# Assessing and Mitigating Financial Risks of New Nuclear

NARUC-DOE Nuclear Energy Partnership

**FRIDAY, JUNE 17, 2022**

**2:00 – 3:00 P.M. (ET)**

# WELCOME

- **Commissioner Anthony O'Donnell**, Maryland Public Service Commission
- **Commissioner Eric Skrmetta**, Louisiana Public Service Commission

# PANELISTS

**Judi Greenwald**

Executive Director, Nuclear Innovation Alliance

**Kirsty Gogan**

Co-Founder, TerraPraxis

Managing Partner, LUCIDCATALYST

**Jeffrey Brown**

Managing Director, Energy Future Financing Forum

Adjunct Professor, Stanford School of Earth, Energy, and Environmental Sciences

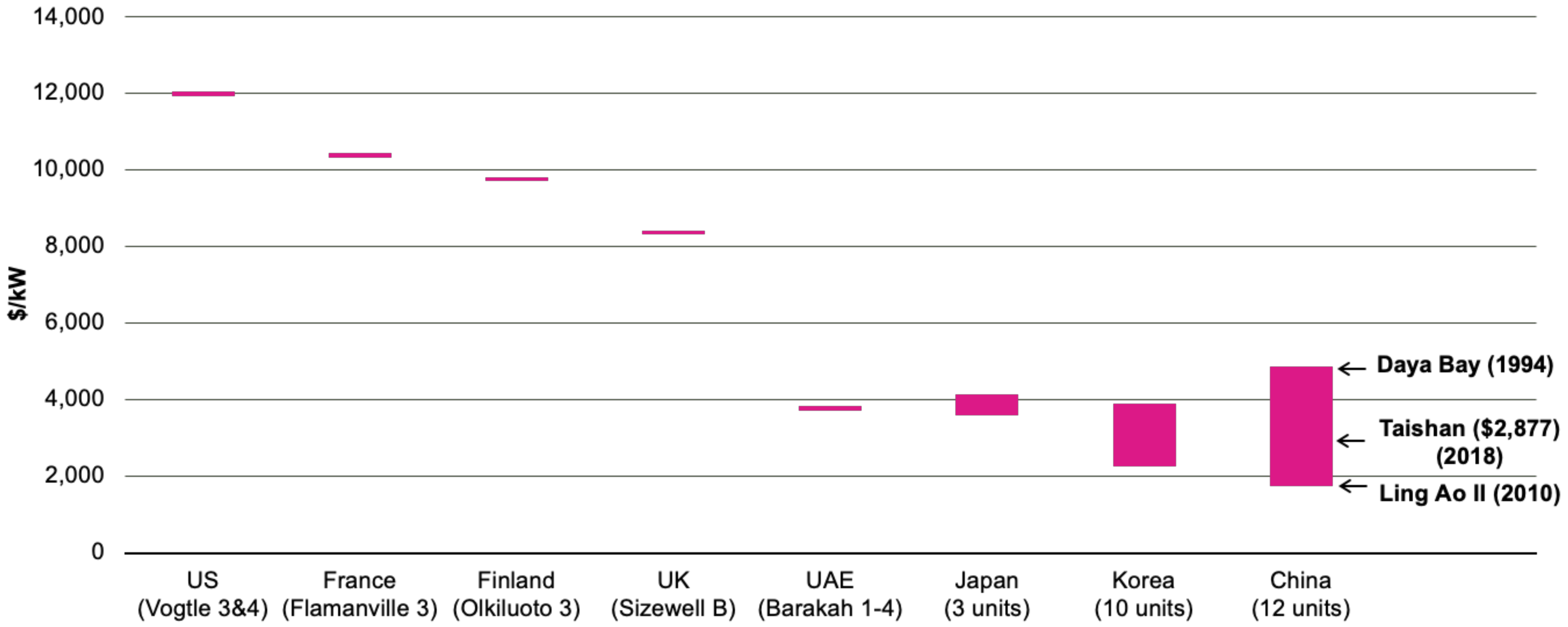
# BEAUTIFUL NUCLEAR

Driving Deep Decarbonization

JUNE 2022

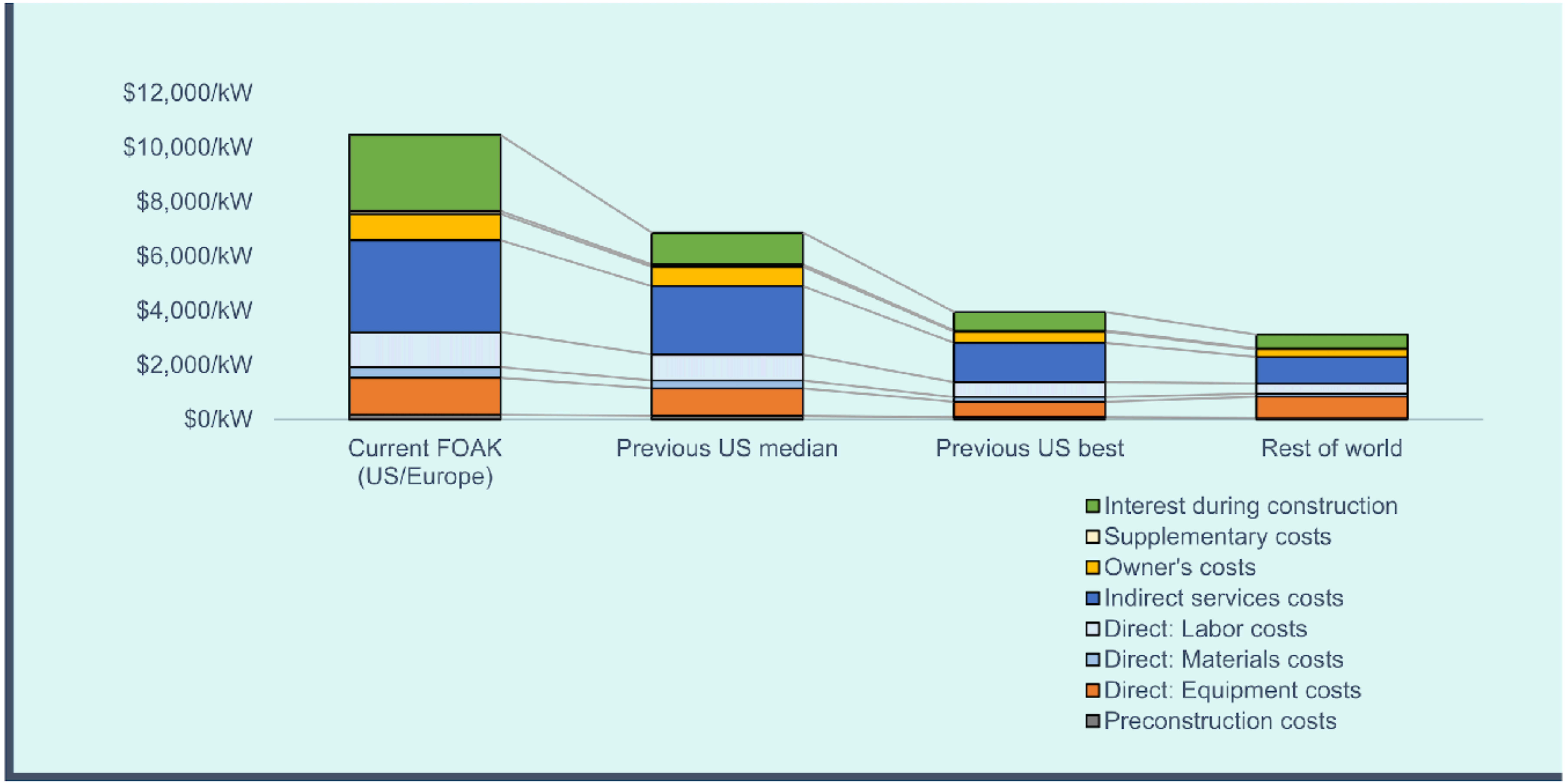
# THE TIME IS NOW

# How to Make Nuclear Cost Competitive



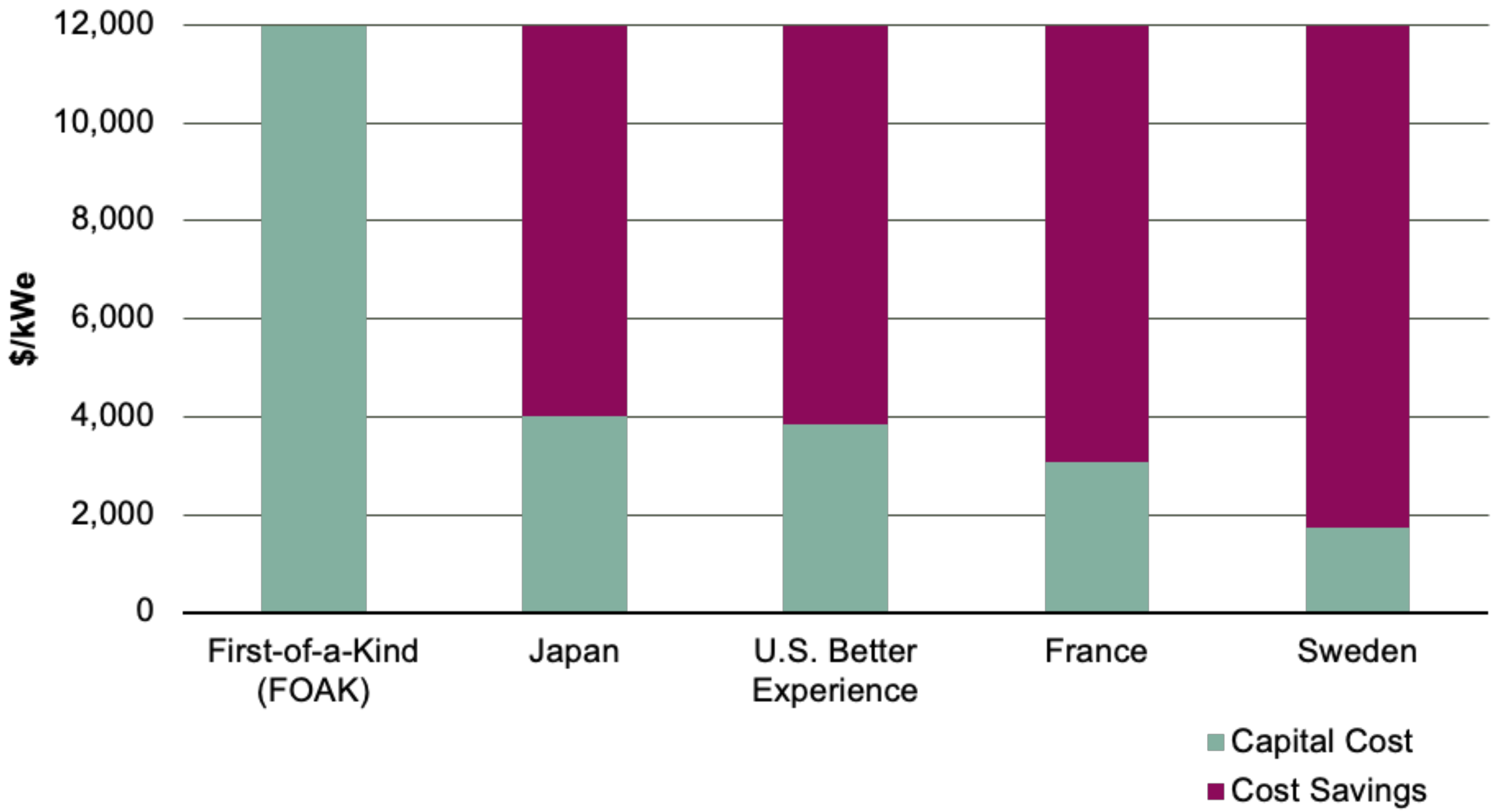

