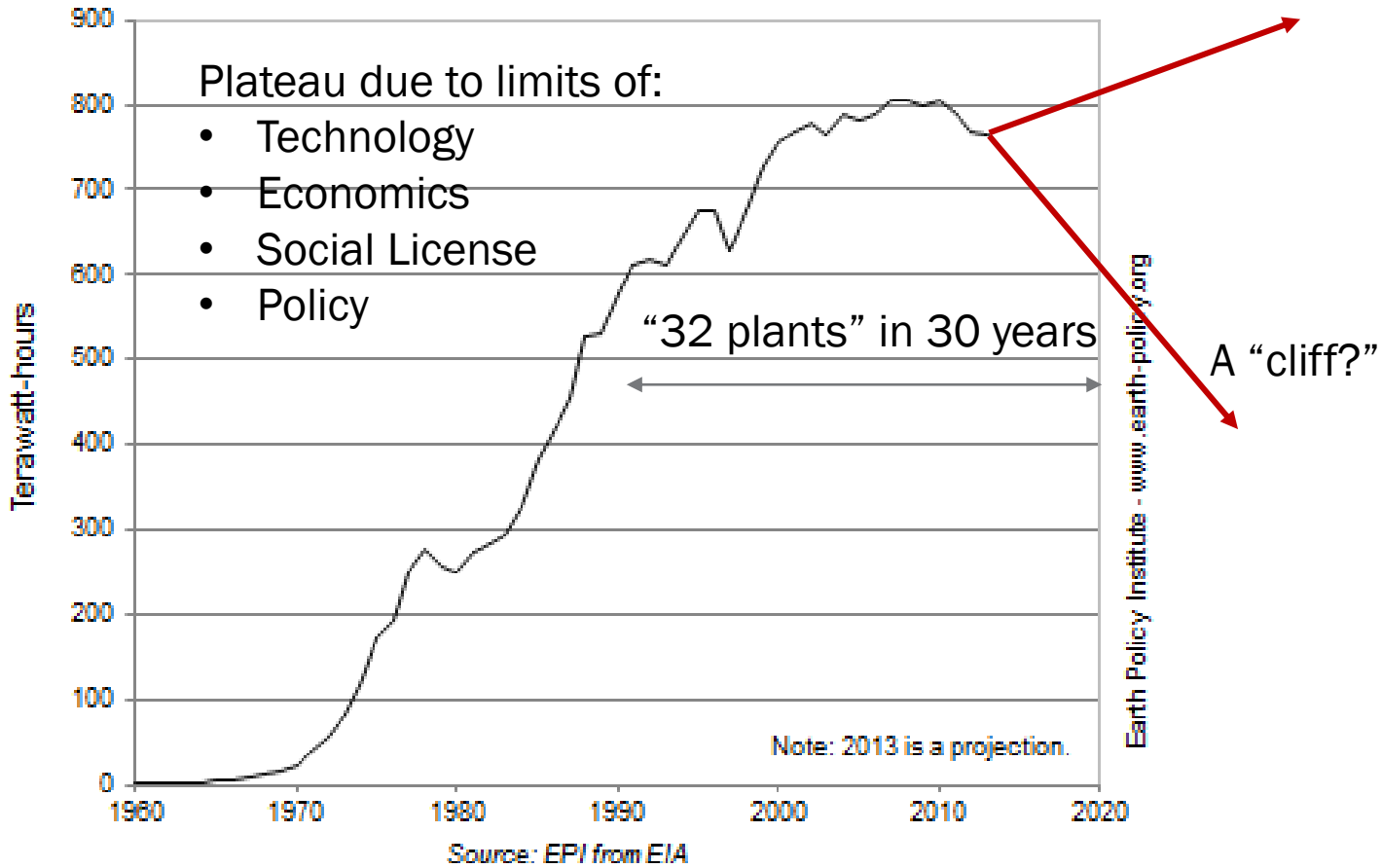
Less than an Acre
(Micro Reactors)

Did you know?

