# Markets and Economic Requirements for Fission Batteries and Other Nuclear Systems (January 27, 2021; 10:00-1:00 Eastern)

10:00: Charles Forsberg/Andrew Foss: Welcome

10:05: Youssef A. Ballout (INL): Fission Battery Initiative

10:15: Jacopo Buongiorno (MIT). Can Nuclear Batteries Be Economically Competitive In Large Markets?

10:40: Paul E. Roege, P.E. (Partner, Creative Erg, LLC): The Resilience Value Proposition

11:05: Elina Teplinsky (Partner: Pillsbury Winthrop Shaw Pittman LLP): Legal feasibility of leasing of Fission Batteries

11:30: Break

11:45: Jerry Schwartz (American Forest & Paper Association): Pulp and Paper Industry Perspectives

12:15: John Parsons (MIT Sloan School of Management) Business Models: Enterprise Controls FB versus Large-scale Cogeneration with Multiple Heat Customers

12:35: Workshop Roundtable

January 13, 2021

**Youssef Ballout, Ph.D.**
Director of the Reactor Systems Design and Analysis Division

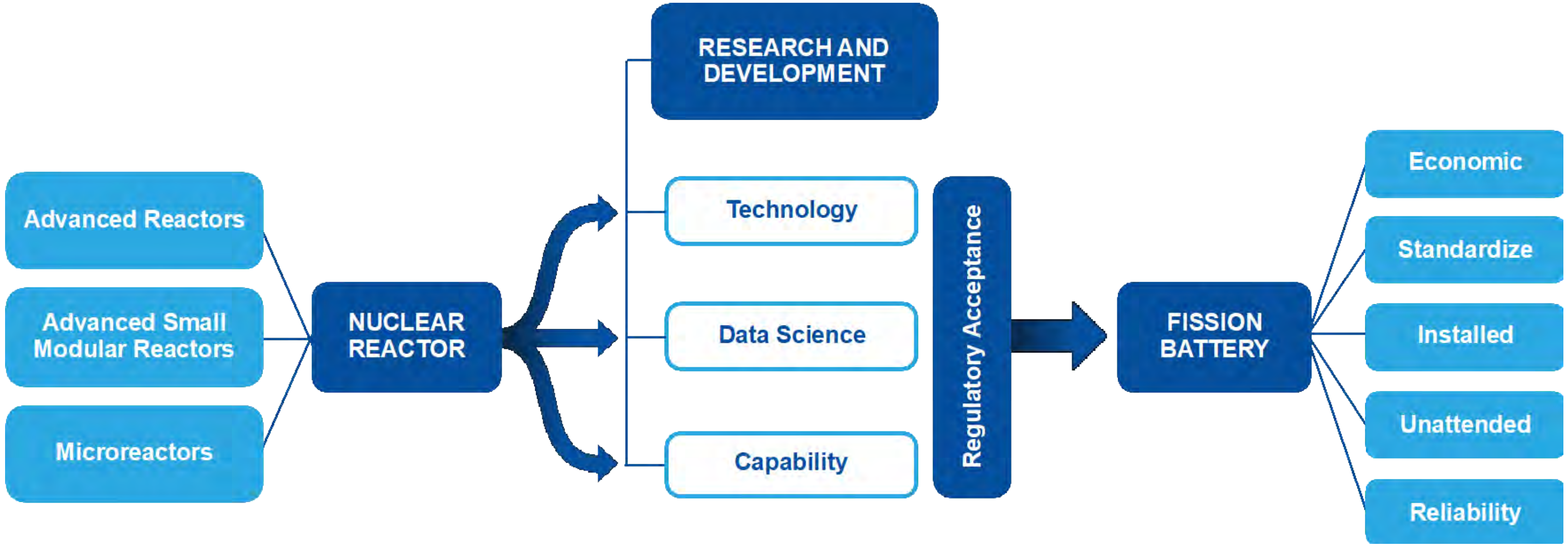
# Fission Battery Initiative

## Nuclear Science and Technology

# Fission Battery Initiative

**Vision:** Developing technologies that enable nuclear reactor systems to function as batteries.

**Outcome:** Deliver on research and development needed to provide technologies that achieve key fission battery attributes and expand applications of nuclear reactors systems beyond concepts that are currently under development.