**Sample of global nuclear project capital costs (with interest)**
Source: LucidCatalyst (2020)

# Differences Between High-Cost and Low-Cost Plants




**Sample of global nuclear project capital costs (with interest)**
Source: LucidCatalyst (2020)

# FOAK Compared to Programmatic Costs

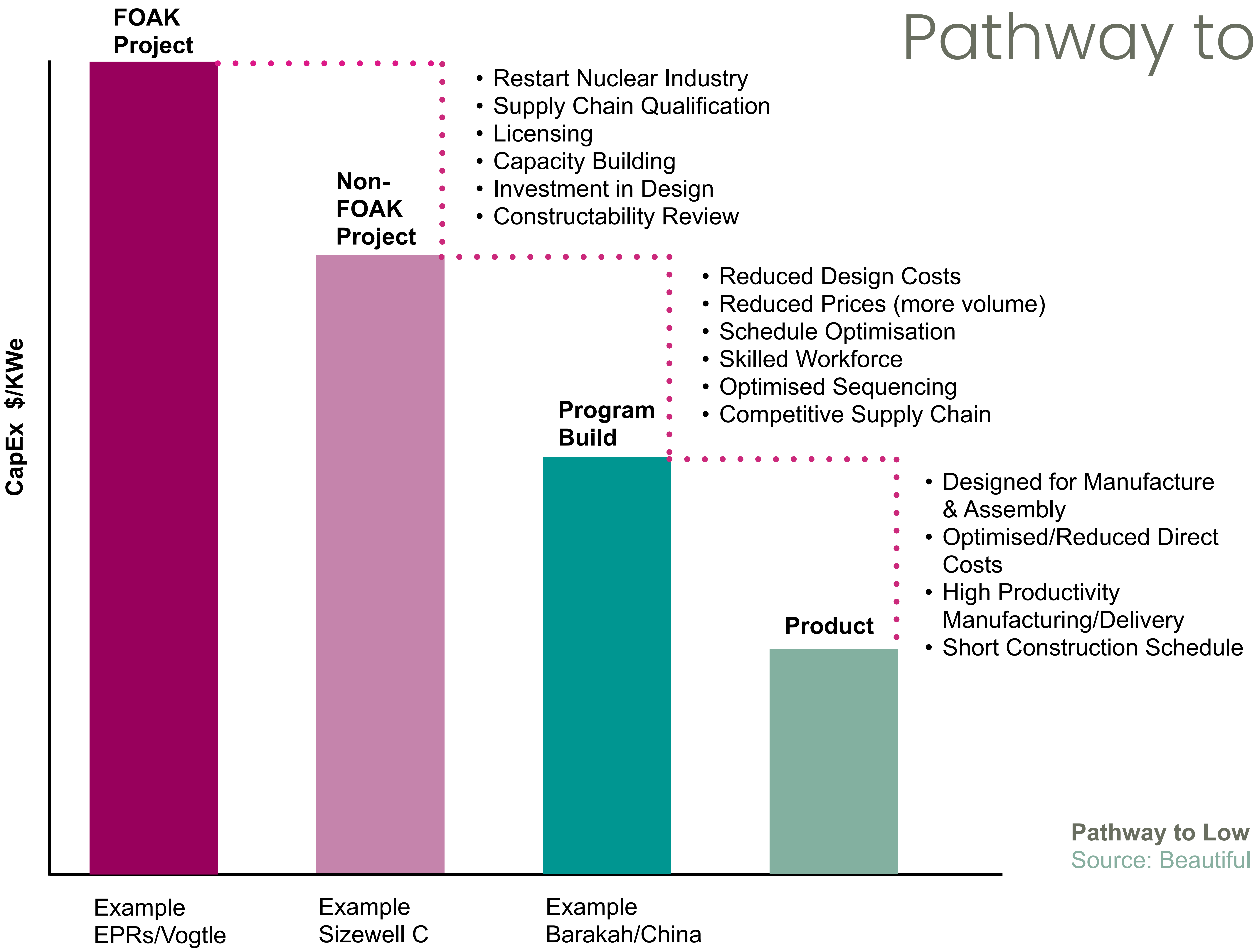



**First-of-a-kind compared to costs achieved in consistent, real world build programmes**
Source: Beautiful Nuclear (2021)

# Common Characteristics of Low- and High-Cost Plants

| Low-Cost Plants | High-Cost Plants |
| --- | --- |
| Design at or near complete prior to construction | Lack of completed design before construction started |
| High degree of design reuse | Major regulatory interventions during construction |
| NOAK design | FOAK design |