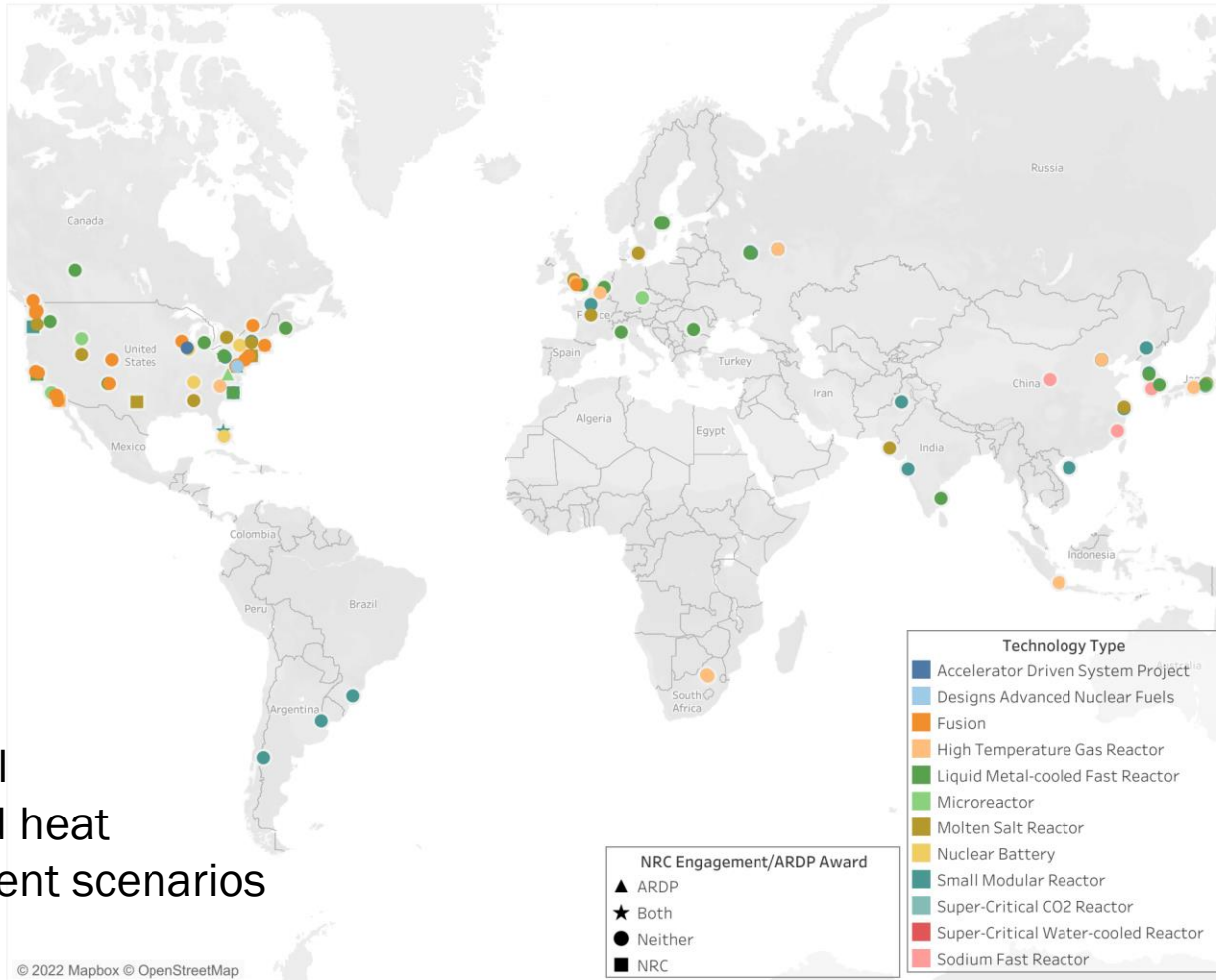
In November 2018, the Union of Concerned Scientists recommended federal and state governments adopt policies to preserve the low-carbon electricity the current fleet of nuclear reactors provides.

