

A VISION FOR ADVANCED NUCLEAR ENERGY TRANSITION

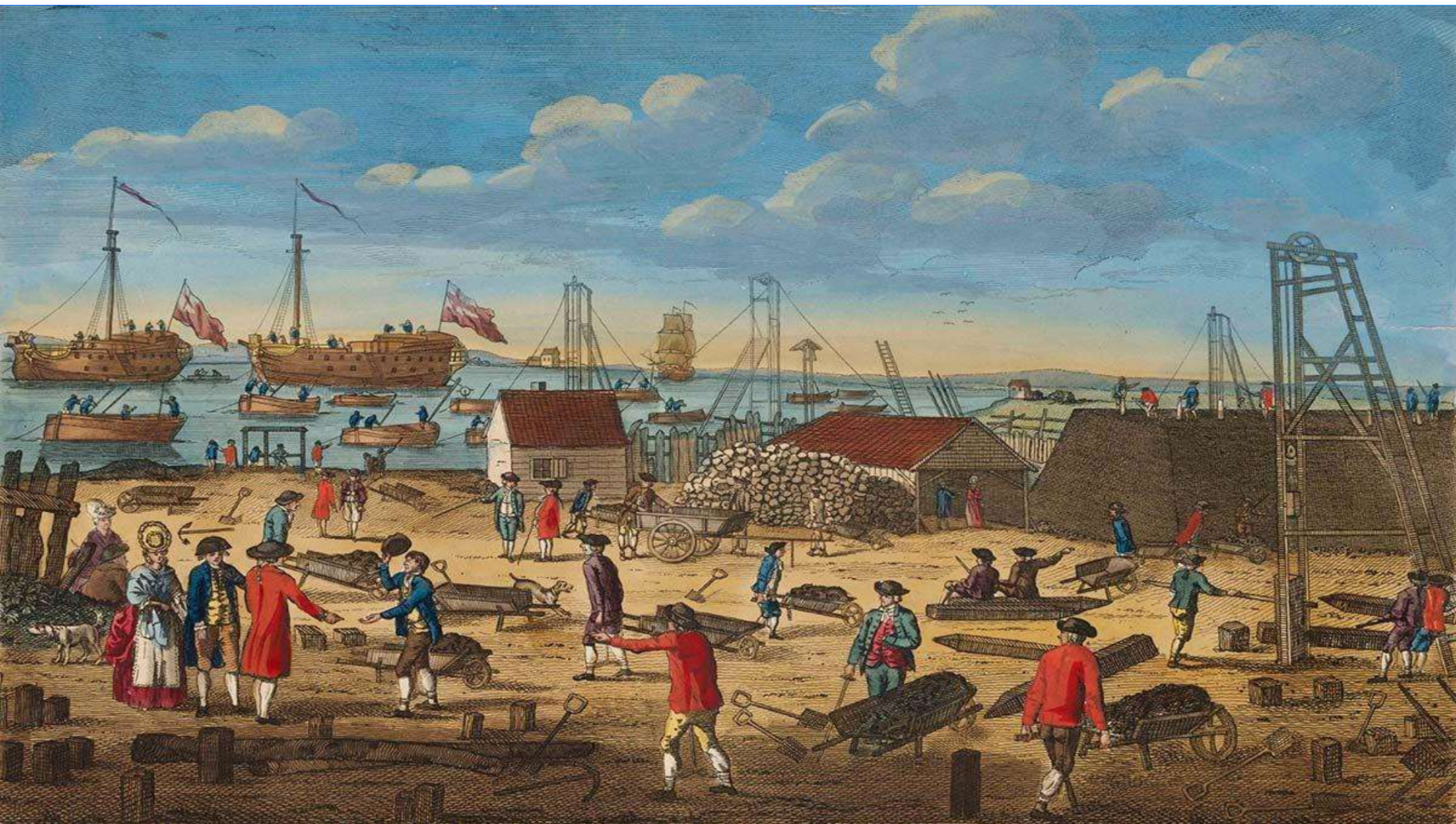
Presentation by Erik Townsend

November 21, 2024



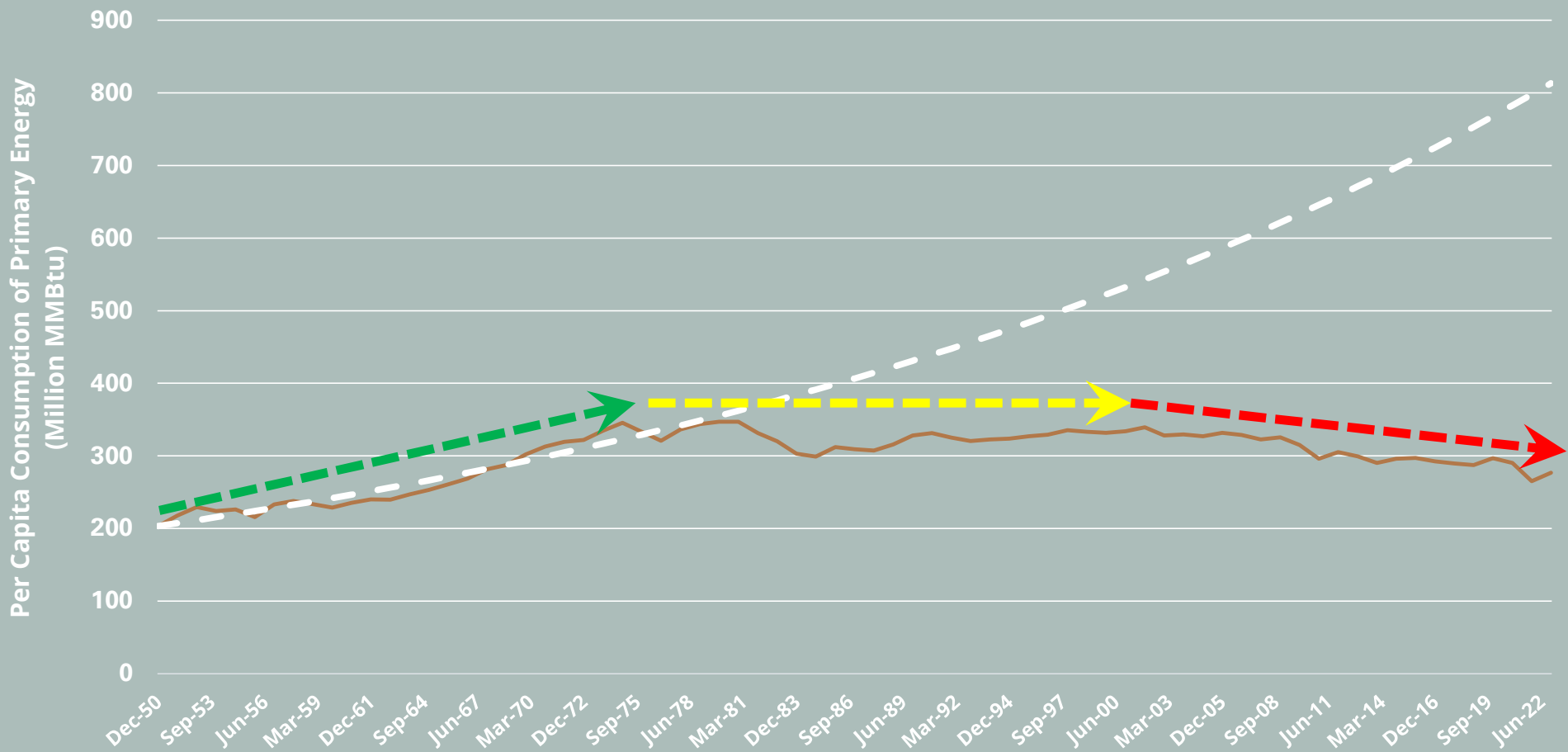
STANFORD
AUSTRALIA
ASSOCIATION

www.energytransitioncrisis.org/stanford





US Energy Consumption per Capita



Source: US EIA, Simplify calculations



ENERGY DEBATE
GOES NUCLEAR

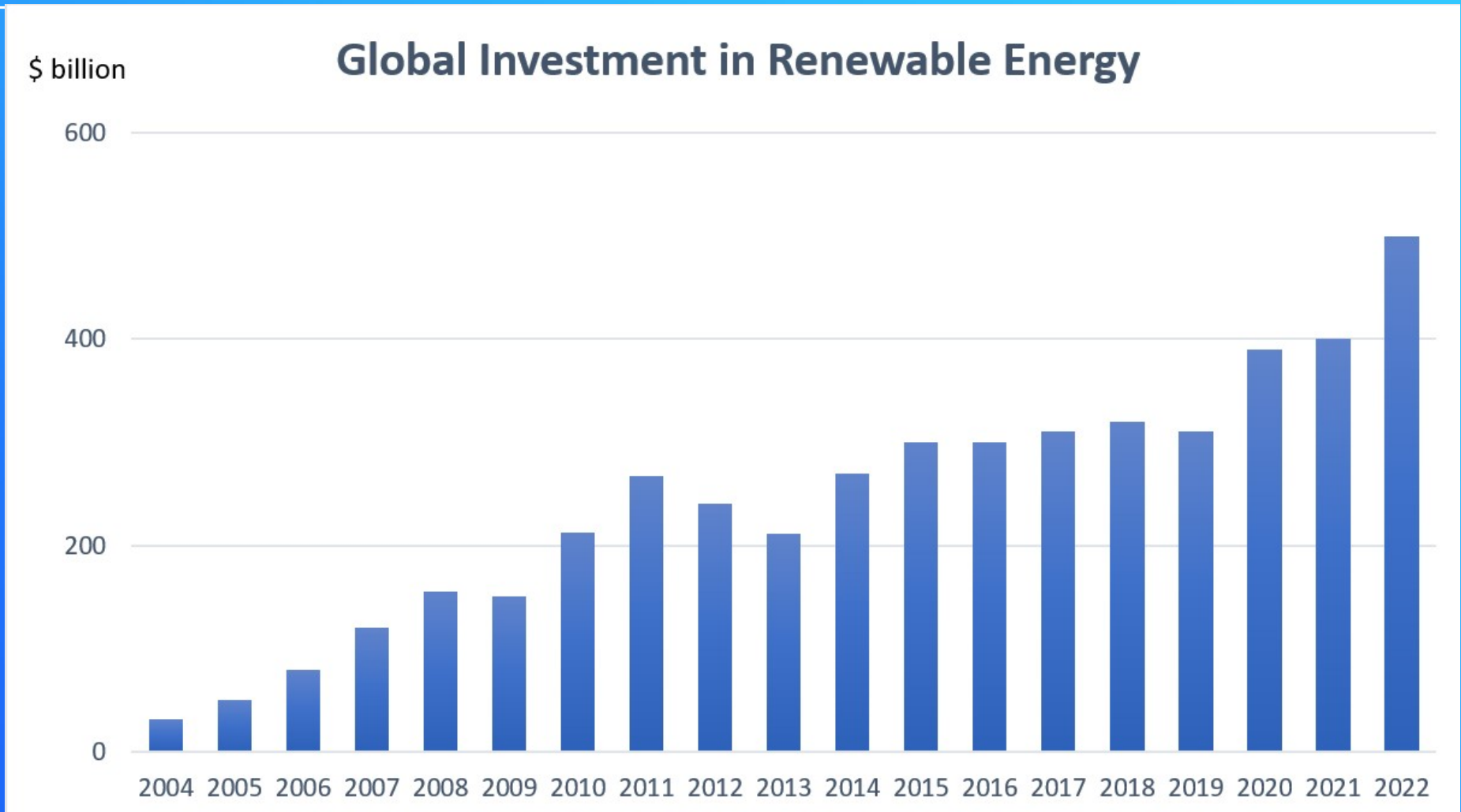
THE AUSTRALIAN

AGENDA

- Fast-paced vision for global energy transition
- Fireside Chat moderated by Matt Barrie: *Nuclear Energy in Australia*