| Experienced construction management | Litigation between project participants |
| Low-cost and highly productive labour | Significant delays and rework required due to supply chain |
| Experienced EPC consortium | Long construction schedule |
| Experienced supply chain | Relatively higher labour rates and low productivity |
| Detailed construction planning prior to starting construction | Insufficient oversight by owner |
| Intentional new build programme focused on cost reduction and performance improvement | |
| Multiple units at a single site | |

# Pathway to Low Cost




**Pathway to Low Cost**
Source: Beautiful Nuclear, LucidCatalyst (2021)

# Extending Operating Life of the Existing Fleet is the Lowest Cost Emissions Reduction

"Extending long-term operation of the current fleet is the most cost-effective way to add clean energy production."

International Energy Agency (2020)

Policy recommendations regarding Long Term Operation could not be clearer: authorise the longest possible lifetime extensions of existing plants, set up risk management and financing frameworks that help mobilise capital for new and existing plants at an acceptable cost, and value the dispatchability and other non-market benefits that nuclear energy can bring to the power system.

The EU should move from premature closures of plants to supporting policy and financing frameworks for refurbishments of existing plants to be funded with the lowest cost of capital possible.

Long term operation allows EU member states to lock in immediate low carbon gains with relatively little additional cost, new infrastructure or socio economic disruption.