TRAJECTORY OF ATOMS FOR PEACE GENERATION

U.S. Net Electricity Generation from Nuclear Power, 1960-2013



2021 Advanced Nuclear Map



Large to small
Electricity and heat
New deployment scenarios

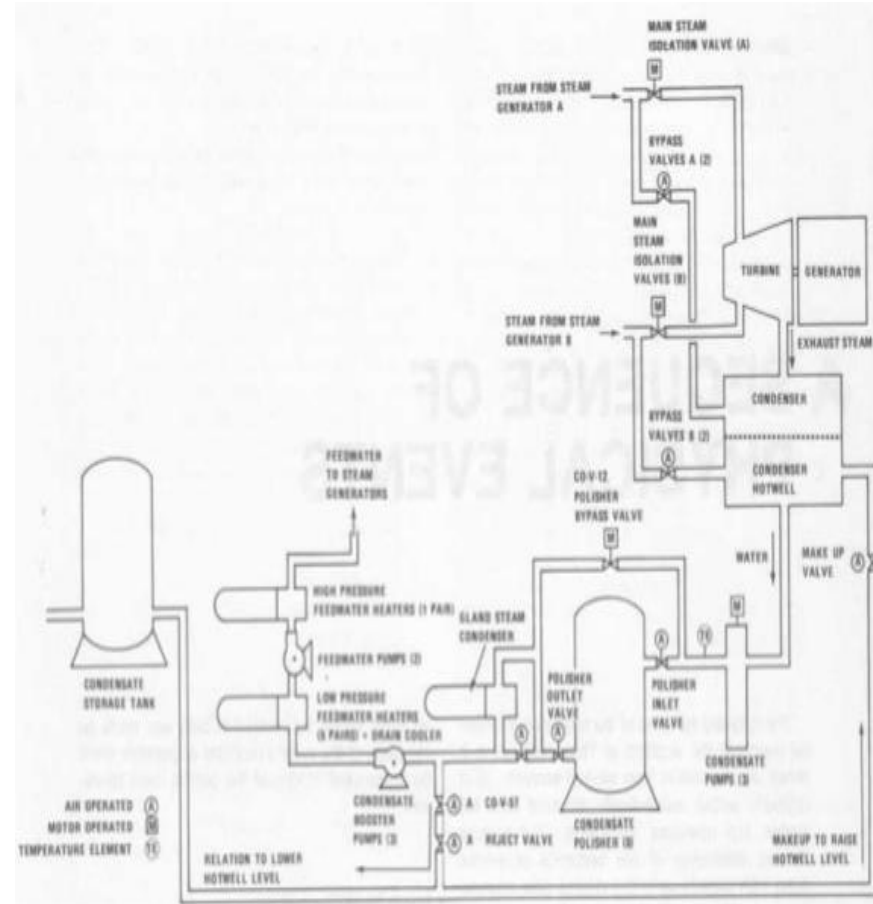
ENERGY TECHNOLOGY COMPLEXITY

THREE MILE ISLAND ACCIDENT

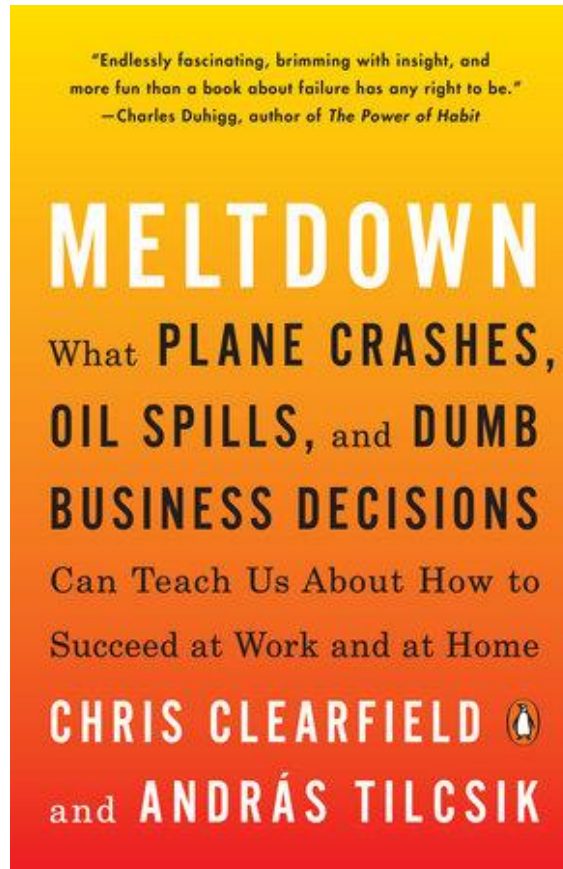
TMI-I shutdown at the time.

- Non-routine maintenance practice
- Violation of an NRC rule
- Design Flaw

The accident progressed faster than the humans responded



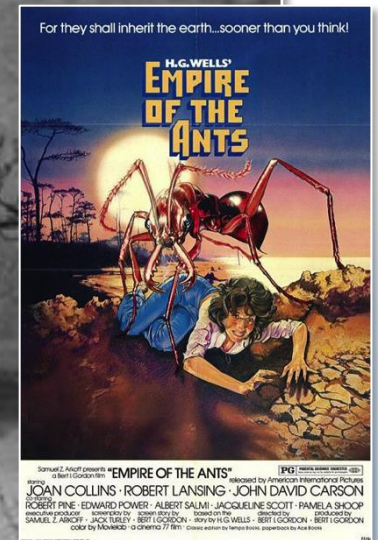
ENERGY TECHNOLOGY COMPLEXITY



Tightly coupled systems can fail fast and in unanticipated ways

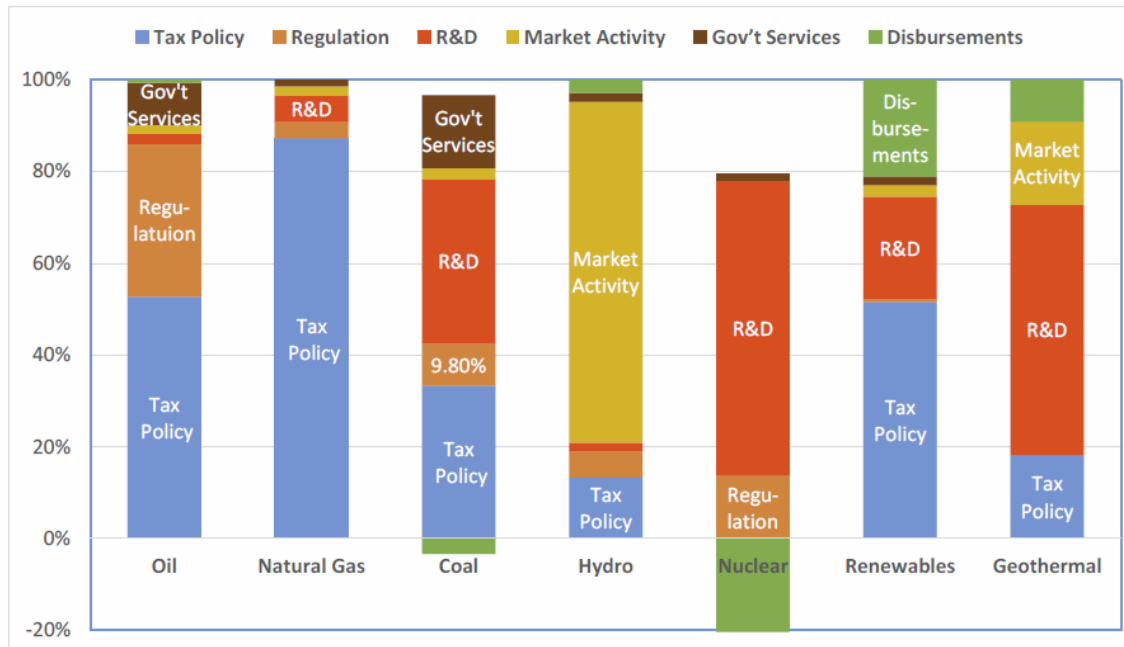
COMMUNITY APPROPRIATENESS

A first entertainment use of radiation-induced mutant creatures



SYSTEM-INFORMED DECISION-MAKING

Exhibit 4 – Mix of Federal Expenditures for Each Energy Source



Expenditures for nuclear need better balance between R&D and tax policy

2015/2016 PIVOT

The 2015/2016 Pivot:

- Research
 - GAIN
 - NRIC
 - ARPA-E
- Legislation & Policy
 - NEIMA/NEICA
 - ARDP
 - NGOs (Third Way, CATF, BTI, Good Energy Collective, NIA, Global Nexus Initiative, Energy for Humanity)
- Education & Advocacy
 - Nuclear Reimagined
 - Nuclear Energy Bootcamp
 - Fastest Path to Zero

Figure 3: Nuclear Plants Closing in Restructured States



Source: Dan Wood, President and CEO, FirstEnergy. Testimony to Nuclear Energy Caucus (4/17/18)

Advanced Reactor Companies



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“There are decades where nothing happens; and there are weeks where decades happen.”