US \$4.6TN SPENT GLOBALLY

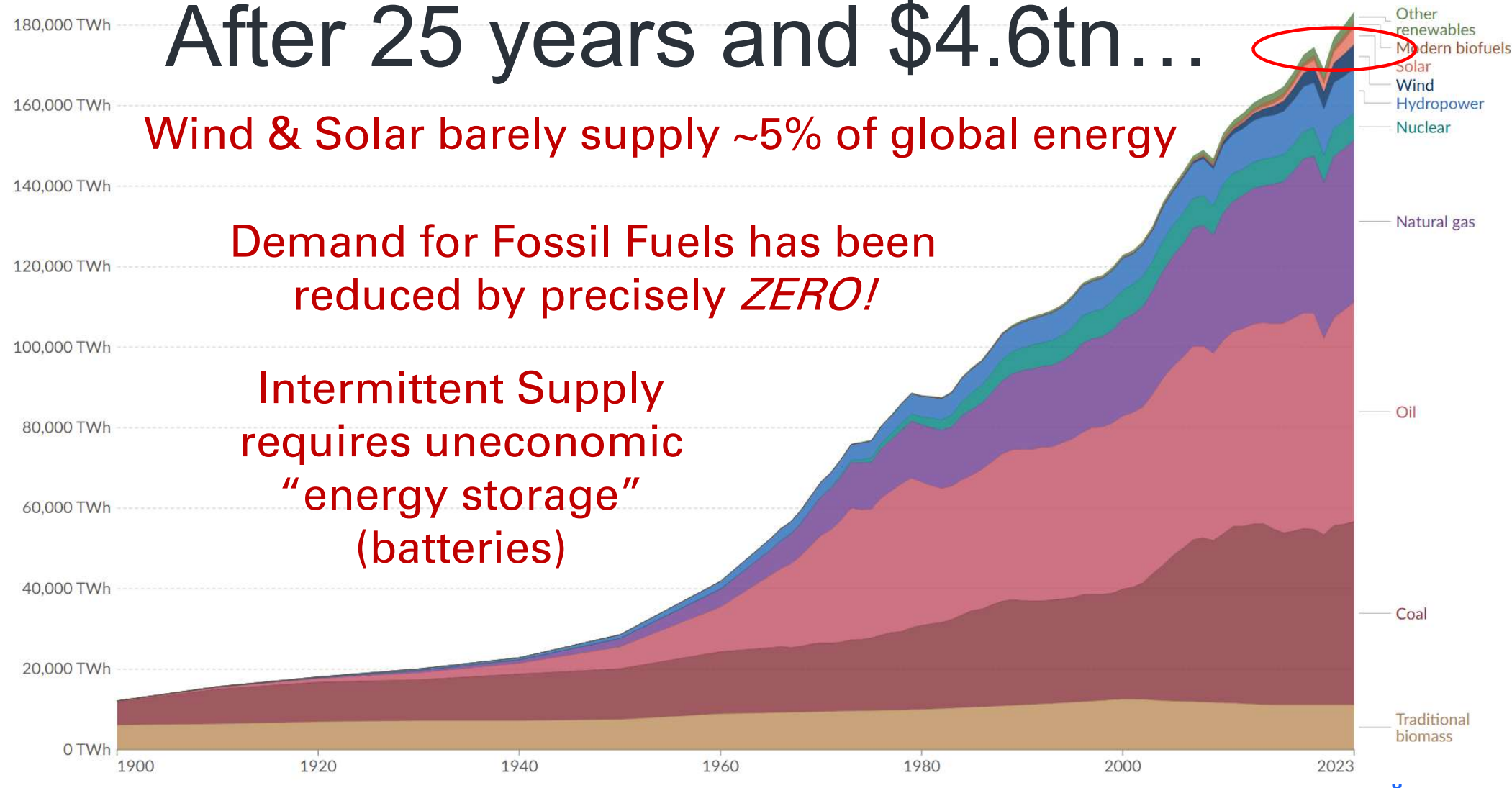


After 25 years and \$4.6tn...

Wind & Solar barely supply ~5% of global energy

Demand for Fossil Fuels has been reduced by precisely *ZERO!*

Intermittent Supply requires uneconomic "energy storage" (batteries)



Nuclear is the only option that scales to meet baseload electric demand for Energy Transition

مضاعفة إنتاج الطاقة النووية ثلاث مرات بحلول عام 2050
الإمارات العربية المتحدة، ديسمبر 2023
TRIPLING NUCLEAR ENERGY BY 2050
United Arab Emirates, December 2023



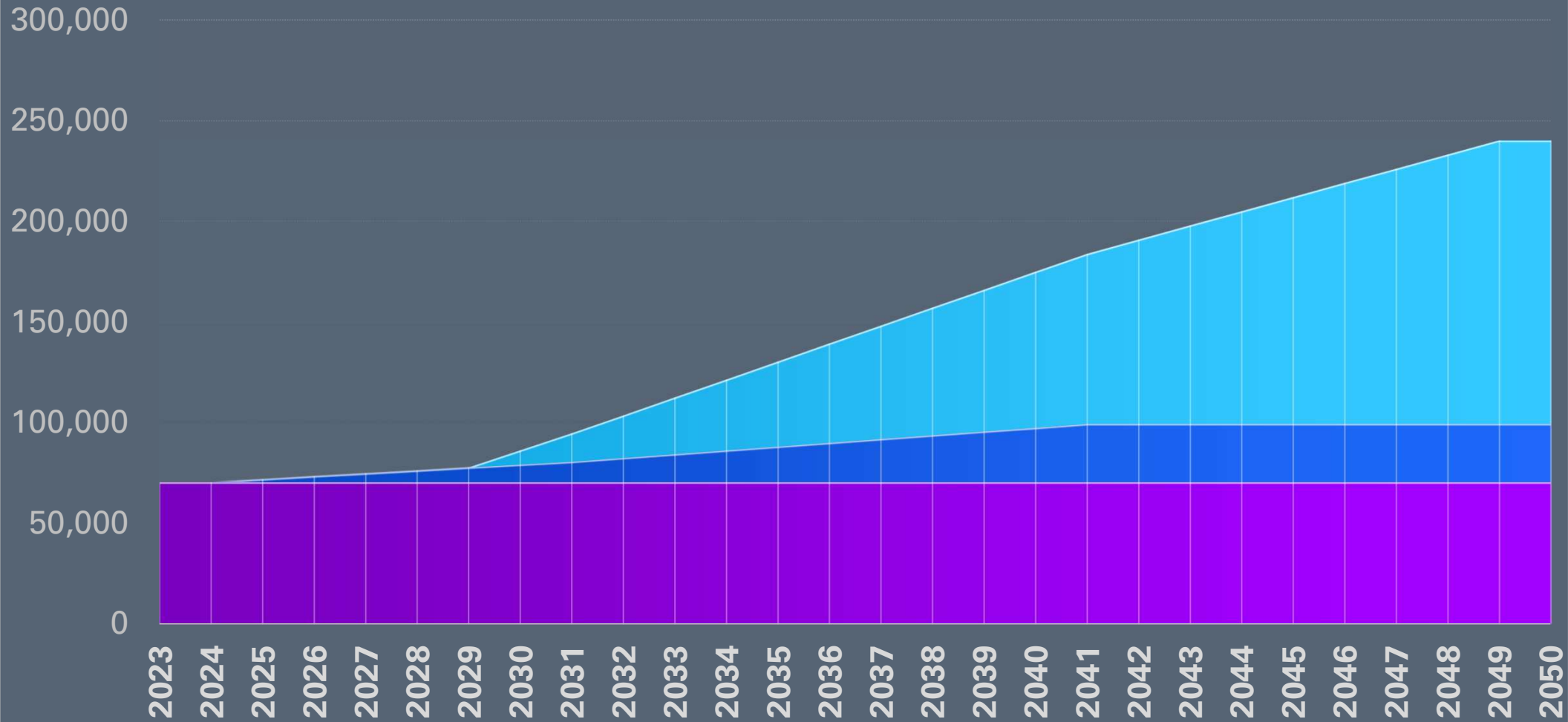
“TRIPLE-NUCLEAR” PLEDGE

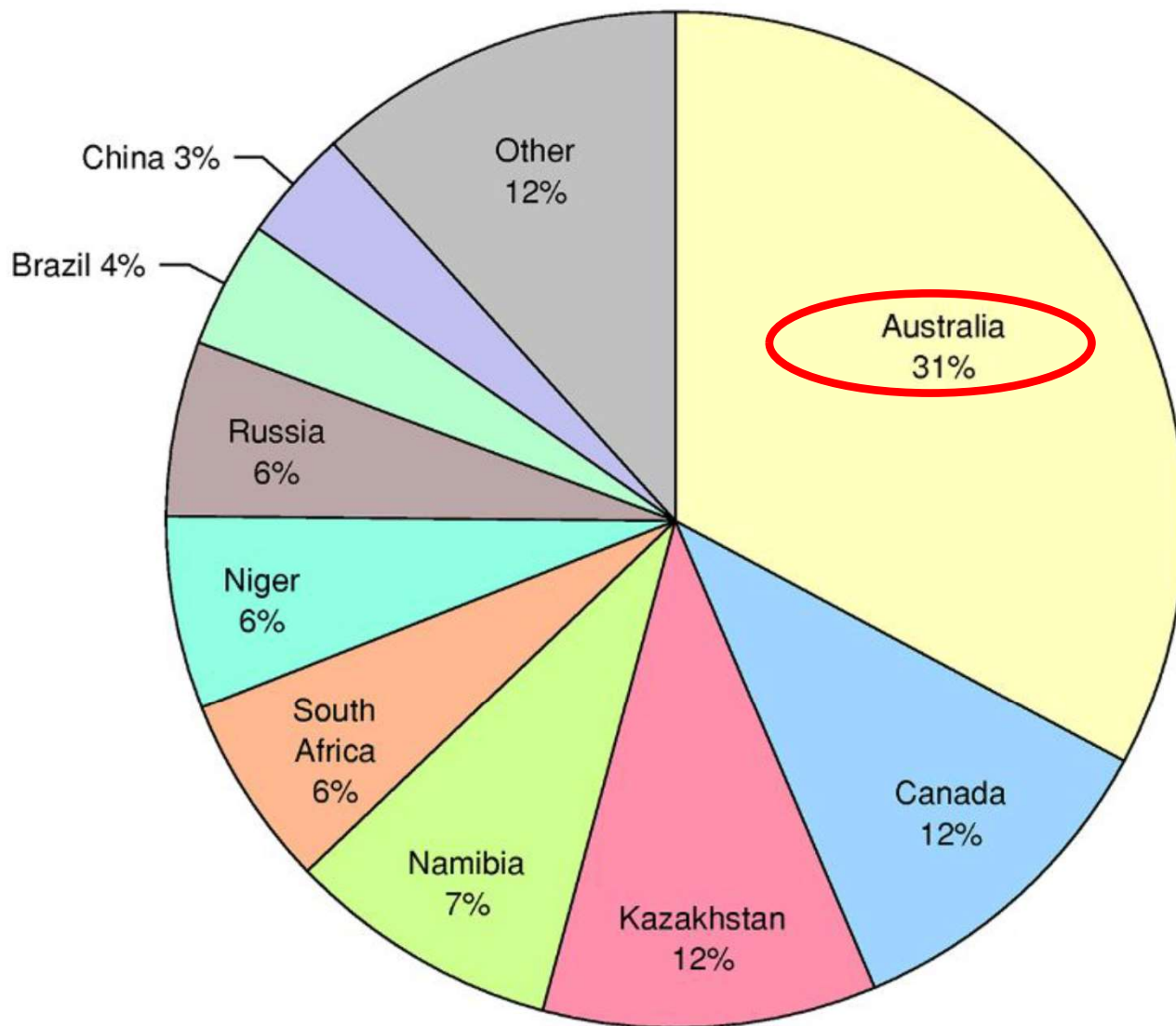


- Build another ~742GW Conventional reactors by 2050
- Approximate cost US\$3.7tn - \$11.2tn
- Build time ~ 5 – 10 yrs
- Electricity more expensive than coal or gas
- Supply ~11% of global energy