*Research and development to enable nuclear reactor technologies to achieve fission battery attributes*

# Fission Battery Attributes

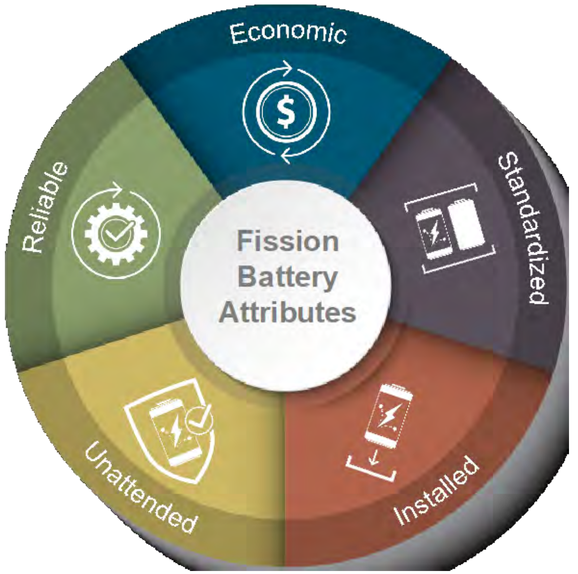
- **Economic** – Cost competitive with other distributed energy sources (electricity and heat) used for a particular application in a particular domain. This will enable flexible deployment across many applications, integration with other energy sources, and use as distributed energy resources.

- **Standardized** – Developed in standardized sizes, power outputs, and manufacturing processes that enable universal use and factory production, thereby enabling low-cost and reliable systems with faster qualification and lower uncertainty for deployment.

- **Installed** – Readily and easily installed for application-specific use and removal after use. After use, fission batteries can be recycled by recharging with fresh fuel or responsibly dispositioned.

- **Unattended** – Operated securely and safely in an unattended manner to provide demand-driven power.

- **Reliable** – Equipped with systems and technologies that have a high level of reliability to support the mission life and enable deployment for all required applications. They must be robust, resilient, fault tolerant, and durable to achieve fail-safe operation.



# Fission Battery Workshop Series

- **Jointly INL and National University Consortium are organizing workshops across <u>five</u> areas:**
  - Market and Economic Requirements for Fission Batteries and Other Nuclear Systems
  - Technology Innovation for Fission Batteries
  - Transportation and Siting for Fission Batteries
  - Security Scoping for Fission Batteries
  - Safety and Licensing of Fission Batteries

- **Expected outcomes:**
  - Each workshop outcomes are expected to outline the goals of each fission battery attribute

INL

Idaho National Laboratory

# CAN NUCLEAR BATTERIES BE ECONOMICALLY COMPETITIVE IN LARGE MARKETS?


**Jacopo Buongiorno**

TEPCO Professor of Nuclear Science and Engineering
Director, Center for Advanced Nuclear Energy Systems
Science and Technology Director, Nuclear Reactor Laboratory


MITei
MIT Energy Initiative

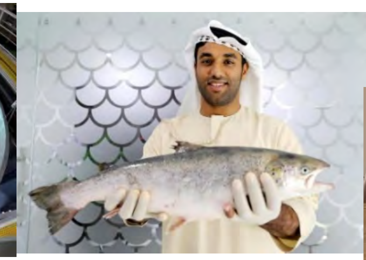
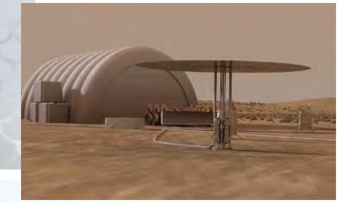
NSE
Nuclear Science and Engineering
science : systems : society

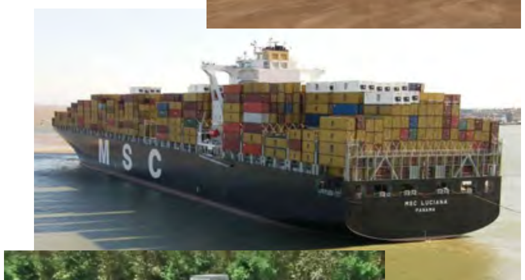
## OBJECTIVES

- Identify *cost targets* for heat and electricity delivered by Nuclear Batteries (NB)
- Identify and quantify *cost drivers* for NB

# WHAT ARE THE POTENTIAL MARKETS?






- Process heat = factories
- Charging stations = e-trucks, hydrogen vehicles
- District heating = home heating
- Desalination = fresh water
- Micro-grids = towns, islands, military bases
- Large pumps = flood protection
- Propulsion = freight ships
- Portable data centers = support local businesses
- Portable farms = fresh produce
- Indoor aquaculture = fresh fish
- Portable biopharma = synthetic insulin, vaccines
- Portable 3D printers = manufacturing
- Space = surface power and propulsion





Heat, electricity and much more

# COST TARGET (ELECTRICITY)

- For electricity the main competition is the grid, but NB are NOT on the grid.