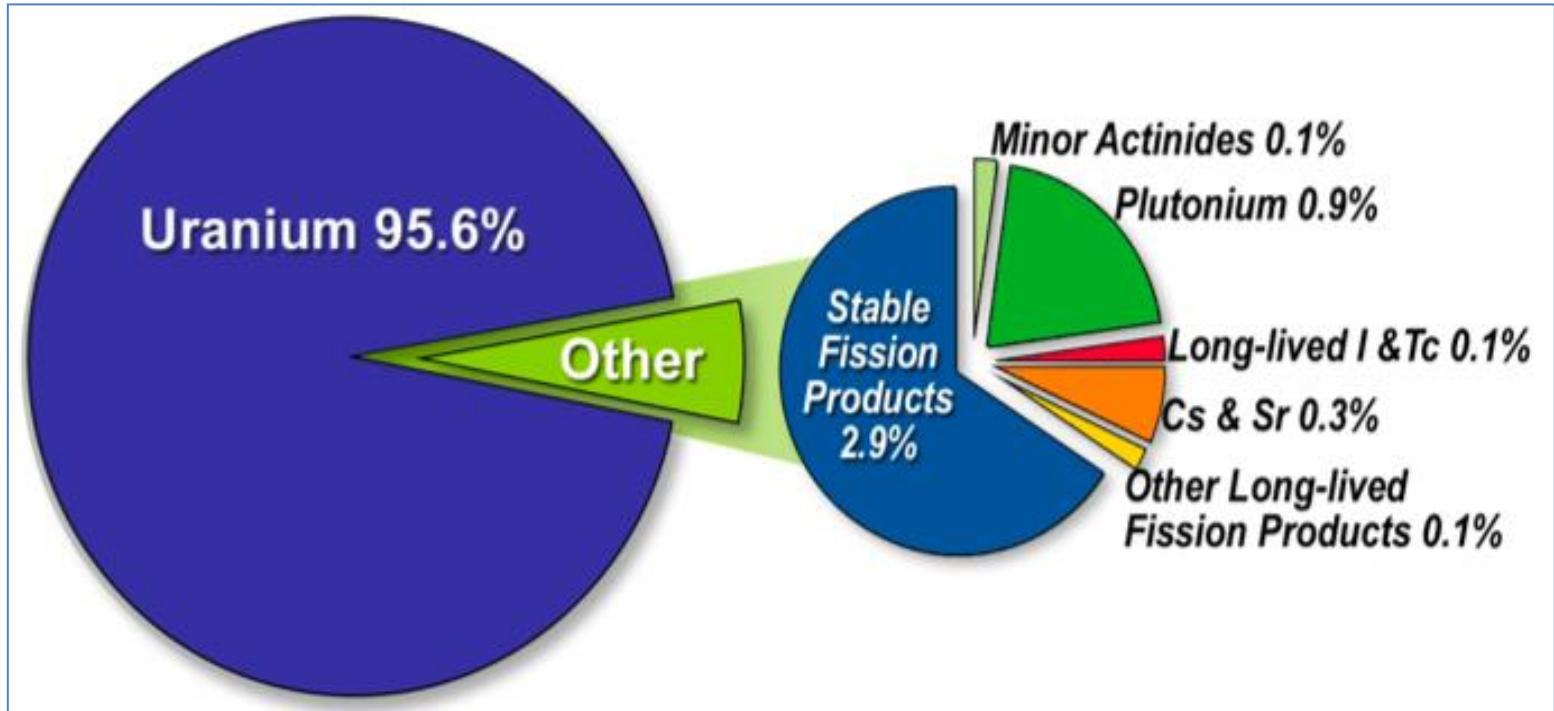
— Vladimir Ilyich Lenin

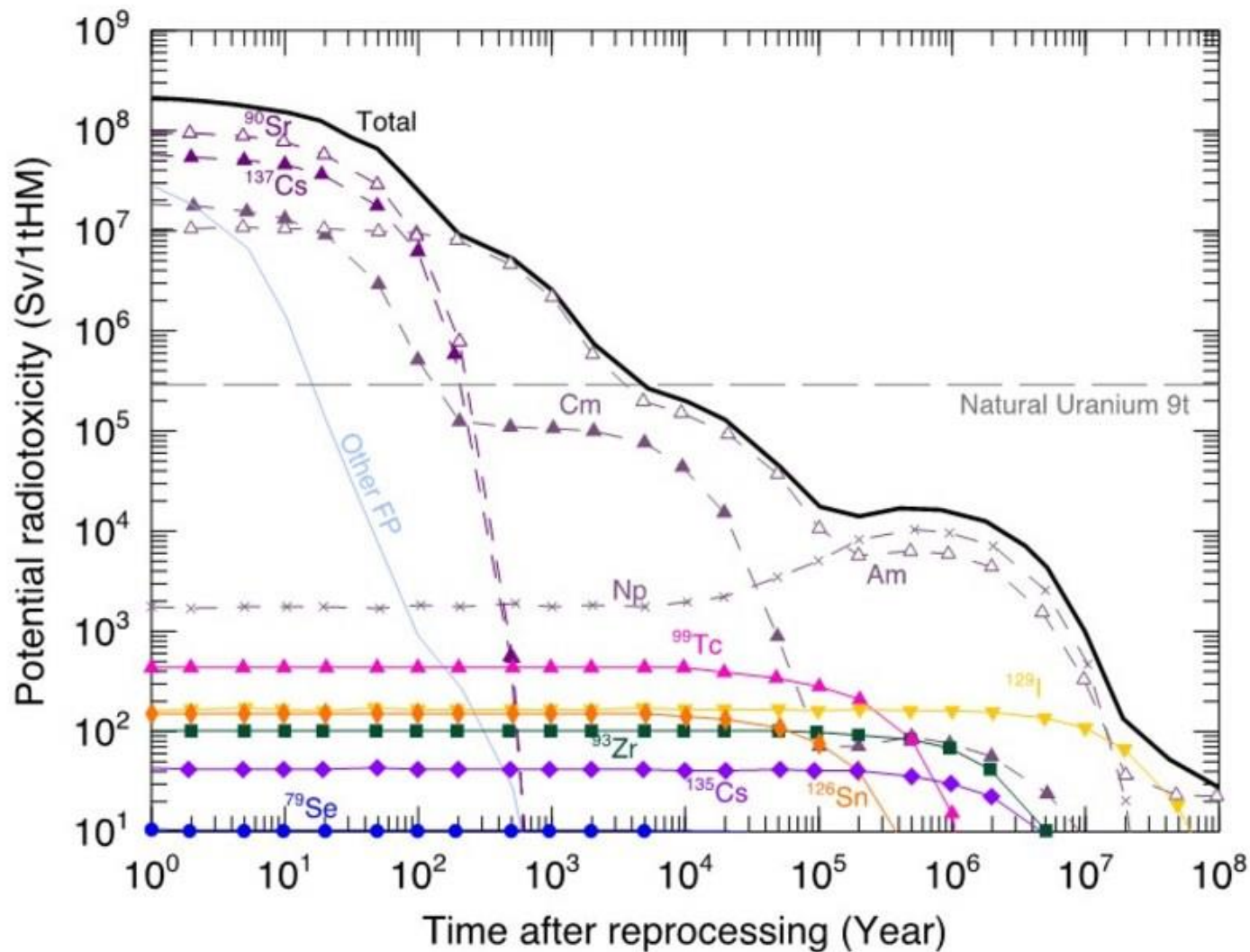
No implied support for Lenin