U₃O₈ Demand: Triple-Nuclear Scenario

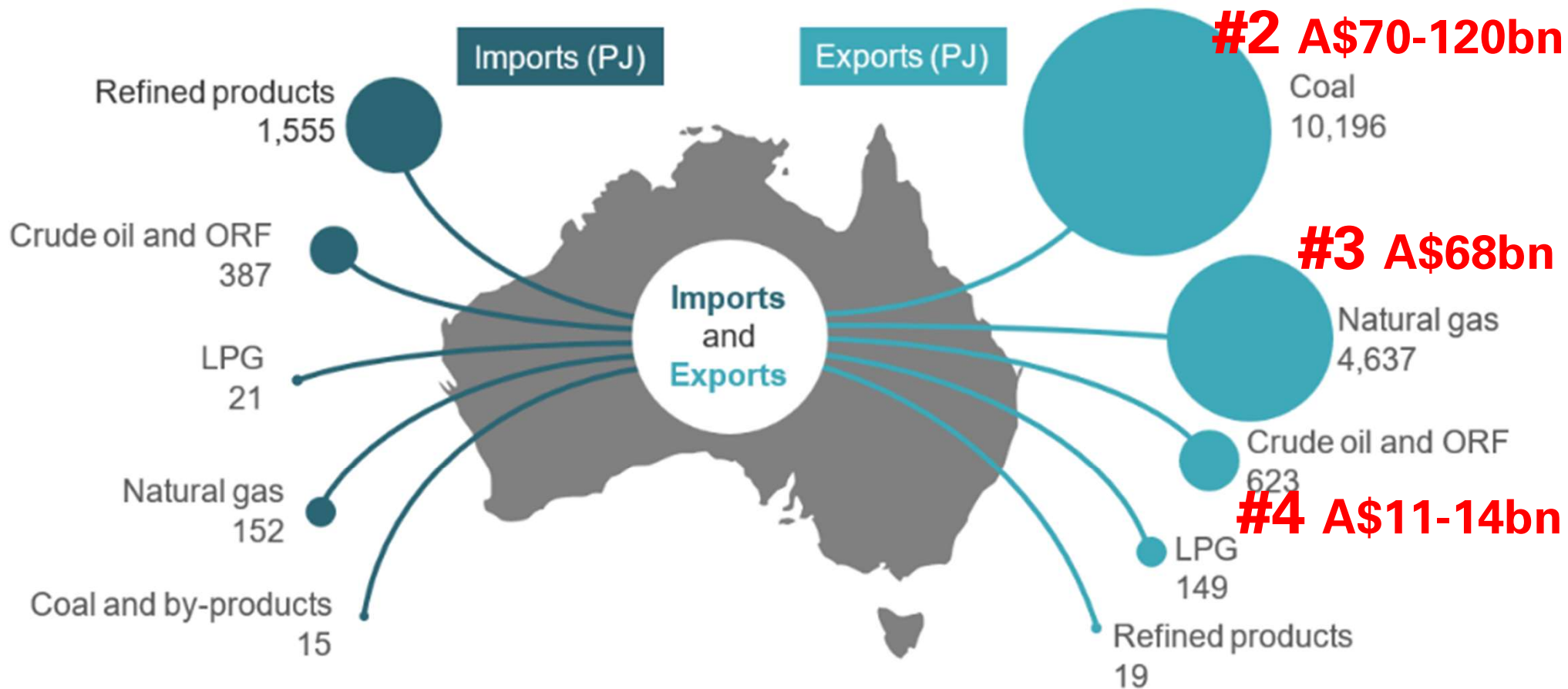
■ Current Fleet ■ Construction & Planned ■ Triple Nuclear





Australia has **TWICE** as much share of global Uranium reserves as Saudi Arabia had Oil reserves!

Source: Uranium 2020: Resources, Production and Demand, NEA No. 7551.

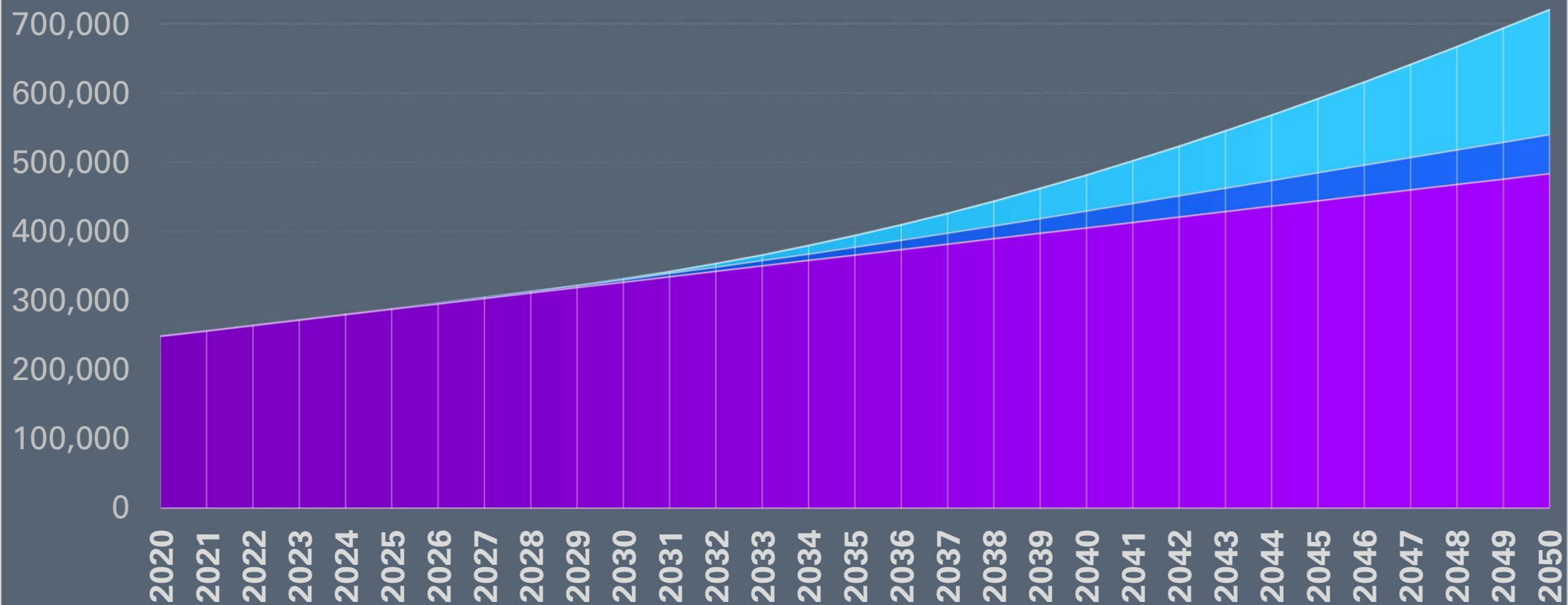


Total Fossil Fuel Export Revenue (approx.): A\$149-202bn (11-15% GDP)

Revenue Data source: <https://www.industry.gov.au/publications/resources-and-energy-quarterly-december-2023>

Nuclear "Waste" in Storage World-Wide "Triple Nuclear by 2050" Scenario

■ Current Fleet ■ Under Construction & Planned ■ Triple-Nuclear: +742 GW



Tripling Nuclear isn't enough!

To replace the energy we now derive from Fossil Fuels, we'd need **24x** Nuclear, not just 3x!

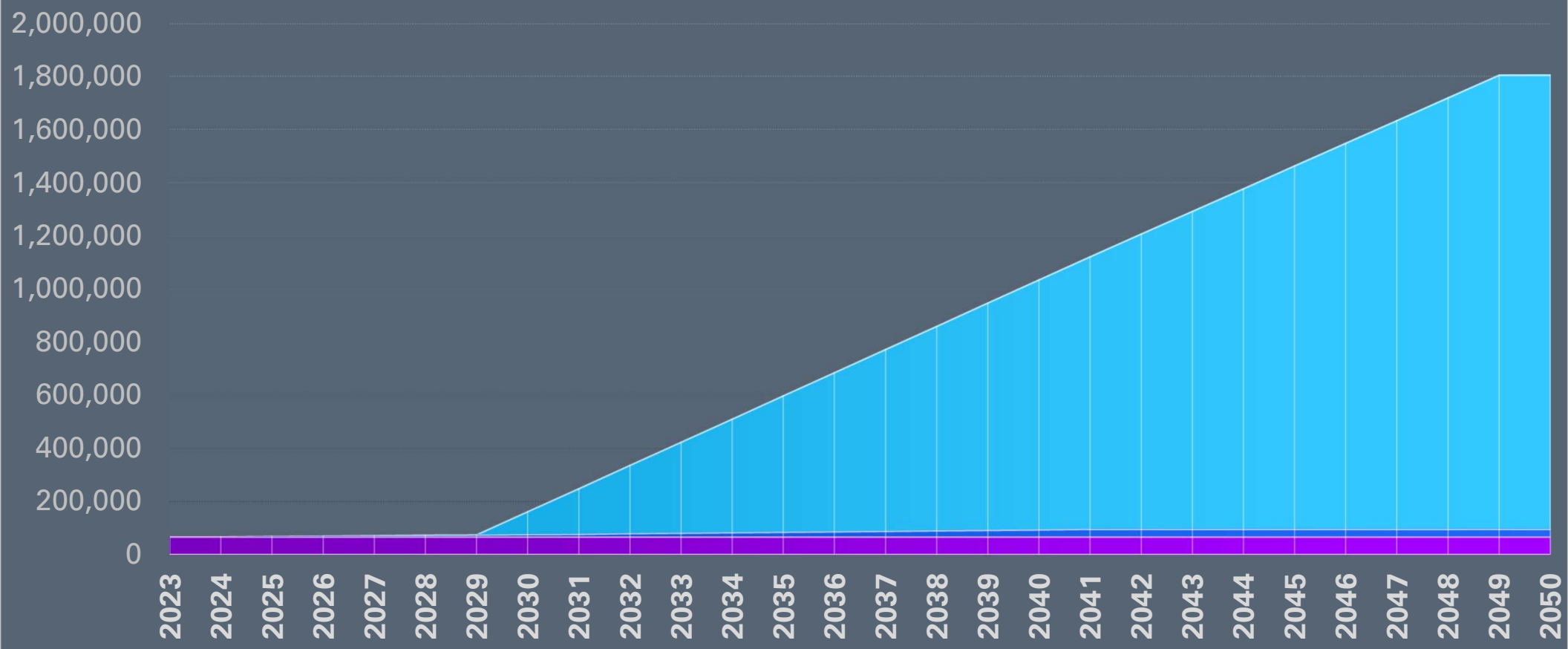
REPLACE ALL FOSSIL FUEL ENERGY



- Probably impossible...
- Build another 9,000 GW of conventional reactors (!)
 - **24x, not 3x current fleet**
- Approx cost US\$45tn - \$135tn
- Build time ?????
- Electricity much more expensive than fossil fuels or renewables
- Supply ~85% of global energy