- NB obviate the need for transmission and distribution charges, thus must be compared to retail prices (not generation cost).

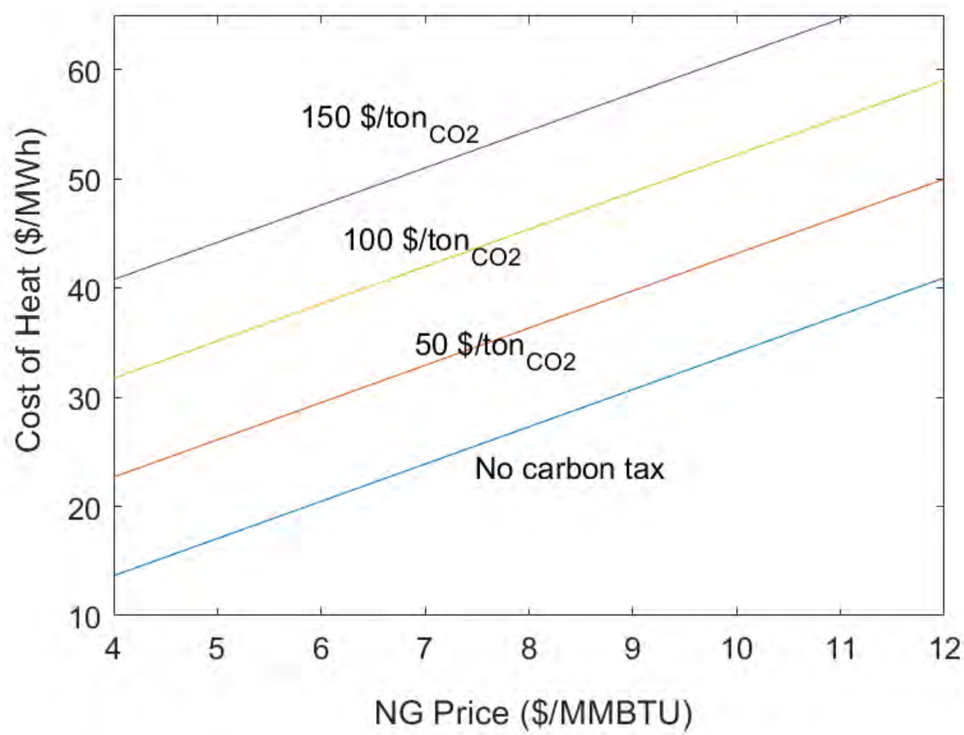
US Electricity Retail Prices 2019 ($/MWh) (includes generation, transmission, distribution)

| Region | Residential | Commercial | Industrial | Transportation | All Sectors |
|---|---|---|---|---|---|
| New England | 210 | 163 | 131 | 92 | 178 |
| Middle Atlantic | 158 | 122 | 66 | 112 | 123 |
| East North Central | 134 | 102 | 69 | 71 | 101 |
| West North Central | 119 | 97 | 73 | 87 | 97 |
| South Atlantic | 119 | 94 | 65 | 79 | 100 |
| East South Central | 114 | 107 | 58 | -- | 94 |
| West South Central | 112 | 82 | 54 | 66 | 84 |
| Mountain | 118 | 96 | 63 | 93 | 94 |
| Pacific Contiguous | 156 | 144 | 97 | 90 | 138 |
| Pacific Noncontiguous | 283 | 245 | 235 | -- | 255 |
| **U.S. Total** | 130 | 107 | 68 | 97 | 105 |

Cost target for electricity 70-100 $/MWh

# COST TARGET (HEAT)

- For heat the main competition is NG-fired boilers.
- NG boilers are too small for CCS*, so burning NG will incur a carbon tax in a carbon-constrained world




*The cost of $CO_2$ capture from a large NG-fired boiler at around 10%mol concentration in the flue gas and 99% efficiency could be up to 100 $/t$_{CO2}$, including compression, but excluding transport and storage, which might add 3-30 $/t$_{CO2}$ depending on location.
(Int. J. Greenhouse Gas Control 105, 2021, 103239)

NG price does not include the cost of the boiler

Cost target for heat 20-50 $/MWh (6-15 $/MMBTU)

# LCOE AND LCOH – BASELINE ASSUMPTIONS

NB is shipped to site with a fueled core, operated continuously for several years, shipped back to a central facility for refueling and refurbishment.