or anything he did except the quote



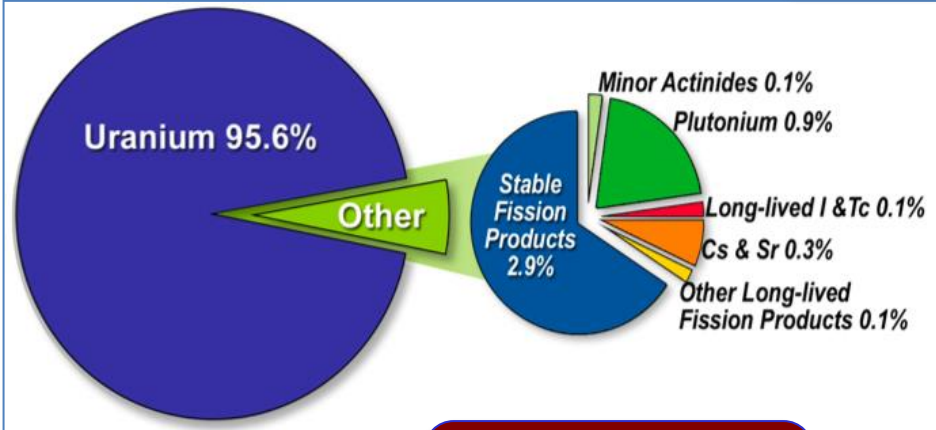
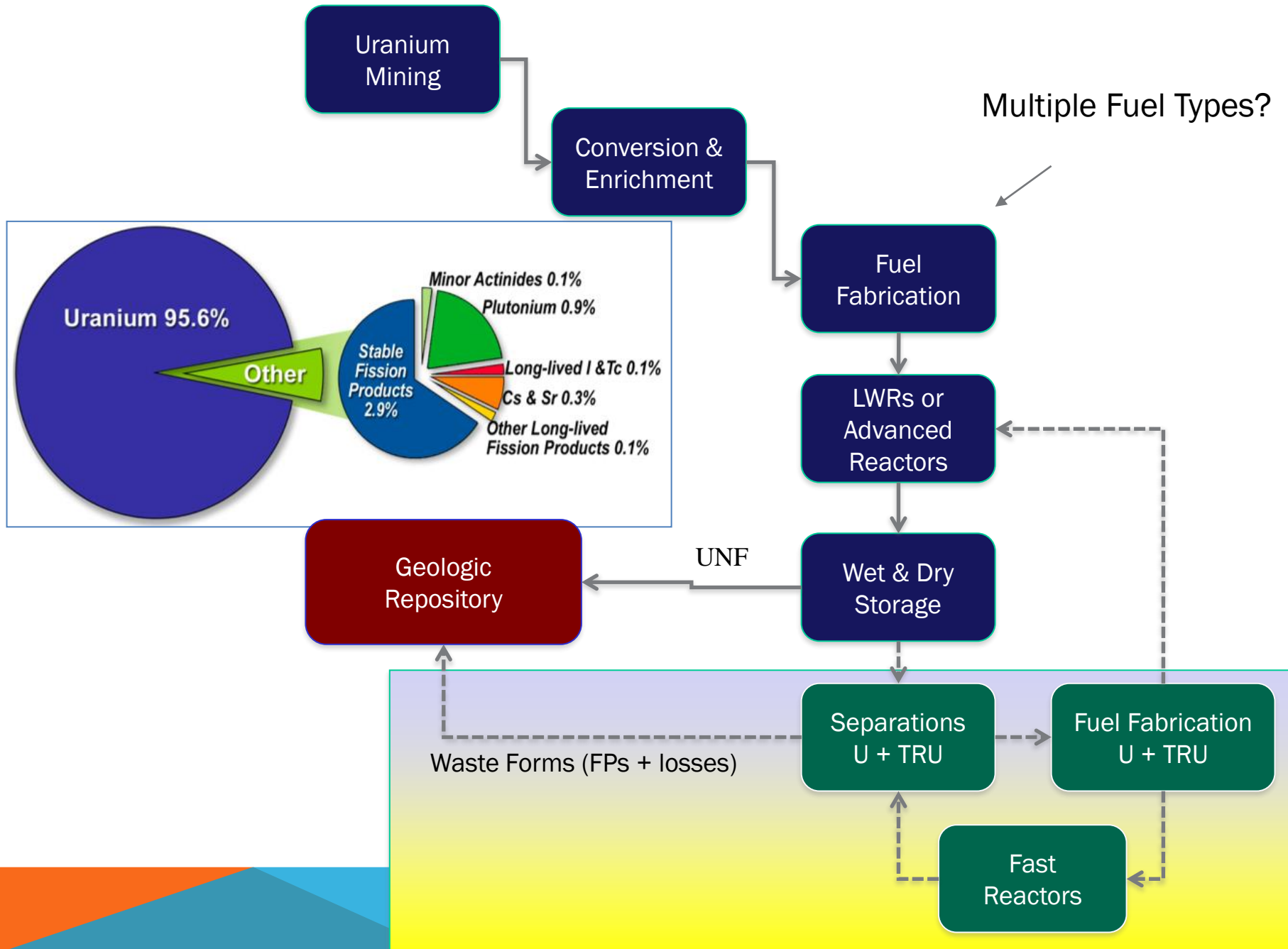
FUEL USAGE