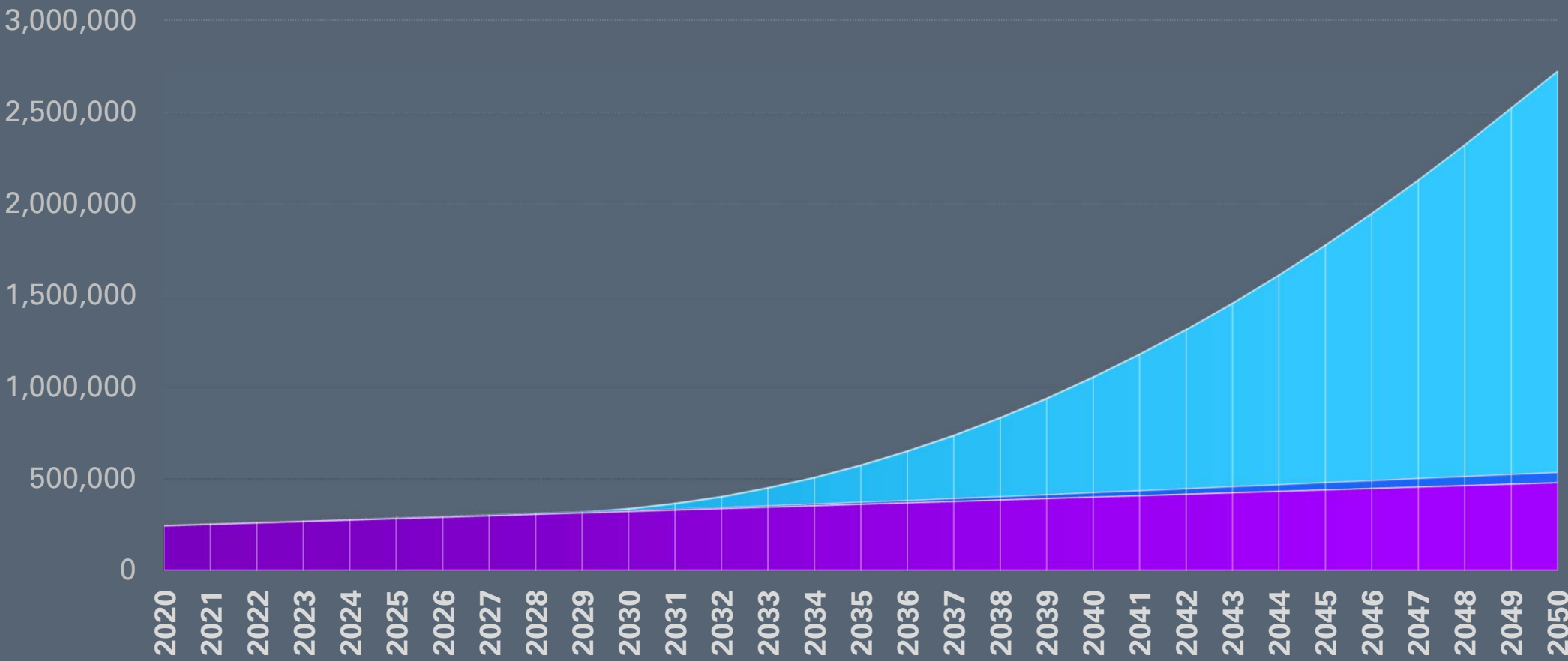
U₃O₈ Demand: Replace Fossil Fuels with Conventional Nuclear

■ Current Fleet ■ Construction & Planned ■ +9,000 GW Conventional

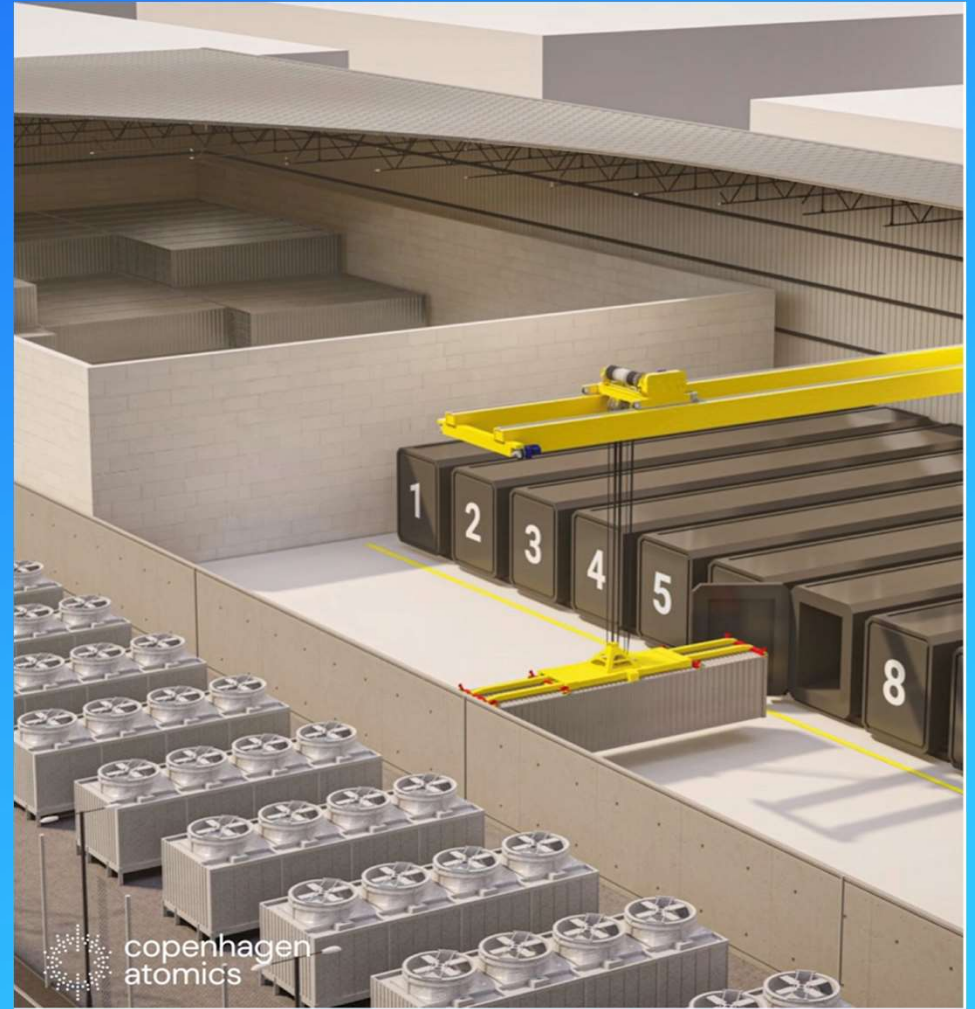


Nuclear "Waste" in Storage World-Wide Replace Fossil Fuels w/ Conventional Nuclear

■ Current Fleet ■ Under Construction & Planned ■ +9,000 GW Conventional



**WE NEED A
COMPLETELY
DIFFERENT
APPROACH!**



Conventional Nuclear costs too much & takes too long

We need a **clean energy solution that costs less** than energy from fossil fuels. It also has to be **fast to build**, in order to make energy transition by 2050 plausible.

Conventional Nuclear



Coal & Gas



Modular Advanced Nuclear



Levelized cost of electricity USD/MW

\$50 - \$150

\$50 - \$85

< \$25

Time to build



7+ Years
4-5 Years

3 – 5 years

< 1 year

Cost to build (per KW)



\$ 7,500 - \$ 12,000
\$ 3,500 - \$ 5,000

Coal \$1,500 - \$4,500
Gas \$ 958 - \$1,810

< \$1,000

\$500/KW is the ultimate target, but will require modularization & mass production of all powerplant components including supercritical CO₂ turbines to replace steam turbines and modularized mass-produced electric generators.

Building power plants can be modularized in a similar way that McDonalds builds restaurants

McDonalds uses prefabricated modular design to build a restaurant in less than 24 hours



Groundwork ready



First module installed



4 modules later, in less than 5 hours



Final module of ground floor installed



Ground floor finished, modular roof now installed



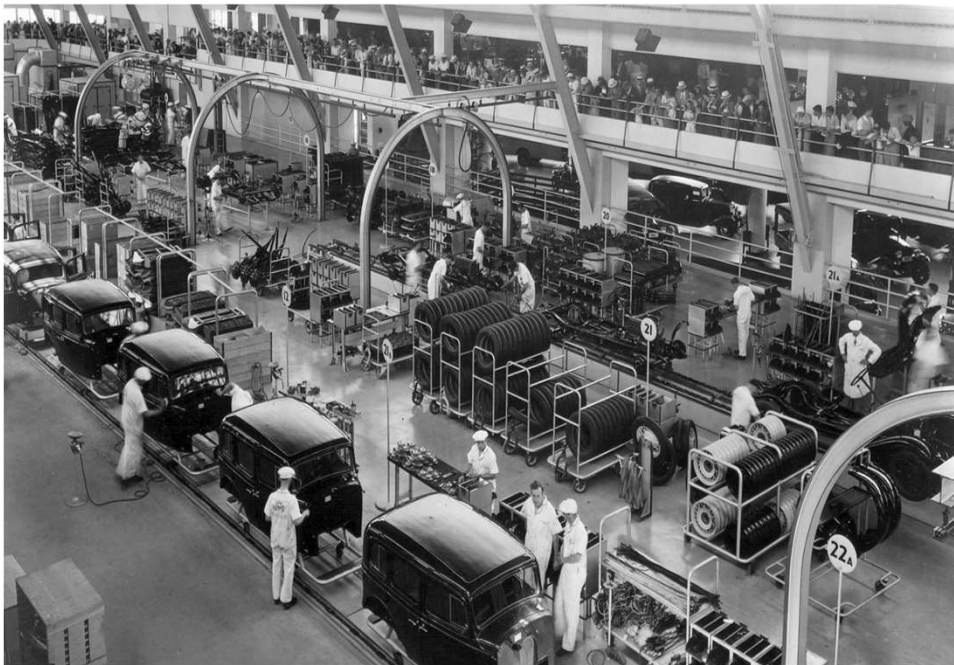
Final restaurant, built in less than 24 hours