| Parameter | Value | Comments |
|---|---|---|
| electric power output | 10 MW | Reasonable value for many NB applications |
| thermal efficiency | 35% | Estimated for open-air Brayton cycle with losses |
| core power | 28.6 MW | = electric power / thermal efficiency |
| capacity factor | 85% | NB and co-located applications must be operated continuously for good economics |
| fuel enrichment | 5% | Does not require relicensing of U.S. fuel cycle facilities |
| discharge burnup | 20 $MWd/kg_U$ | Lower than LWR because of small cartridge core |
| refueling interval | 5 yrs | From fresh fuel load in central facility to spent fuel return |
| cost of uranium | 40 $/lb of $U_3O_8$ | Conservative assumption for cost of yellow cake |
| cost of uranium conversion | 6 $\$/kg_U$ | Conservative assumption for cost of converting yellow cake into $UF_6$ |
| cost of uranium enrichment | 160 $/SWU | Conservative assumption in current U market |
| cost of fuel fabrication | 500 $\$/kg_U$ | 2x higher than traditional LWR fuel fabrication |
| cost of spent fuel disposal | 1 $/MWh | U.S. spent nuclear fuel disposal fee |
| # of FTE for O&M | 5 | Same FTE/MW of current US fleet |
| wages per FTE | 150,000 $/yr | Includes benefits and taxes |
| cost of fabrication | 30 M$ | 3000 $/kW, excluding fuel |
| other capital costs | 1.7 M$ | Includes site preparation, NB vault, electric transformer, office container, NB shipment to/from site, installation and connection |
| NB economic lifetime | 20 yrs | NB technical lifetime likely longer |
| cost of decommissioning | ½ cost of NB fabrication | Incurred at the end of the project |
| Discount rate | 5%/yr | Reasonable for small project |

# LCOE AND LCOH ESTIMATES

$$\text{LCOE} \; [\$/\text{MWh}] = \frac{\text{Annualized Fuel + O\&M + Fabrication + Deployment + Decommissioning Costs}}{(\text{electric power} \times \text{capacity factor} \times 8760)}$$

$$\text{LCOH} \; [\$/\text{MWh}] = \frac{\text{Annualized Fuel + O\&M + Fabrication + Deployment + Decommissioning Costs}}{(\text{thermal power} \times \text{capacity factor} \times 8760)}$$

Baseline case results:

**LCOE = 71 $/MWh**

**LCOH = 25 $/MWh (7.3 $/MMBTU)**

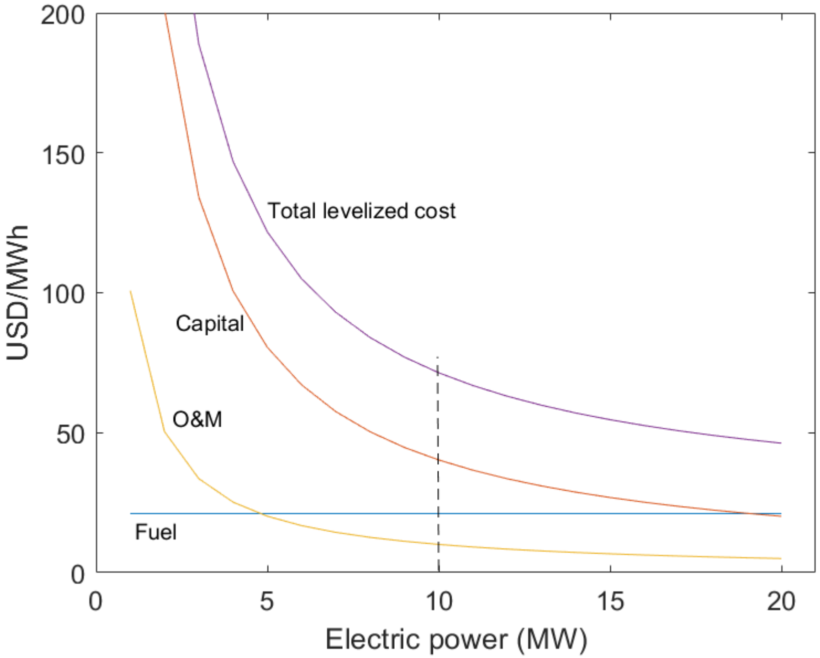
Depending on specific applications and business models, NB will be used for electricity only, heat only or cogeneration, requiring more sophisticated FOMs than LCOE and LCOH