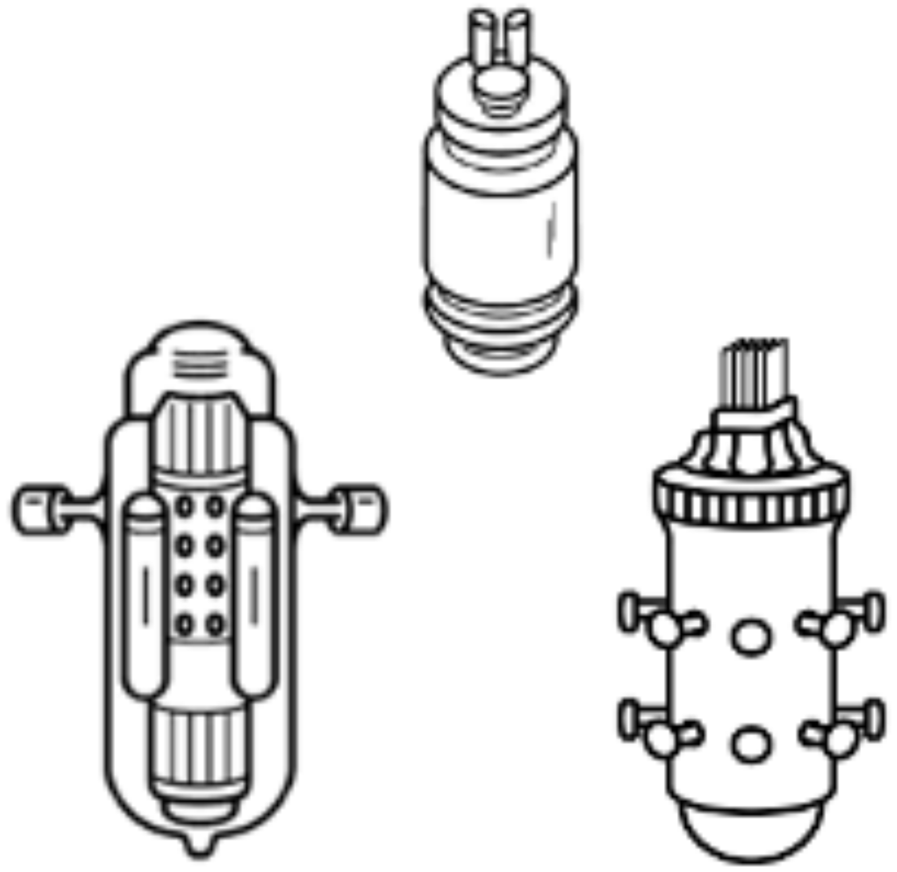
# TOWARDS A BRIGHT FUTURE

# A Platform for Repurposing Coal

- Repurpose 2TWe coal fleet
- De-risk clean energy transition
- Social, economic and environmental justice benefits

# Standardization to Address Wide Variety of Requirements

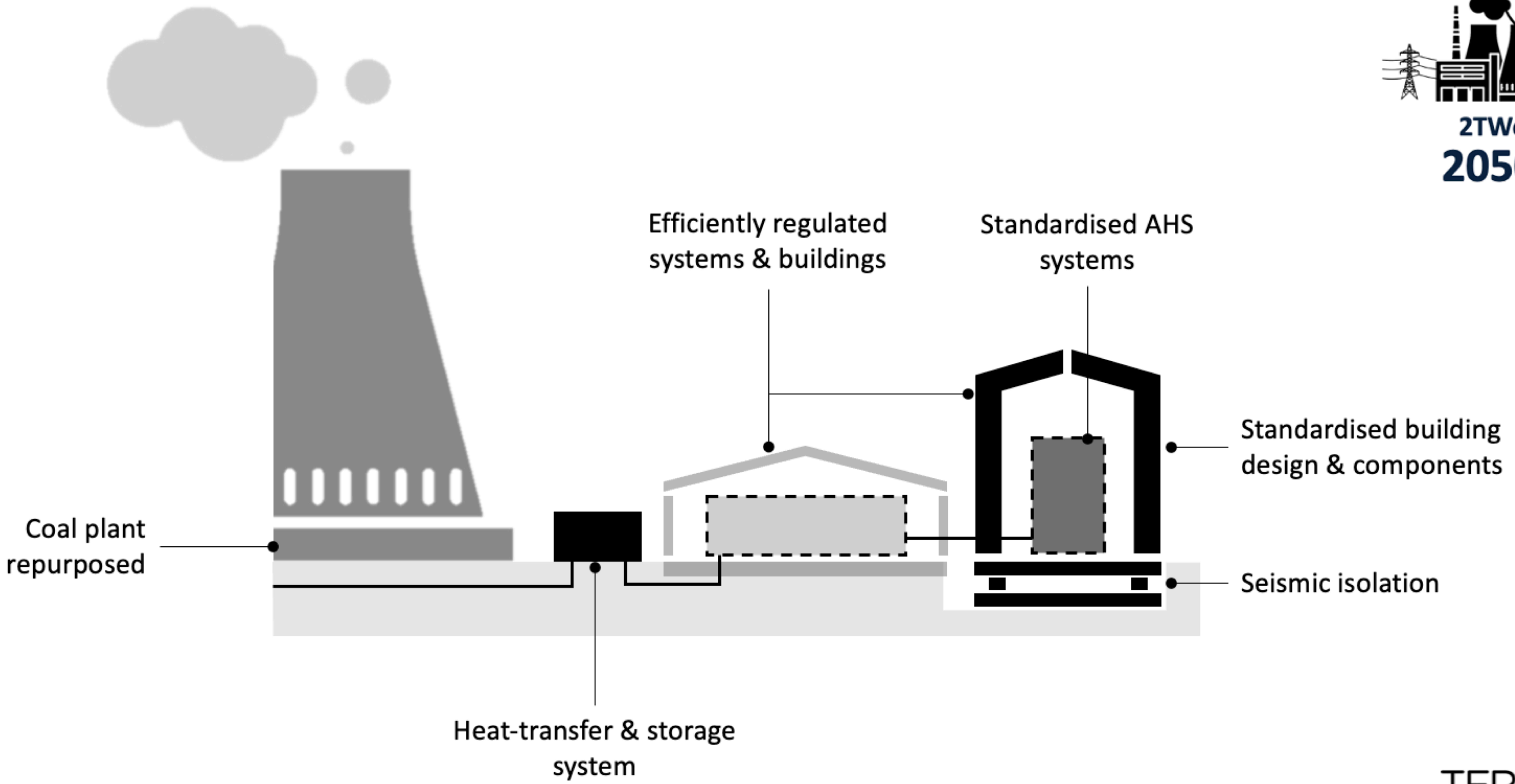
**Different**
Energy and heat requirements