TIMELAPSE OF A MODULAR BUILD MCDONALDS RESTAURANT - COMPLETED BY SUMMERFIELD DEVELOPMENT AND DEVON CONTRACTORS AT WESTPARK 26, WELLINGTON, SOMERSET, UK IN 2021

The Nuclear Henry Ford Moment

(Why right now is an unprecedented moment of opportunity in Nuclear History)



Ford Assembly line in the 1920s

- The key to the whole plan is to **embrace economies of scale inherent to assembly line mass-production** of reactor modules, CO₂ turbines, and other powerplant components.
- There are **<500** power reactors operating today worldwide
- The proposition is to build **~126,840** more over 20 years (!)
 - Begs the obvious question... Is there really demand?
- Unprecedented “Henry Ford Moment” of opportunity!
 - Even the “Green” Climate Community has warmed up to Nuclear
 - Energy Transition movement creates unprecedented demand for **economically viable clean energy**
 - **Beating everyone including fossil fuel energy on cost enables massive demand creation!**

THE CONCEPT

GIGAWATT POWERPLANTS

MADE FROM FACTORY-BUILT
SMRs RATHER THAN
CONVENTIONAL LARGE SCALE
NUCLEAR REACTORS

● Storage for decommissioned reactors

● Remote controlled crane

● Each tube holds 2x 40 foot containers

● Cooling

● Double lock

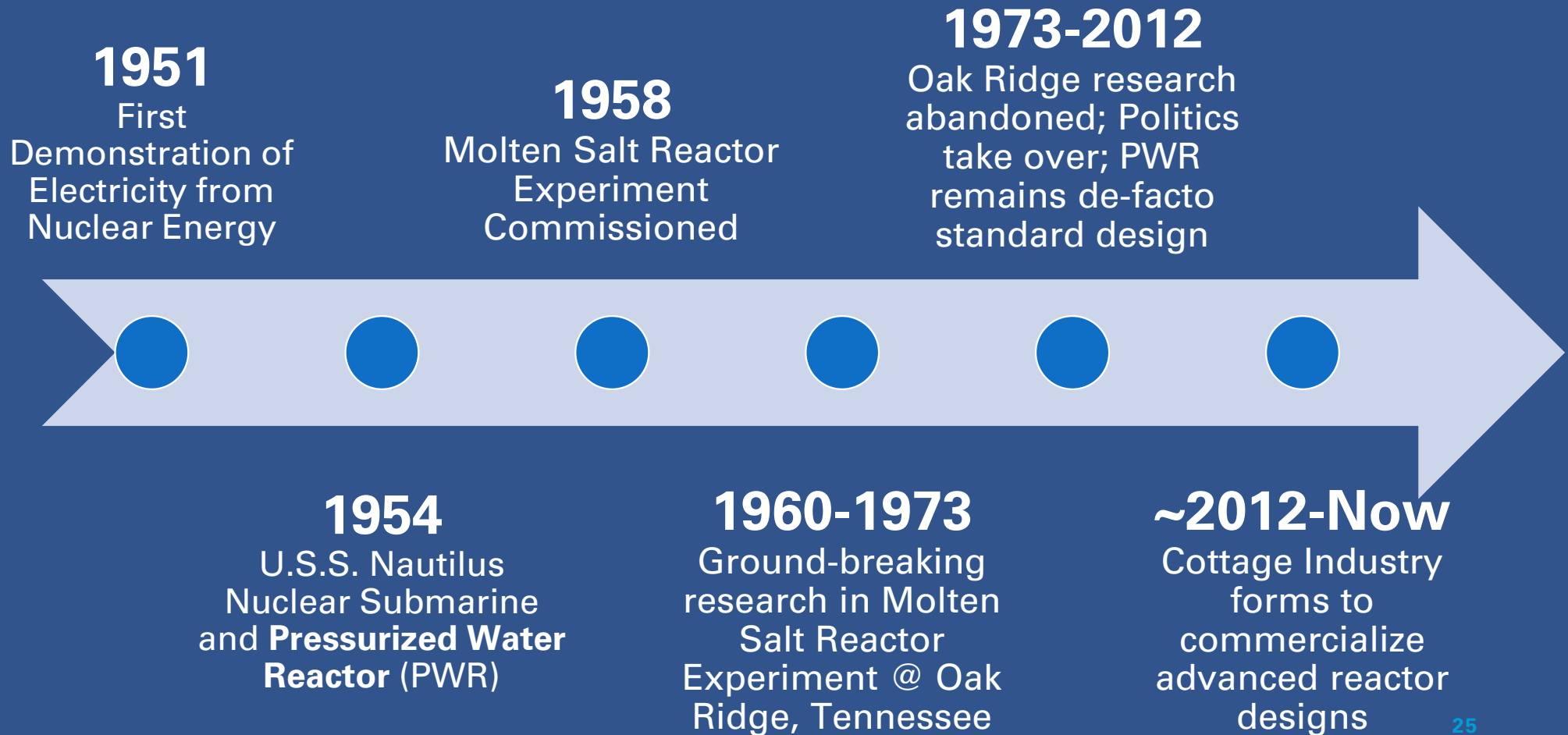
● 1x reactor being delivered by truck

SMRs Inside Containers

**SMRs ARE BUILT IN
FACTORIES, ON FULLY
ROBOTIC ASSEMBLY
AND TEST LINES**

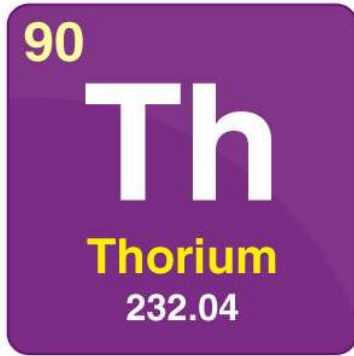


The History of Nuclear Energy



NO ENRICHMENT
REQUIRED

NO WEAPONS
PROLIFERATION
RISK



PRIMARY FUEL



5% U-235 95% U-238

²³⁵₉₂U ⁹²_U
Uranium
238.03

OR

RECYCLED
SPENT NUCLEAR
FUEL WASTE

LOW ENRICHED URANIUM

"KICK-STARTER" FUEL



JUST ONE
INITIAL LOAD
REQUIRED

36kg of
Thorium
per year!

(cost \$1800)

 copenhagen
atomics

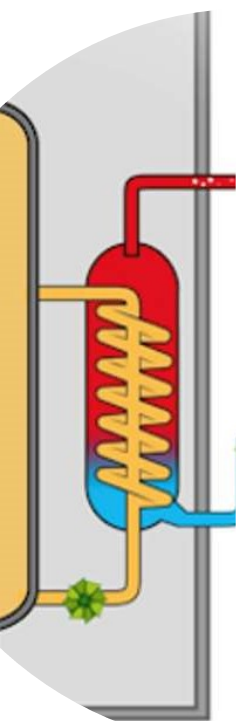
100MW(t)

Powered by
stardust



x 6,130

613,000 metric
tons COAL per
year (89km
railway train)



Feature	Benefit
Unpressurized molten salt coolant	Completely eliminates core depressurization and hydrogen explosion risks. Can operate in the desert , without requiring cooling water.
Liquid Fueled	Eliminates melt-down risk & enables load-following . Can refuel while operating.
Much higher temperatures than pressurized LWRs	Use for seawater desalination & hydrogen based synthetic liquid fuel production.
Thorium Fueled	Reduces waste storage to 300 years from 100k years and reduces weapons proliferation risks.
Waste Burning	Can burn spent nuclear fuel waste from reactors of yesteryear, disposing of that waste and eliminating need to store it for 1,000's of years.
Fully automated, remotely managed	No control room or human operator needed. Human operator error risk eliminated.

The challenges are
Capital Formation and
Regulatory Reform

(NOT Technology)

Nuclear Tech Adoption Cycle



U.S. National Labs developed all the nuclear power tech
Gigantic government budgets, no need to worry about making a profit



Gov't Contractors directed to Commercialize Nat Lab Designs
Entire regulatory process designed around assumption the Nat Labs do all the innovation and private sector only builds to their design



Private Sector Nuclear Innovation has never been or Economic
Regulatory framework assumes all the innovation comes from national labs with unlimited budgets. But those budgets were cancelled in the 1970s!



We cannot make progress until we reform the regulatory system!
Government's job should be to **enable** rather than **prevent** Energy Transition, but few if any leaders in Gov't understand the problem.

THERE IS NO ECONOMICALLY VIABLE PROCESS FOR PRIVATE SECTOR NUCLEAR INNOVATION

This is a Capital Formation Problem



- Nuscale spent >US\$600mm on certification costs alone!
 - Just to approve a design based entirely on “old-school” LWR tech
- But the RIGHT tech requires...
 - Changing the coolant to molten salt
 - Changing the fuel to Thorium
 - Changing the moderator
 - Building a “breeder” reactor design
- \$billions of speculative technology risk capital required *just for compliance!*
 - Any VCs in the room care to ante up?

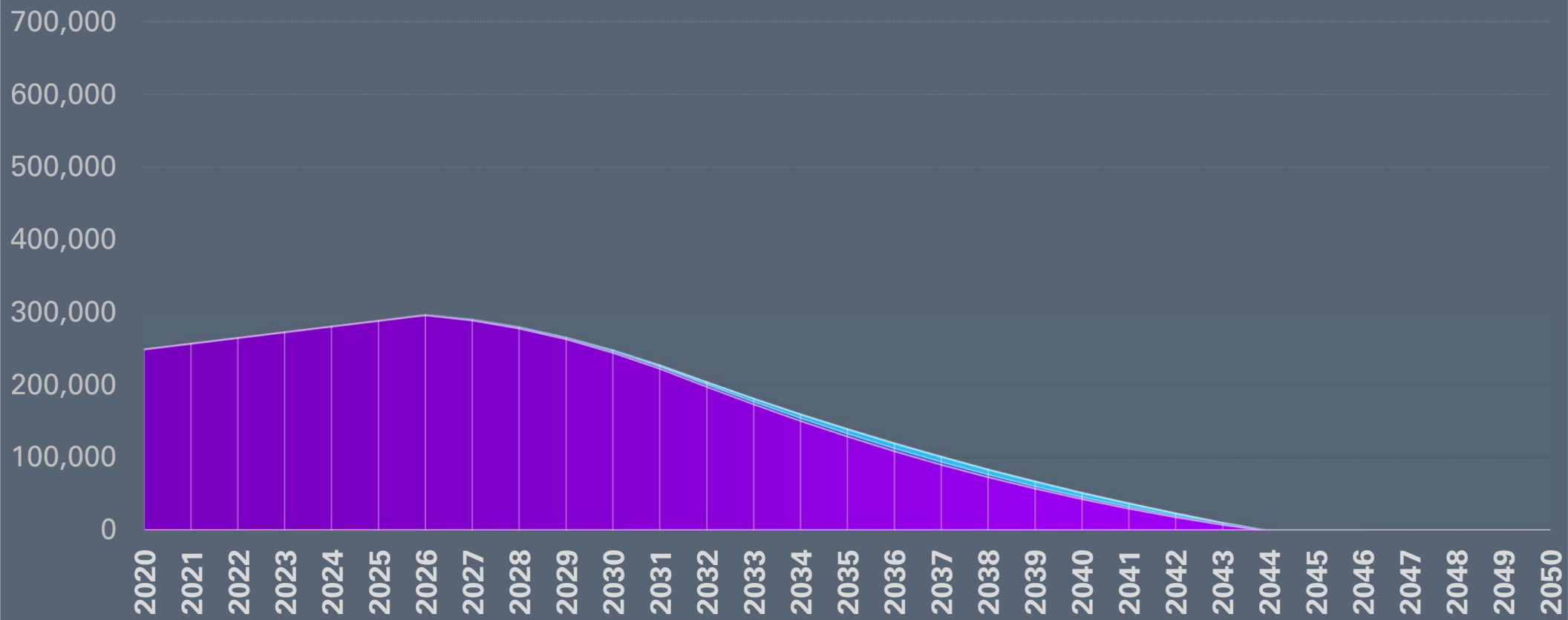
NO SOURCE OF RISK CAPITAL FOR THE MOST PROMISING AND IMPORTANT DESIGNS

ERIK'S ENERGY TRANSITION VISION

- 1** Embrace "Triple-Nuclear" initiative!
Tripling nuclear using *conventional* technology will increase Uranium demand by 140k MT and triple nuclear waste to 750k+ MT by 2050
- 2** Re-process ALL Nuclear Waste in storage worldwide.
Yields 2,500 mt plutonium, kick-starts first 12,500 MSR_s = 1,250GW(t) + 1,170 = 117 GW/yr
- 3** Mass-produce 9,000 GW modular power plants based on Thorium MSR_s (24x)
Fully replace ALL fossil fuels!
1 Reactor *per hour* 24/7/365 for 20 years!
Costs **\$4.5tn - \$6.75tn**
ZERO risk of melt-down or hydrogen explosions