Transmutation:
Use neutron
probabilities to
create shorter -
lived isotopes



Geologic Repository

UNF

Separations U + TRU

Fuel Fabrication U + TRU

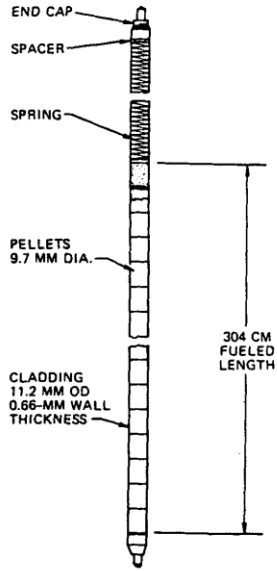
Fast Reactors

Waste Forms (FPs + losses)

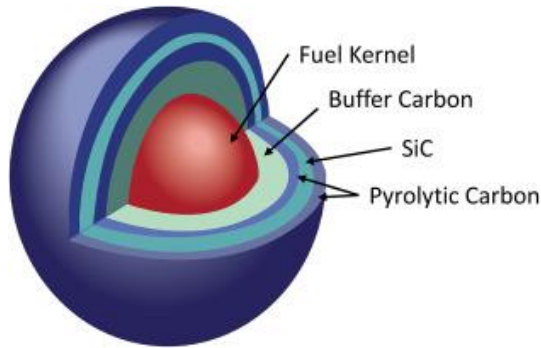
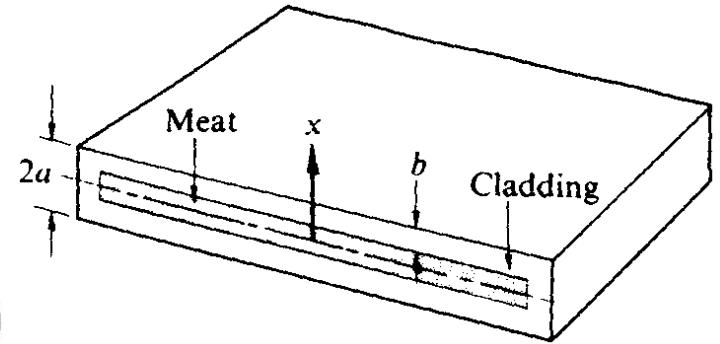
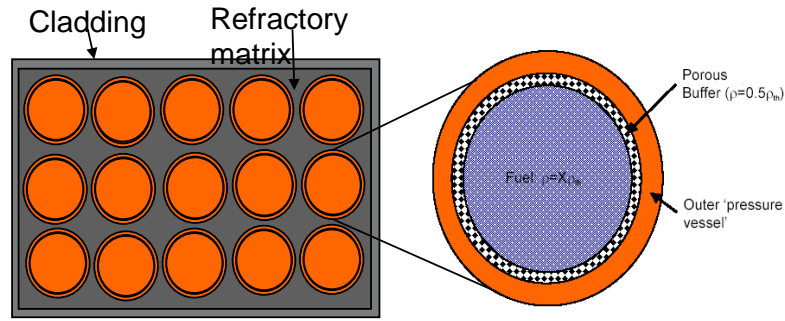
FUEL



FUEL TYPES



Fuel rod of a pressurized-water reactor.