# LCOE PARAMETRIC STUDY

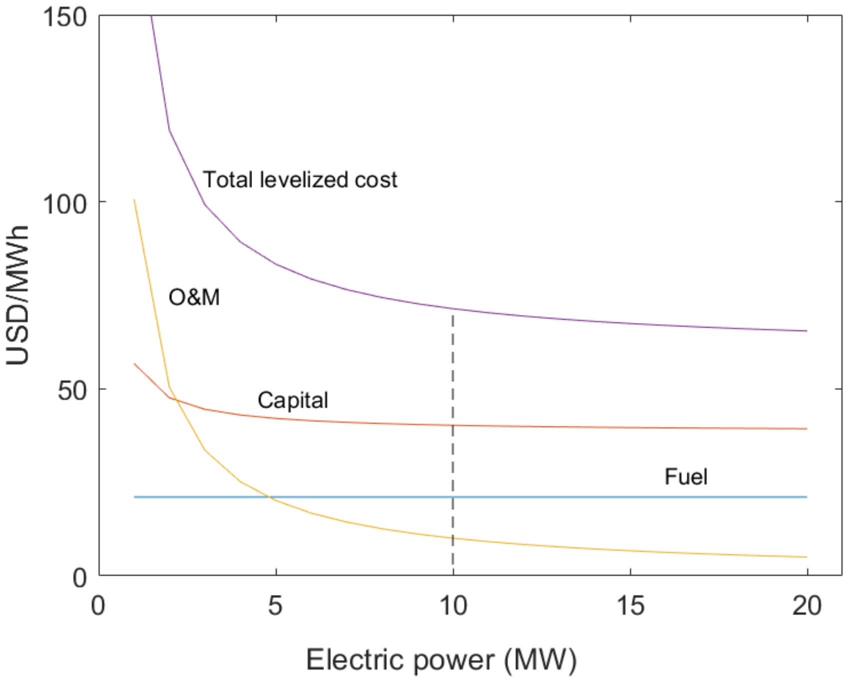
Parameters varied one at a time:

- Power output: 1 to 20 MW
- Fuel enrichment: 5 to 20%
- Discharge burnup: 5 to 30 $MWd/kg_U$
- Refueling interval: 3 to 10 years
- NB fabrication cost (excluding fuel): 1000 to 10000 $/kW
- # of FTEs for O&M: 2 to 15
- Discount rate: 2 to 15 %/yr

# THE EFFECT OF POWER OUTPUT



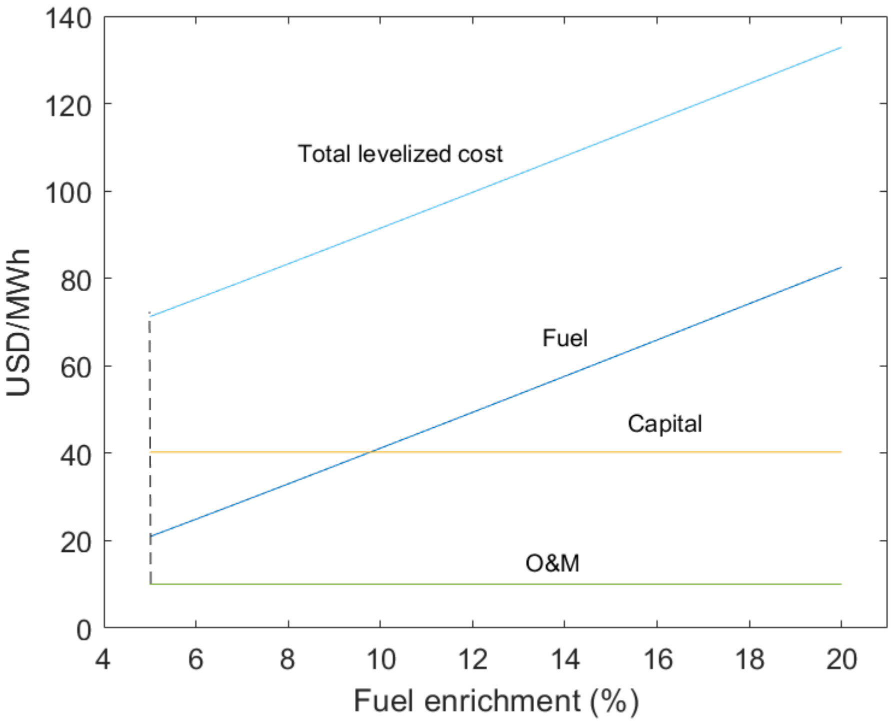

Zero scaling
(fixed fabrication cost, $)