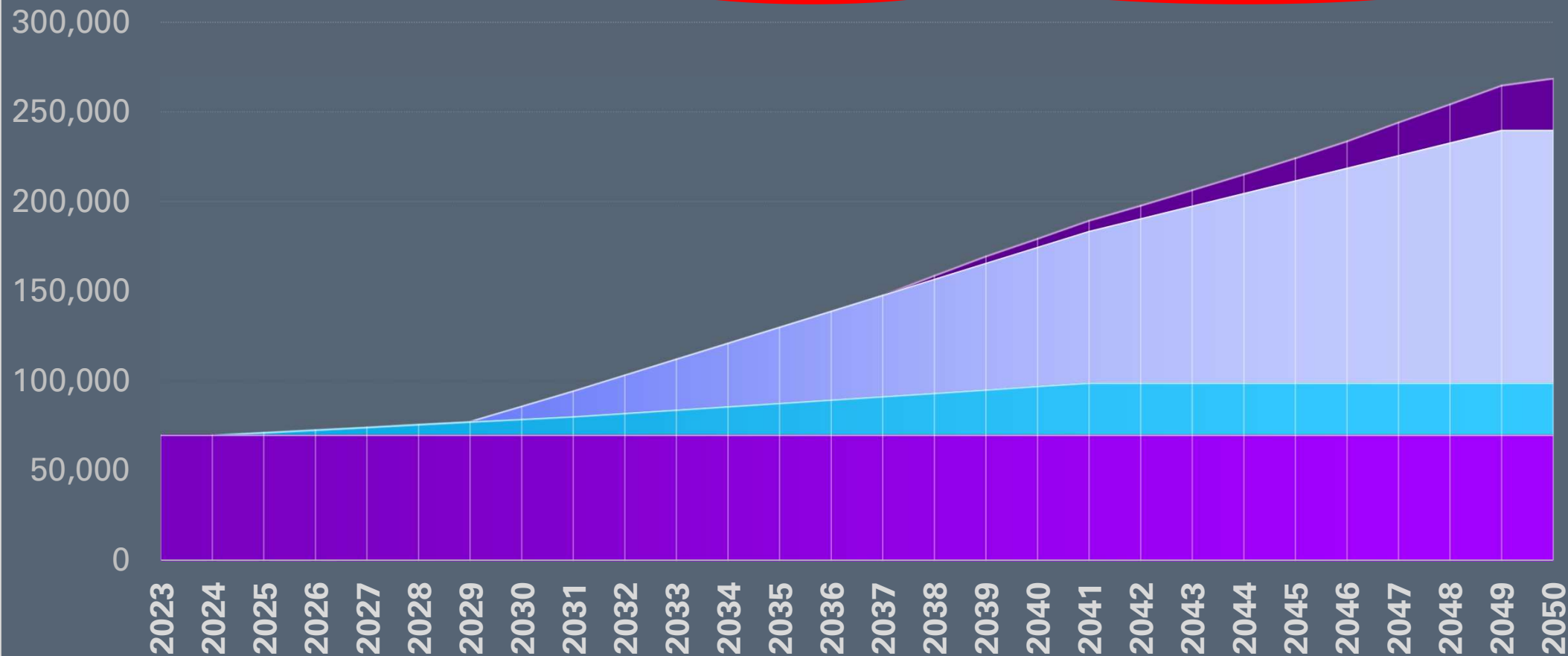
Nuclear "Waste" in Storage World-Wide Replace Fossil Fuels w/ Thorium MSR

■ Current Fleet ■ Construction/Planned ■ Triple-Nuclear +742 GW ■ Replace Fossil Fuels w/Thorium MSR +9,000 GW

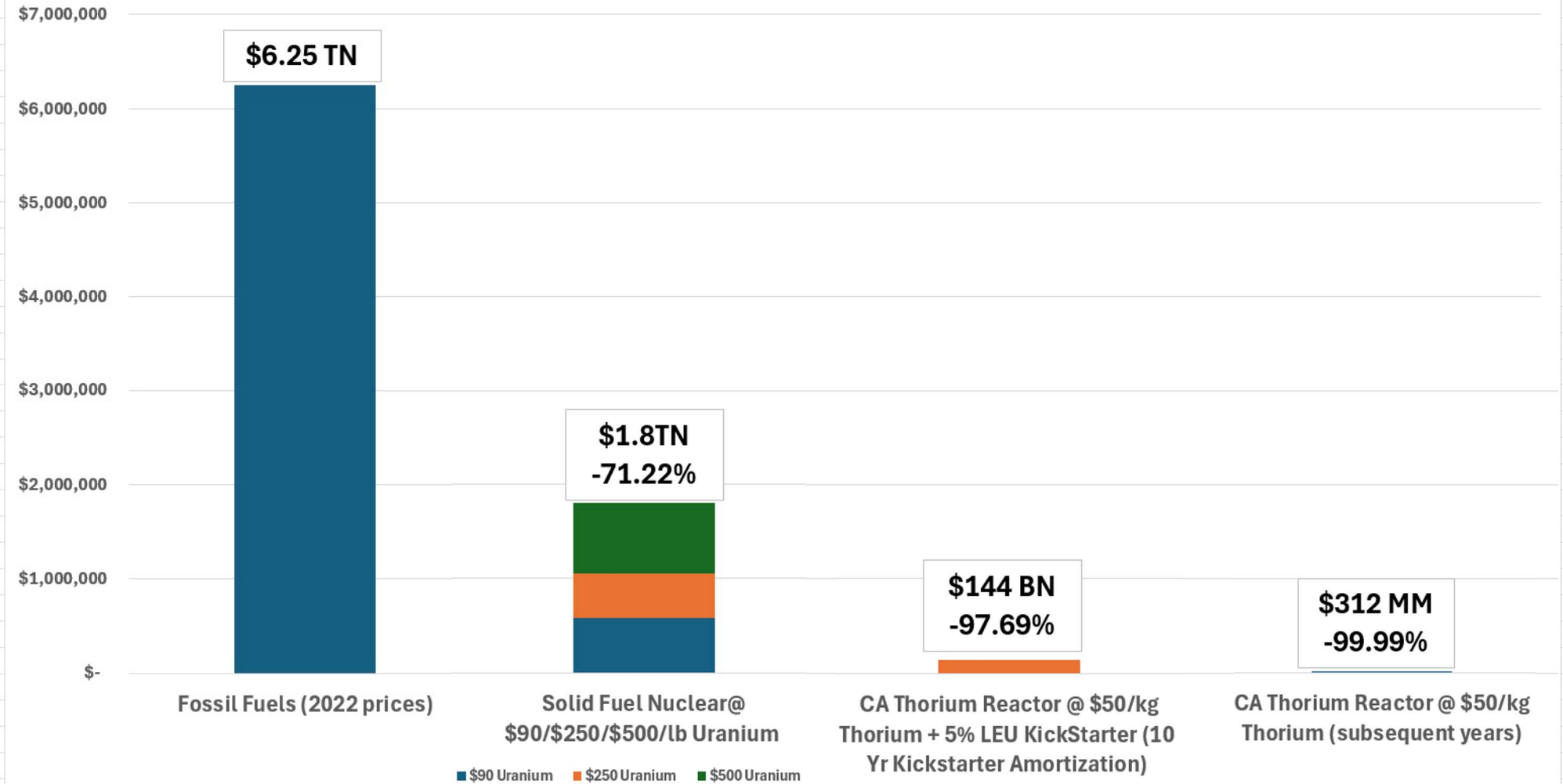


U₃O₈ Demand: Triple-Nuclear + Replace Fossil Fuels with Thorium MSR

Current Fleet Construction & Planned Triple-Nuclear: +742 GW +9,000 GW Thorium MSR Kickstarter



Fuel Cost to Run Planet Earth (\$Millions USD)