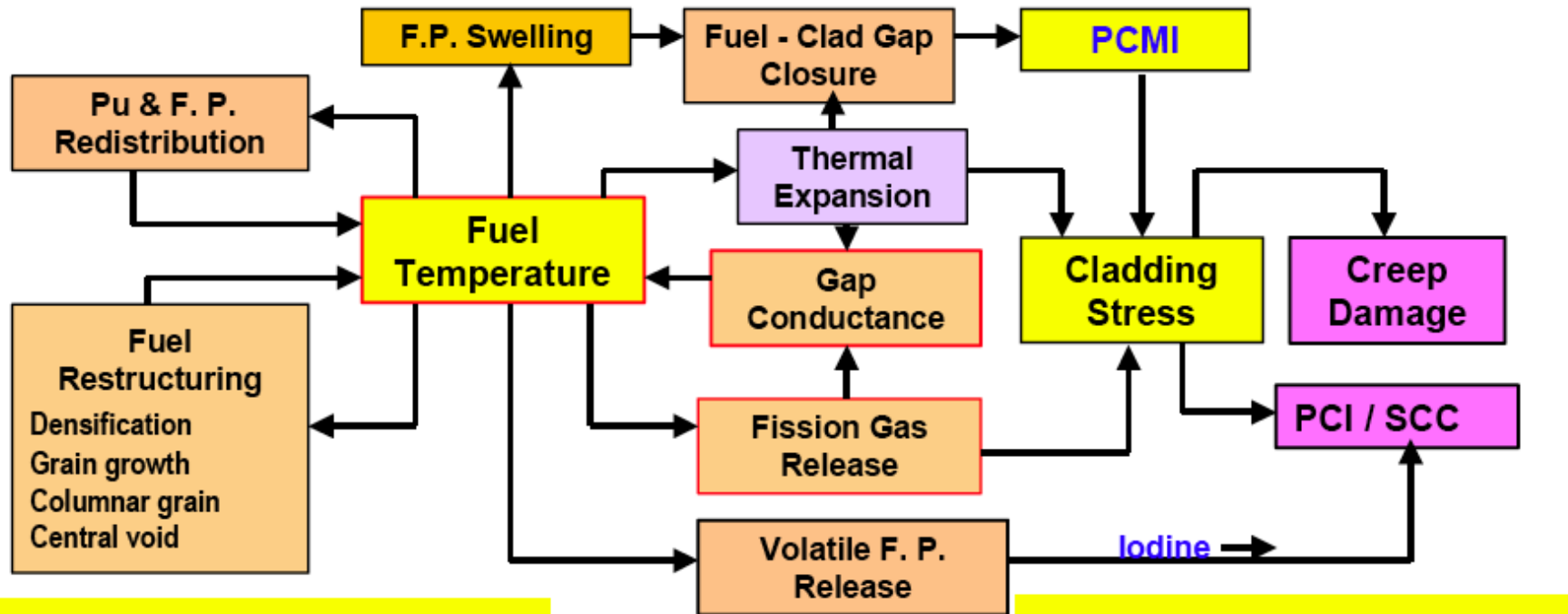


Fuel-clad system is designed to

- Produce and transfer heat to the coolant while
- Preventing fission products from reaching the coolant

FUEL ENVIRONMENT

Interactive Phenomena Operating in Fuel during Irradiation



FUTURE



MOTIVATION

Build nuclear fuels to:

- Optimize resource utilization
- Minimize product lifecycle waste
- Minimize cost
- Simplify manufacturability
- Maximize operational lifetime while minimizing failures/eliminate failure mechanisms
- Maximize social acceptance

But these goals were the same 70 years ago so what is new

GILBERT nuclear physics
No. U-238

ATOMIC ENERGY LAB

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FOR THE JUNIOR SCIENTIST

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- WATCH ACTUAL ATOMIC DISINTEGRATION—RIGHT BEFORE YOUR EYES!
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CONTENTS

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That's what the outstanding discovery of Uranium has done for the world! Now it's your chance to win \$10,000.00 Cash Reward! Find out how to prospect for Uranium and other radioactive ores with the Gilbert Geiger-Mueller Counter. It's exciting! It's safe! It's yours!

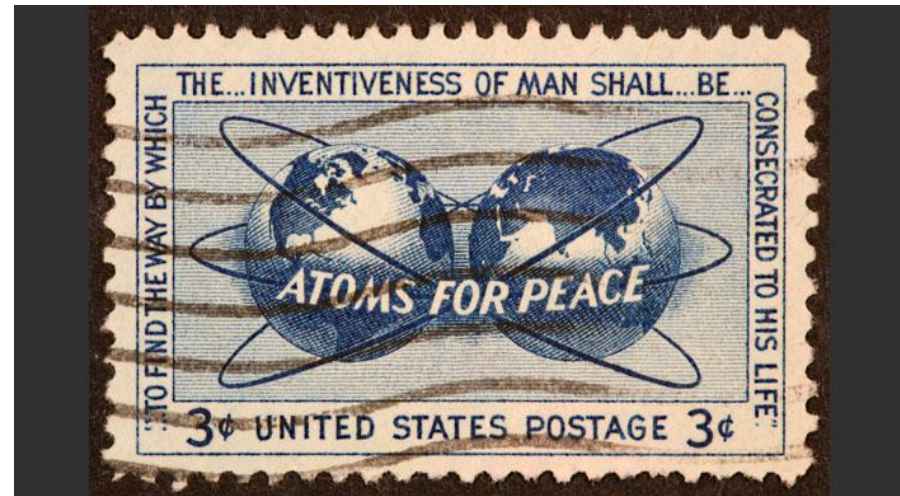
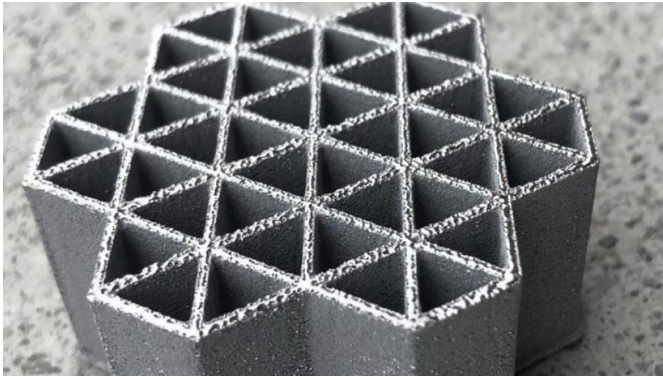
Exciting! Safe! ANOTHER GILBERT HALL OF SCIENCE PRODUCT