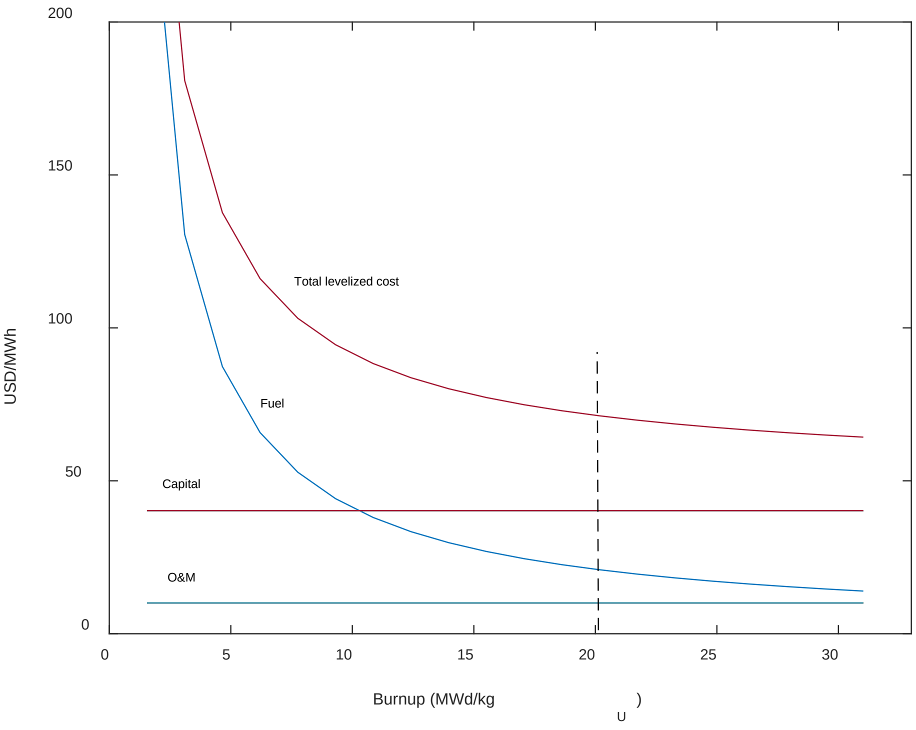



Linear scaling
(fixed *specific* fabrication cost, $/kW)

Economy of scale applies also to micro-reactors!