OUR NEXT CHALLENGE: **STEAM TURBINES**

- COST TOO MUCH
- TOO BIG TO MODULARIZE
- ONLY ~40% THERMAL EFFICIENCY
- REQUIRE TOO MANY REACTOR MODULES

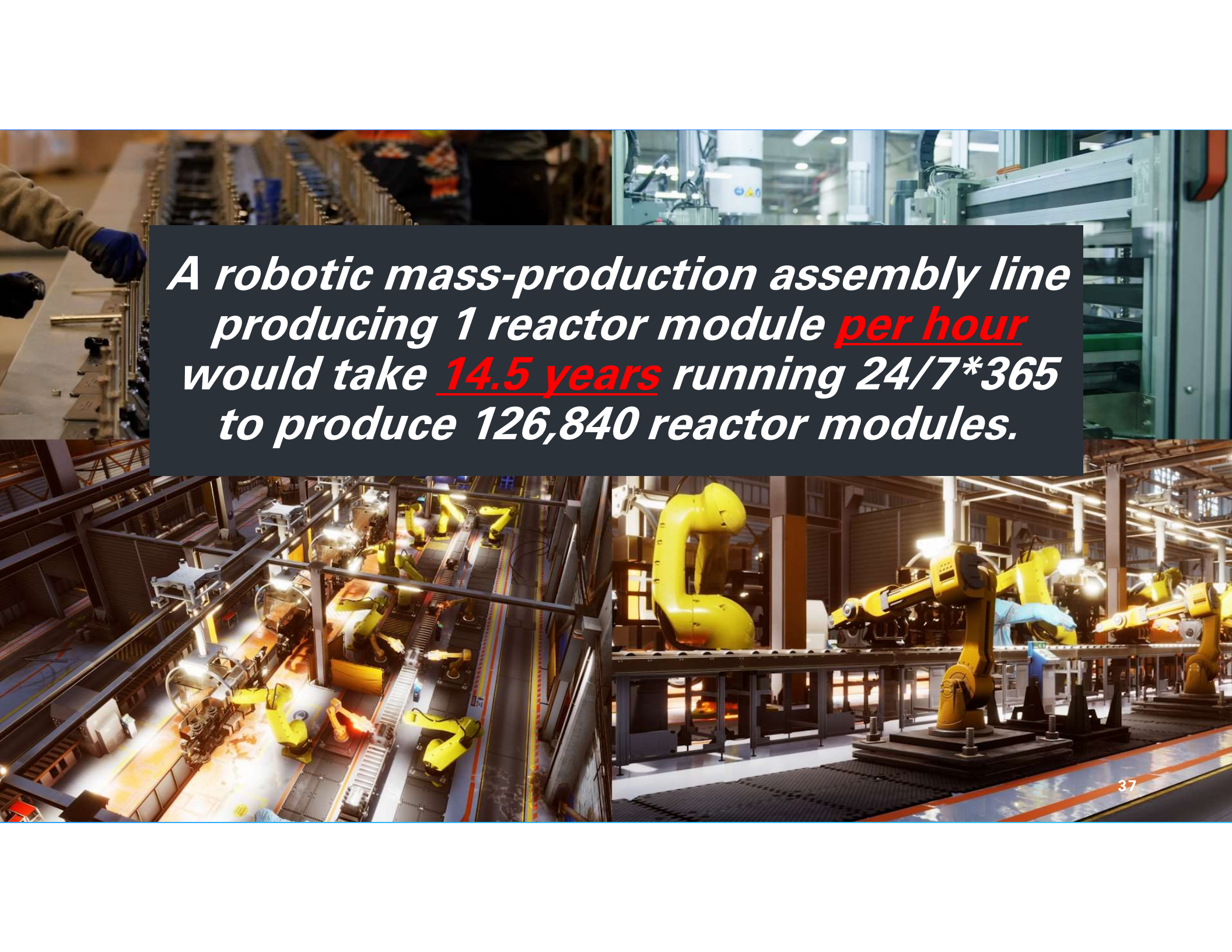
SIEMENS SST-9000 COSTS WELL OVER \$1BN INSTALLED!



SUPERCRITICAL CO₂ TURBINES

- REPLACEMENT FOR STEAM TURBINES
- MUCH SMALLER (1/10TH SIZE/WEIGHT)
- MUCH LESS EXPENSIVE TO MANUFACTURE
- HIGHER THERMAL EFFICIENCY (50%)
- REQUIRES 20% FEWER REACTOR MODULES
- CONDUCIVE TO MODULARIZATION
- THE UNIT IN PHOTO IS 10MW. **IMAGINE A 500MW MASS-PRODUCED VERSION IN A 40' SHIPPING CONTAINER**





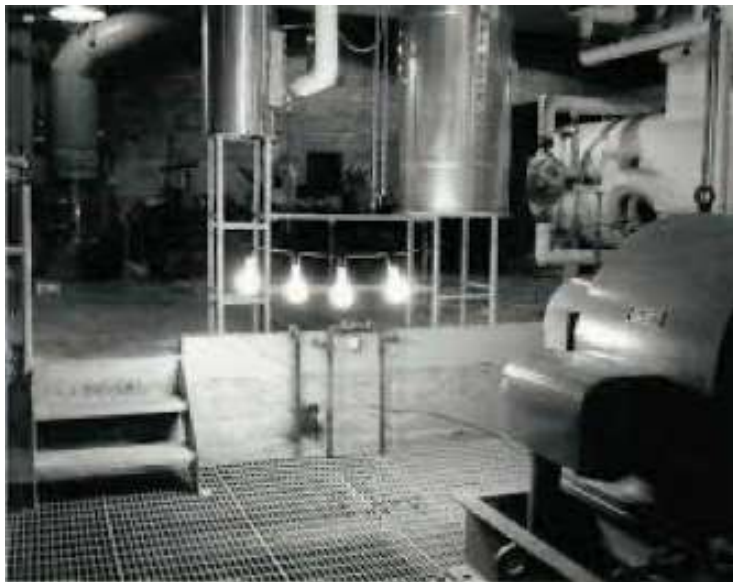
*A robotic mass-production assembly line producing 1 reactor module per hour would take 14.5 years running 24/7*365 to produce 126,840 reactor modules.*

A world map with a dark blue background. The map is overlaid with numerous white logos for 'NEW CO'. Each logo consists of a stylized atomic symbol (a central circle with three elliptical orbits) and the text 'NEW CO' below it. The logos are scattered across the map, with some appearing in clusters and others in pairs or groups. The map also shows some geographical labels like 'North Atlantic Ocean', 'South Atlantic Ocean', 'Indian Ocean', and 'South Pacific Ocean'.

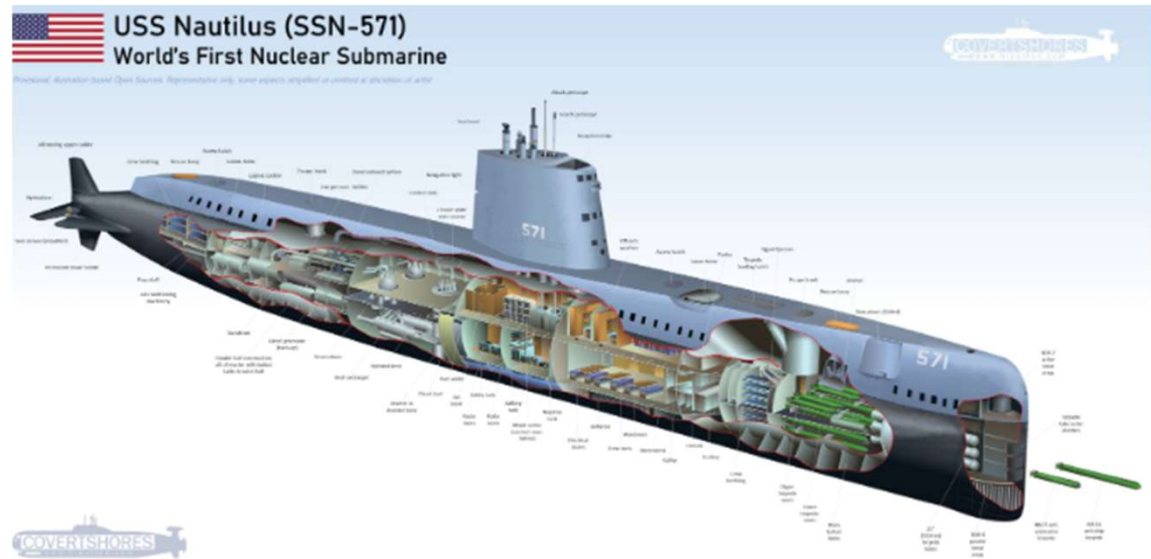
*To build **3,171** Modular Electric Power Plants (~50% of 2050 Total Demand) would require building **159** ~2GW Power Plants per year for **20** years.*

When the government wants to make something happen ...

In 1951, the very first demonstration of electricity from nuclear was proven *in a laboratory*. Four years later, the first Nuclear submarine entered service! **Far less engineering is required for the NewCo Energy vision.**



1951: FIRST ELECTRICITY FROM NUCLEAR



1955: USS NAUTILUS ENTERS SERVICE!



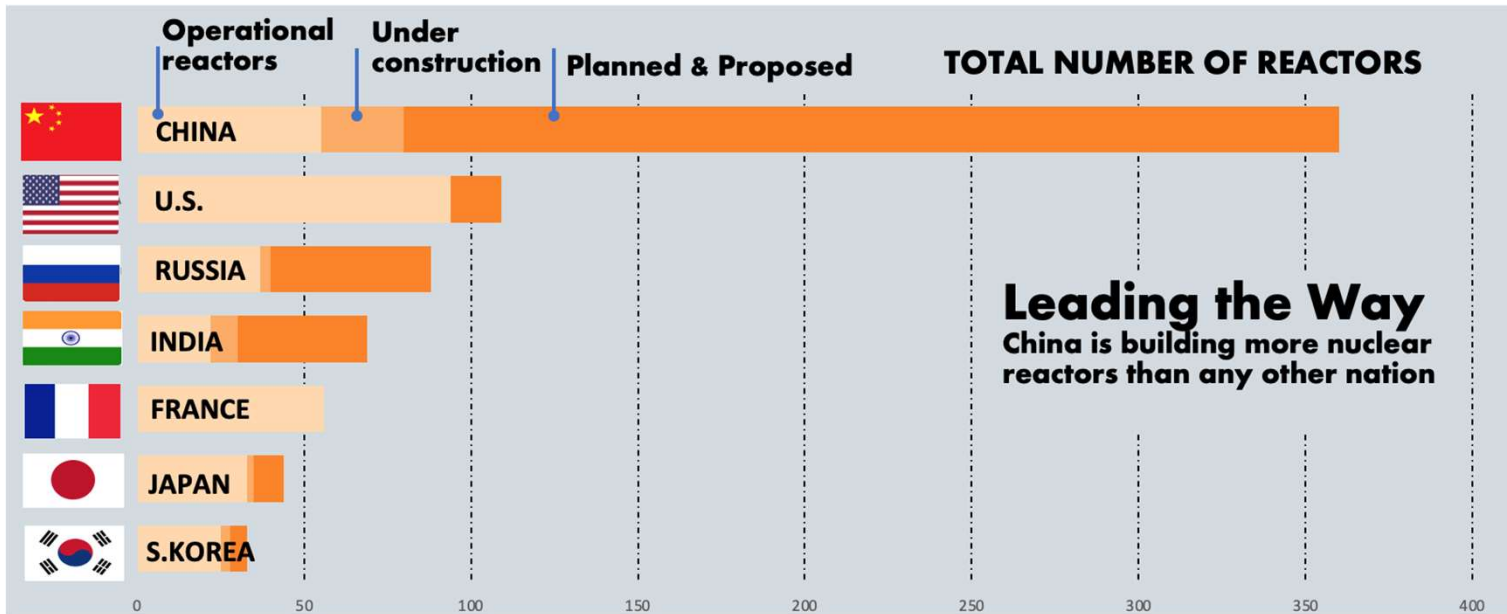
**EVERYTHING IN
THIS
PRESENTATION
WILL HAPPEN.**

**THE ONLY OPEN
QUESTION IS
WHETHER **WE** DO IT
OR **CHINA** DOES IT.**

****CHINA** STARTED
WORKING ON THIS
DECADES AGO AND
ALREADY HAS THE
LEAD!**

China is already a serious threat, and we need to act now!

China is already planning to build the most CONVENTIONAL nuclear reactors. And they're already way ahead of everyone else on ADVANCED nuclear research as well (see next slide).