ALL SAMPLES OF RADIOACTIVE MATERIALS ARE COMPLETELY HARMLESS.

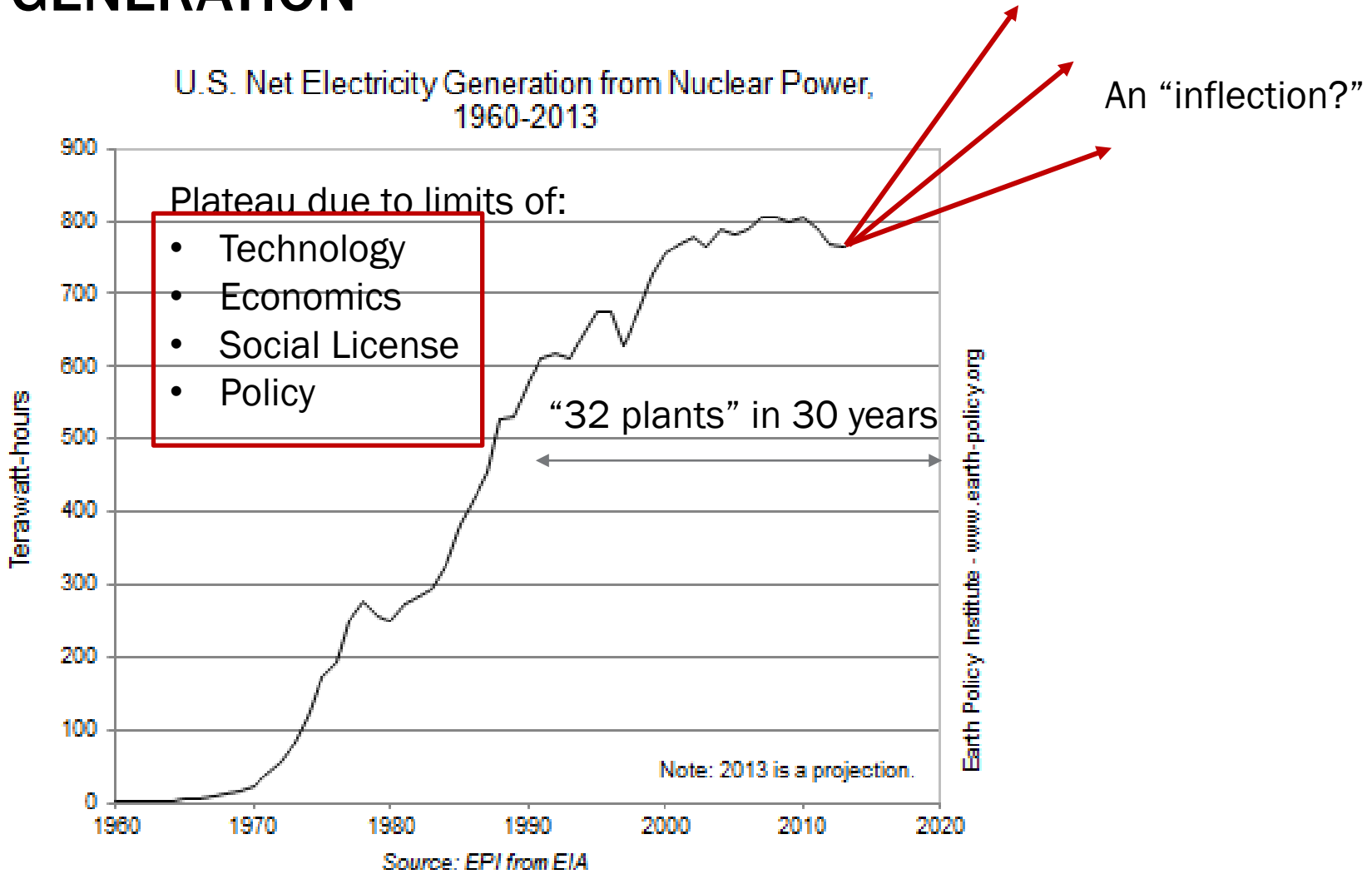
21ST CENTURY

We can now notionally:

- Build through additive manufacturing (fuel “chips” by design)
- Embed designer sensors
- Build digital twins
- Use artificial intelligence
- Design structures to simplify reprocessing
- Connect with community members during the design phase (TRISO versus pin)
- Craft the associated policy levers



TRAJECTORY OF ATOMS FOR PEACE GENERATION



END