# THE EFFECT OF FUEL PARAMETERS

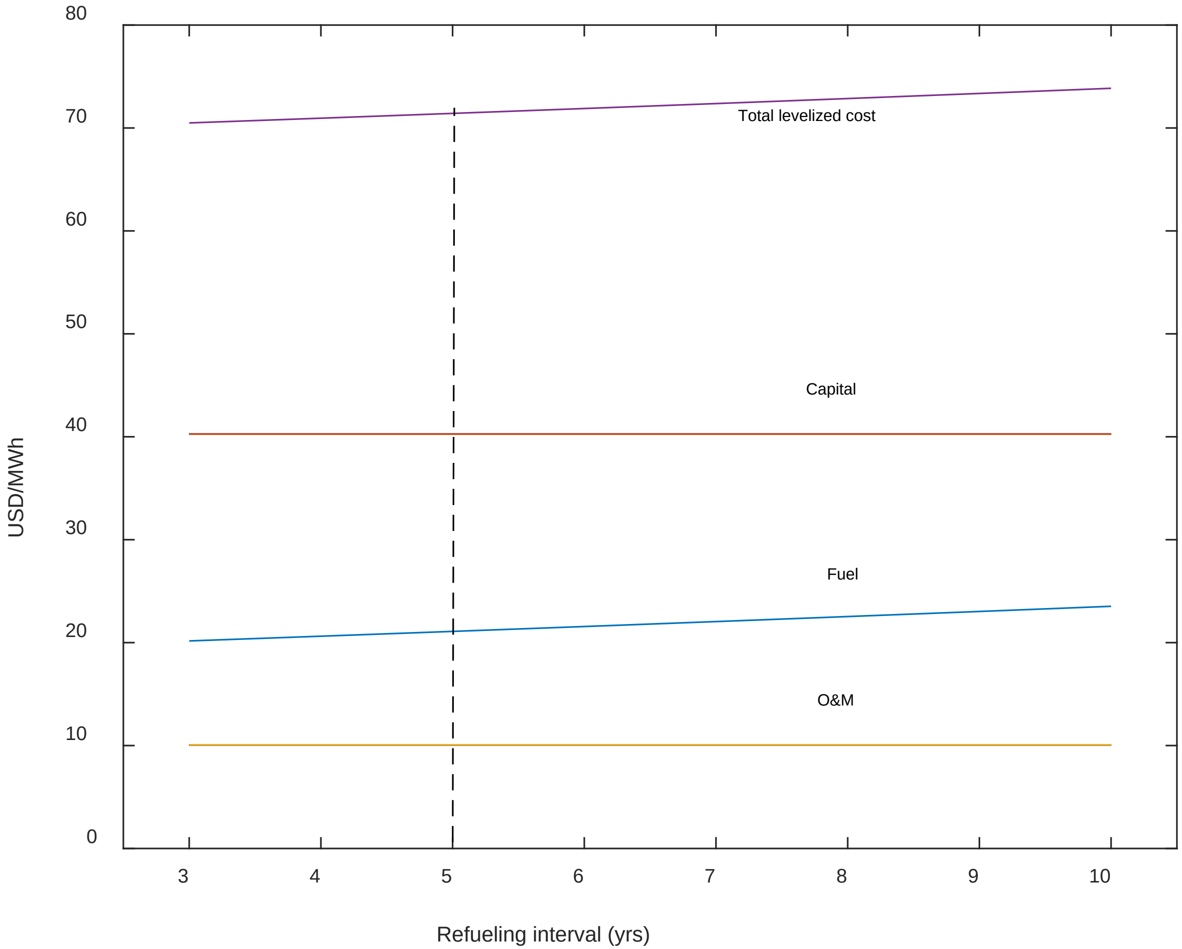



>5% enrichment requires relicensing of U.S. fuel cycle facilities

Fuel costs can quickly become unreasonable

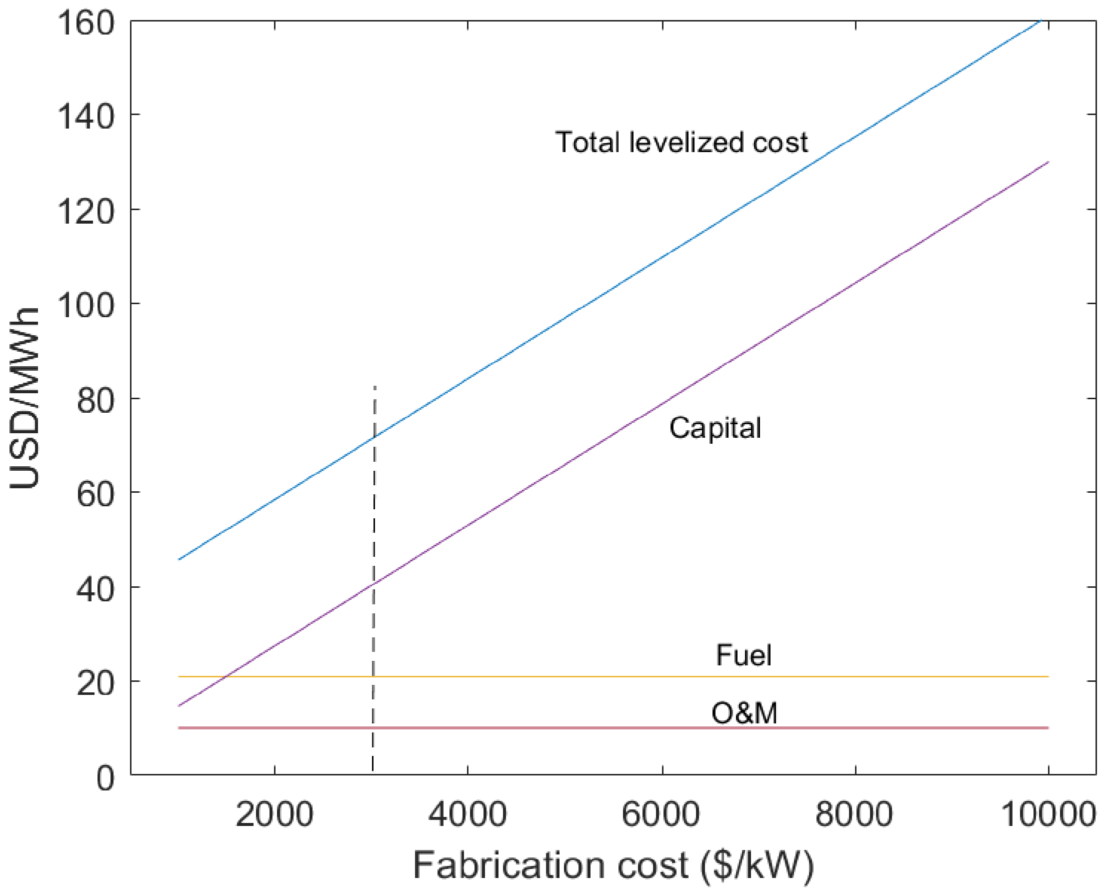
# THE EFFECT OF REFUELING INTERVAL




⇐ High power density    Low power density ⇒

Weak sensitivity wrt refueling interval, BUT fuel mass in the core and core dimensions are inversely proportional to refueling interval (for given core power and discharge burnup)