**Different**
Advanced heat-source (AHS) technologies

**Different**
Site layouts and local requirements

# Built Systems Must Enable Scale and Speed



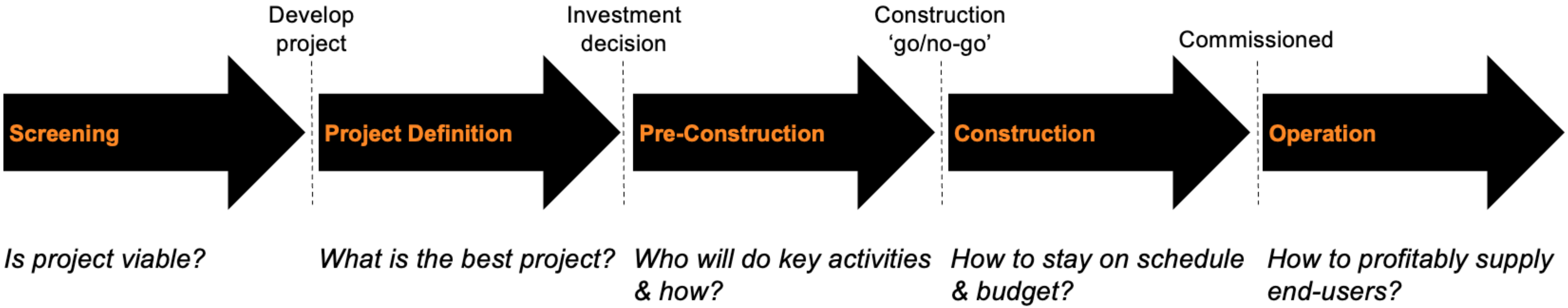

2TWe
2050

TERRA PRAXIS

## Thermal energy storage

**De-links the nuclear heat island safety case from the existing coal plant power island. This enables flexible generation and continued use of the existing plant.**

# Project Processes Must Enable Scale and Speed




TERRA PRAXIS

**TerraPraxis has assembled a world-class team to deliver Repowering Coal**

Microsoft

Bryden Wood

SIMPSON GUMPERTZ & HEGER

Engineering of Structures and Building Enclosures

MIT

TERRA PRAXIS

University at Buffalo

Southern Company

ELEMENTL

aeci

Associated Electric Cooperative, Inc.


MOVING
FORWARD

# Five Priorities for Clean Energy Transition

## 1 / EXPAND

**Expand clean electricity generation as quickly as possible**

## 2 / REPOWER

**Repower most coal plants with advanced heat sources**

## 3 / CONVERT

**Convert remaining liquid fuel use to carbon-neutral fuels**

## 4 / REPLACE

**Replace natural gas for industry and heat**

## 5 / INCREASE

**Massively increase investment in clean electricity generation and clean e-fuels production to support global energy access, especially in Africa**

# Recommendations

## ACCESS TO FINANCE /

In the same way that investors must take a portfolio approach to investments in order to reduce exposure to risk, global efforts to limit climate change should be spread across a portfolio of technology options. Consistent, technology-inclusive access to finance is critical to realising this.

## STOP CLOSURES /

Premature closures of nuclear power stations need to stop, and whenever possible, those shut down should be restarted.

## EXTEND LIFETIMES /

Operating fleet should seek lifetime extensions whenever possible, and funding for the necessary refurbishment needs to be made available at low interest rates.

## DIVERSIFY MODELLING /

Energy system modelers and policy makers should include the wide range of potential applications for advanced heat sources into energy and climate scenario modelling where it is currently absent.

## INCLUDE GREEN HYDROGEN /

'Green Hydrogen' and the associated mandates, policy incentives, and financing should include all low-carbon hydrogen production as per their sustainability (carbon intensity, land use, etc.), not just a cherry-picked selection of technologies.

## FUNDING COMMERCIALISATION /

Europe should fund the rapid and large-scale commercialisation of new delivery and deployment models for advanced heat sources for re-powering coal plants, hydrogen, heat and power production, with an emphasis on achieving cost-competitiveness and scale relevant to the fossil fuel markets they are designed to address.

"Without an important contribution from nuclear power, the global energy transition will be that much harder."

Dr Fatih Birol, Executive Director, International Energy Agency

LUCID CATALYST

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# Regulatory Pre-Conditions to Successful Nuclear Deployment

Presentation to NARUC/DOE Working Session

June 17, 2020

Jeff Brown

Stanford
SCHOOL OF EARTH, ENERGY
& ENVIRONMENTAL SCIENCES

B2E2
BROWN BROTHERS
ENERGY & ENVIRONMENT

# Thought Experiment: What Would it Take to Make SMRs "Investable"?

- Key concepts: (1) SMR FOAK won't find investors unless there is a clear economic path—based on public support and a solid future "order book"—to making enough units to reach a market-competitive cost level. (2) "Market-competitive" is affected by dispatch rules and forms of contracts. *Must be light at the end of the tunnel for owners/manufacturers.*
- Started with public information re NuScale SMR First-of-a-Kind (FOAK)
  - Capital cost ($6.1 B for 720MW, or about $8,500/kW)
  - That probably includes ~$2 B for the NRC process, leaving actual capex of ~$5,700/kW. DOE grant anticipated for $1.4 B.
- Looked to see how many identical units required, made on a single fabrication line and using typical cost decline rates (15% per doubling), to compete with NGCC.