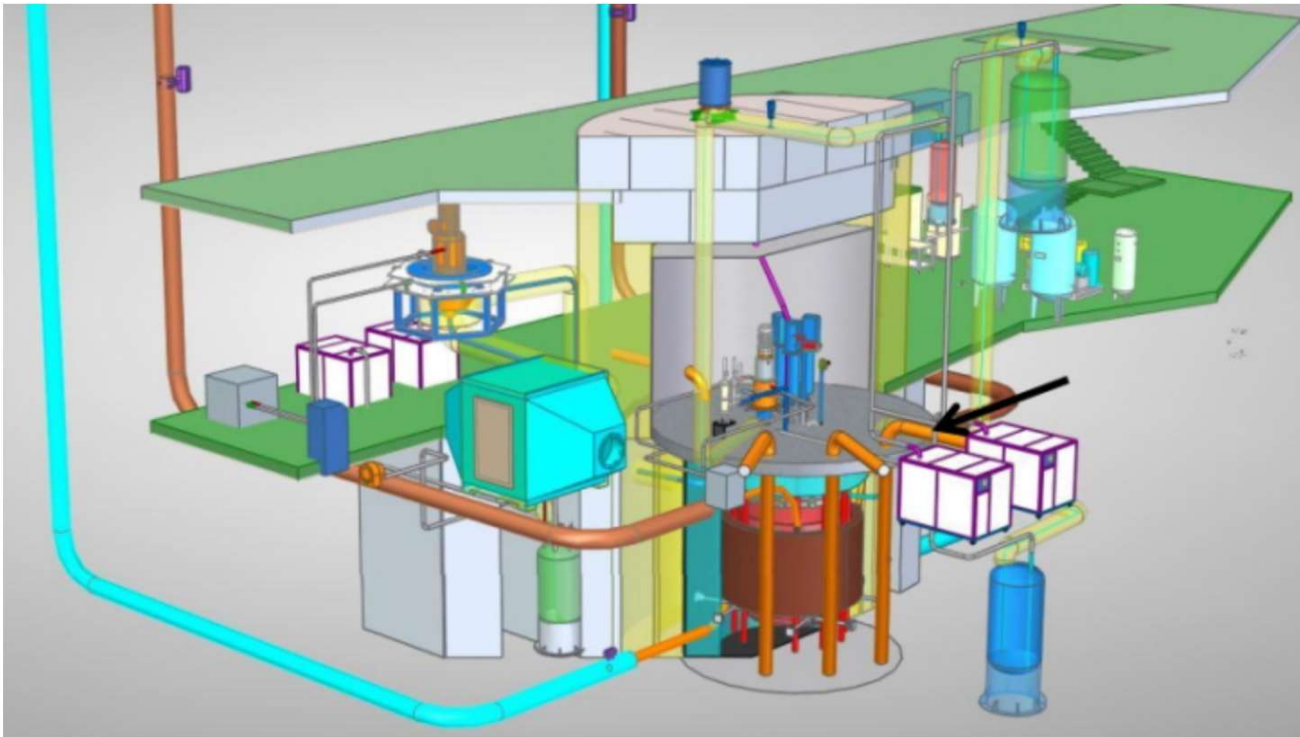
Source: World-nuclear.org 2023

Operating permit issued for Chinese molten salt reactor

15 June 2023



The Shanghai Institute of Applied Physics (SINAP) of the Chinese Academy of Sciences has been granted an operating licence for the experimental TMSR-LF1 thorium-powered molten-salt reactor, construction of which started in Wuwei city, Gansu province, in September 2018.



A cutaway of the TMSR-LF1 reactor (Image: SINAP)



Zhao DaShuai 无条件爱国

@zhao_dashuai

China will build nuclear powered container ships 🚢☢️

It's powered by a Thorium Molten Salt Reactor (MSR), the significance of which is beyond shipping.

The immediate [other] application would be nuclear powered aircraft carrier.

1/3



...

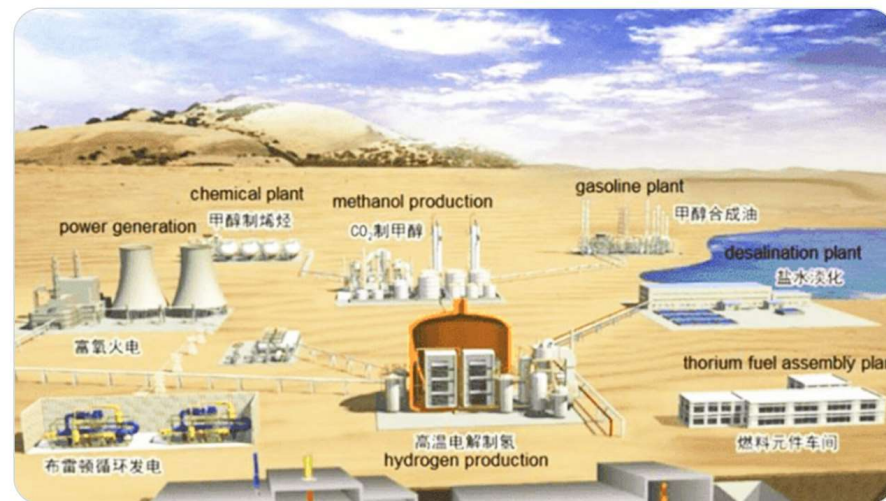


Zhao DaShuai 无条件爱国 @zhao_dashuai · 13h

Thorium Molten Salt Reactor (MSR), would provide affordable and safe nuclear energy.

MSRs doesn't need water for cooling, so they can be built away from seas or rivers.

Allowing much greater flexibility in location choice, very important for a continental country like China.



3

38

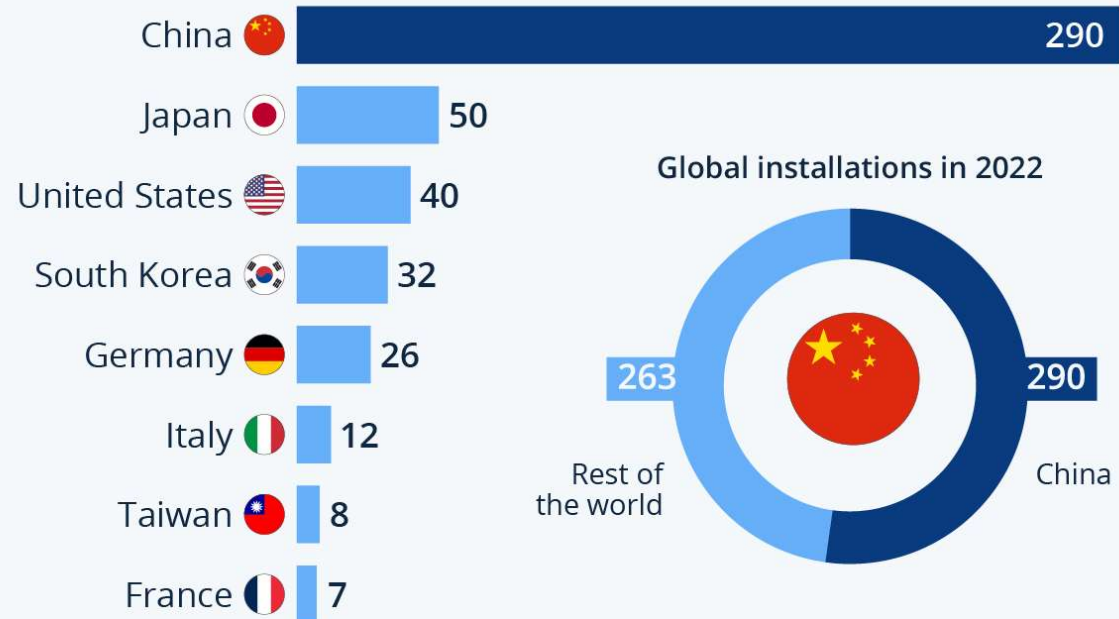
248

6.7K



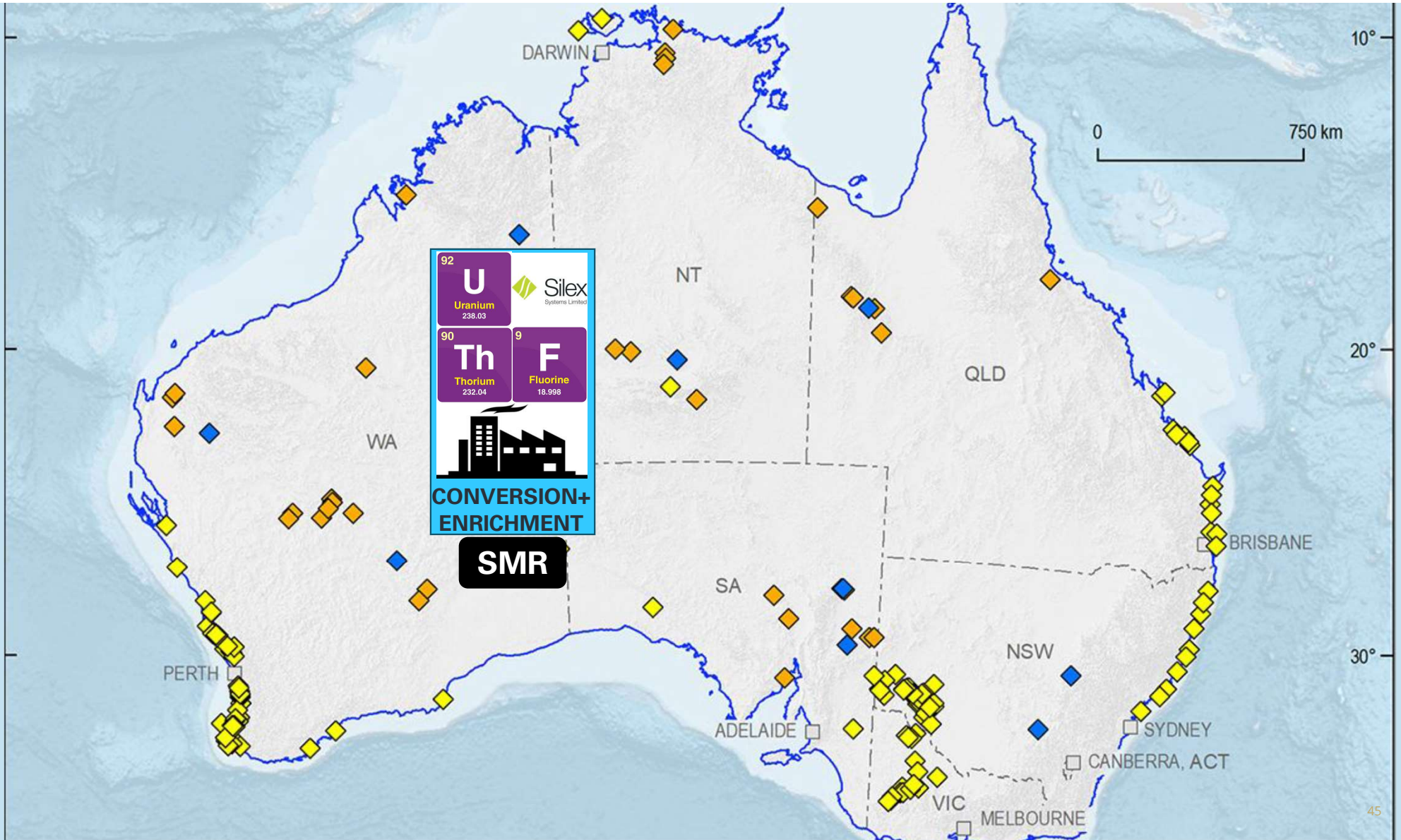
China Leads Growth of Global Industrial Robot Stock

New installations of industrial robots in 2022 (in thousands)



Source: International Federation of Robotics









THANK YOU!



CONTACT INFO:

- Erik Townsend
- erik@energytransitioncrisis.org
- www.energytransitioncrisis.org