[Note: With very few exceptions new low-carbon dispatchable power projects have been proposed with municipal, co-op, or federal owners (as is case for NuScale). *Exception is Petra-Nova coal CCS in ERCOT, now closed because revenues insufficient.]*

# UAMPS Cost Target: Parity with NGCC @ $55/MWh

- A Utah Associated Municipal Power Systems spokesman says] that energy markets in California have shown that without some flexibility to produce electricity when renewable supplies dip, utilities must still rely on carbon-intensive coal. The deal protects UAMPS customers by specifying a maximum cost for electricity from the plant of $55 per MWh, Webb says, which should make it competitive with the future price of electricity from gas. DOE will help ensure that rate, he says, as it recently finalized a plan to bear $1.4 billion of the cost of the plant. "If it's more than $55 [per MWh] we will not build the plant," he says.

Even as the Department of Energy has pledged $1.4 billion to the project, several public utilities have backed out of a plan build a NuScale nuclear power plant. NUSCALE POWER, LLC

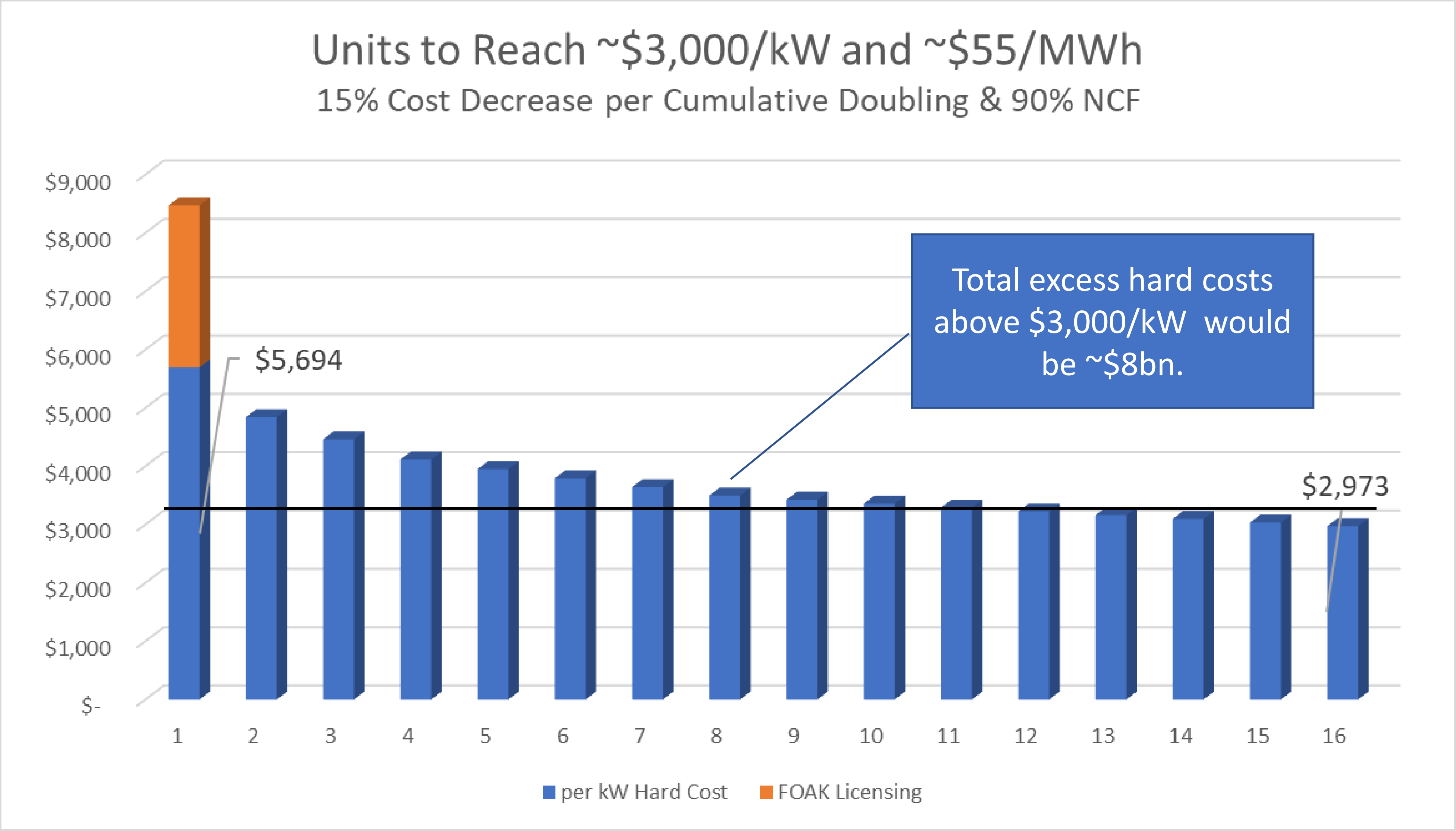
| | UAMPS FOAK Total Cost (incl. NRC), less $1.4 B Grant |
|---|---|
| **Capital Cost per MW** | $ 6,527,778 |
| **CRF (Muni for UAMPS)** | 5.7% |
| **O&M** | 3% |
| **Cost per Yr Fixed** | $ 570,710 |
| | |
| **MW-hr Per Yr at 0.9 NCF** | *7884* |
| | |
| **Fixed per MWh** | $ 72.39 |
| **plus VOM per MWh** | $ 11.5 |
| **Total per MWh** | $ 83.89 |

# Declining Cost to ~$55/MWh: Possible if Factory-Made to Save $ on Engineering and Benefit from "Learning Curve"

| | IOU LSE FOAK | IOU LSE 2nd Unit | IOU LSE After 2 More Units | IOU LSE After 4 More Units | IOU LSE After 8 More Units |
|---|---|---|---|---|---|
| **Capital Cost per MW** | $ 5,694,444 | $ 4,840,278 | $ 4,114,236 | $ 3,497,101 | $ 2,972,536 |
| **Capital Charge Factor** | 8.13% | 8.13% | 8.13% | 8.13% | 8.13% |
| **O&M Factor as % Capital** | 3% | 3% | 3% | 3% | 3% |
| **Fixed Cost per MW-yr** | $ 633,792 | $ 538,723 | $ 457,914 | $ 389,227 | $ 330,843 |
| | | | | | |
| **MWh per MW @ 90%** | 7884 | 7884 | 7884 | 7884 | 7884 |
| | | | | | |
| **Fixed Cost per MWh** | $ 80.39 | $ 68.33 | $ 58.08 | $ 49.37 | $ 41.96 |
| **VOM per MWh** | $ 11.5 | $ 11.5 | $ 11.5 | $ 11.5 | $ 11.5 |
| **Total Production Cost** | $ 91.89 | $ 79.83 | $ 69.58 | $ 60.87 | $ 53.46 |

1. *Capital cost excludes assumed $2 B for initial licensing. Capital costs then assumed to drop 15% for every doubling of cumulative volume. I.e., 2nd unit costs $4.8 B, and 4th unit costs $4.1 B (85% x $4.8).*
2. *As opposed to prior 100% debt funding with tax-exempt bonds for UAMPS, we use 8.13% CCF which is a 30-yr capital charge factor assuming 55% debt: cap; 10% after-tax levered ROE, 4% debt, and 15-yr MACRS depreciation.*

# “Order Book” of 16 Units Could Drive Costs Low Enough



# Dispatch regime can make or break competitiveness: the wheels fall off @ 60% NCF for SMR

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| | | | | | |
| **MW-hr Per Yr at 0.6 NCF** | *5256* | *5256* | *5256* | *5256* | *5256* |
| | | | | | |
| **Fixed Cost per MWh** | $ 120.58 | $ 102.50 | $ 87.12 | $ 74.05 | $ 62.95 |
| **VOM per MWh** | $ 11.5 | $ 11.5 | $ 11.5 | $ 11.5 | $ 11.5 |
| **Total Production Cost** | $ 132.08 | $ 114.00 | $ 98.62 | $ 85.55 | $ 74.45 |

A new nuclear plant cannot eke out financial viability by selling spot during peak hours and dumping “nuclear surplus” to make room for preferential dispatch of wind and solar. That idea is downright silly.

# Path to Successful Nuclear Deployment in the US

1. Federal government picks up the ~$2 B of licensing expense per FOAK unit of each desired design
2. Costs can be driven down by replicating construction of identical units (the "learning curve")
3. SMRs are assured of a deep "order book" so that learning curve effects drive unit capital cost down to ~$3,000/kW, which would result in ~$55/MWh power cost (competitive w/ gas—*assuming must-run or take-if-available contracts*)
4. That would require federal incentive/subsidy of the early unit capital costs in excess of $3,000/kW (~$8 B spread over early units)
5. Serious changes to the current power markets regulatory regime:
   - Not so difficult in traditional regulated markets for vertically integrated IOUs.
   - In "organized" markets serious changes would need to occur:
     - Either renewables-like fixed price take-if-available <u>energy-only</u> contracts and must-run dispatch or
     - <u>20+ year bilateral tolling contracts</u>*covering all fixed costs & fuel, plus top-up for cash variable costs of operation. Also, should allow the nuclear plant to make other products (e.g., electrolytic hydrogen) at times of zero or negative spot energy price.

     [*a capacity price of ~$30-35k per kW-month would be adequate—but variable cost would be near zero]

# UPCOMING PARTNERSHIP WEBINARS

- The next partnership meeting will take place on July 8 from 1-2pm (ET). A calendar invitation will be emailed to members after this webinar. This meeting is open to NEP members only.
- **naruc.org/cpi-1/energy-infrastructure-modernization/nuclear-energy**

# THANK YOU

Chair Tim Echols, Georgia

Chair Anthony O’Donnell, Maryland

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