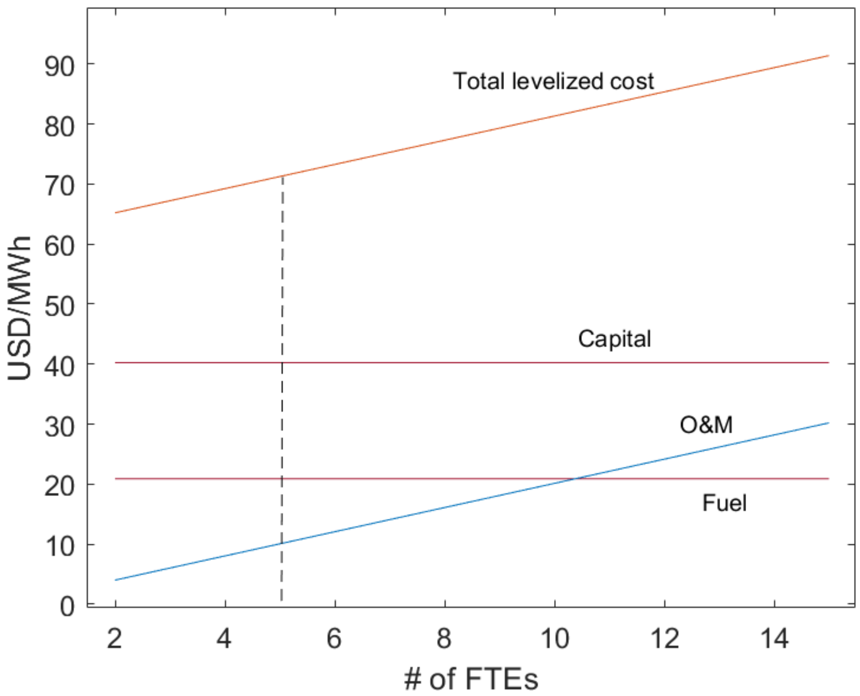
# THE EFFECT OF FABRICATION COST




Fabrication cost makes a big difference, as expected

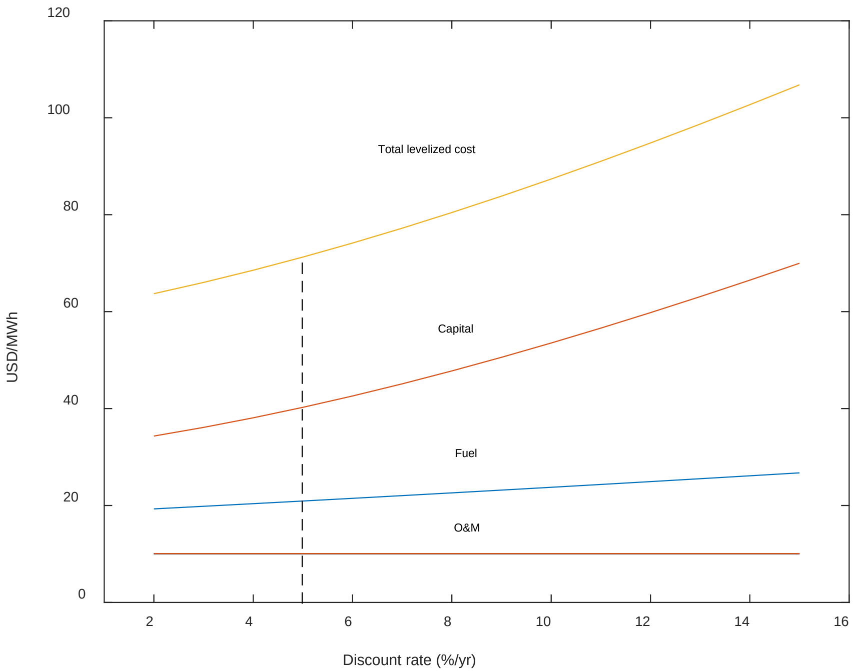
Compare to large jet engines (delicate and complex machines built in factories) generating 50 MW peak mechanical power at takeoff: cost $25M or 500 $/kW.

# THE EFFECT OF STAFF SIZE AND DISCOUNT RATE




LCOE not overly sensitive to # of FTEs within the range explored. 8 FTEs translates to two staff onsite 24/7.

Low cost of financing is key. Should be achievable with small, low-risk project.

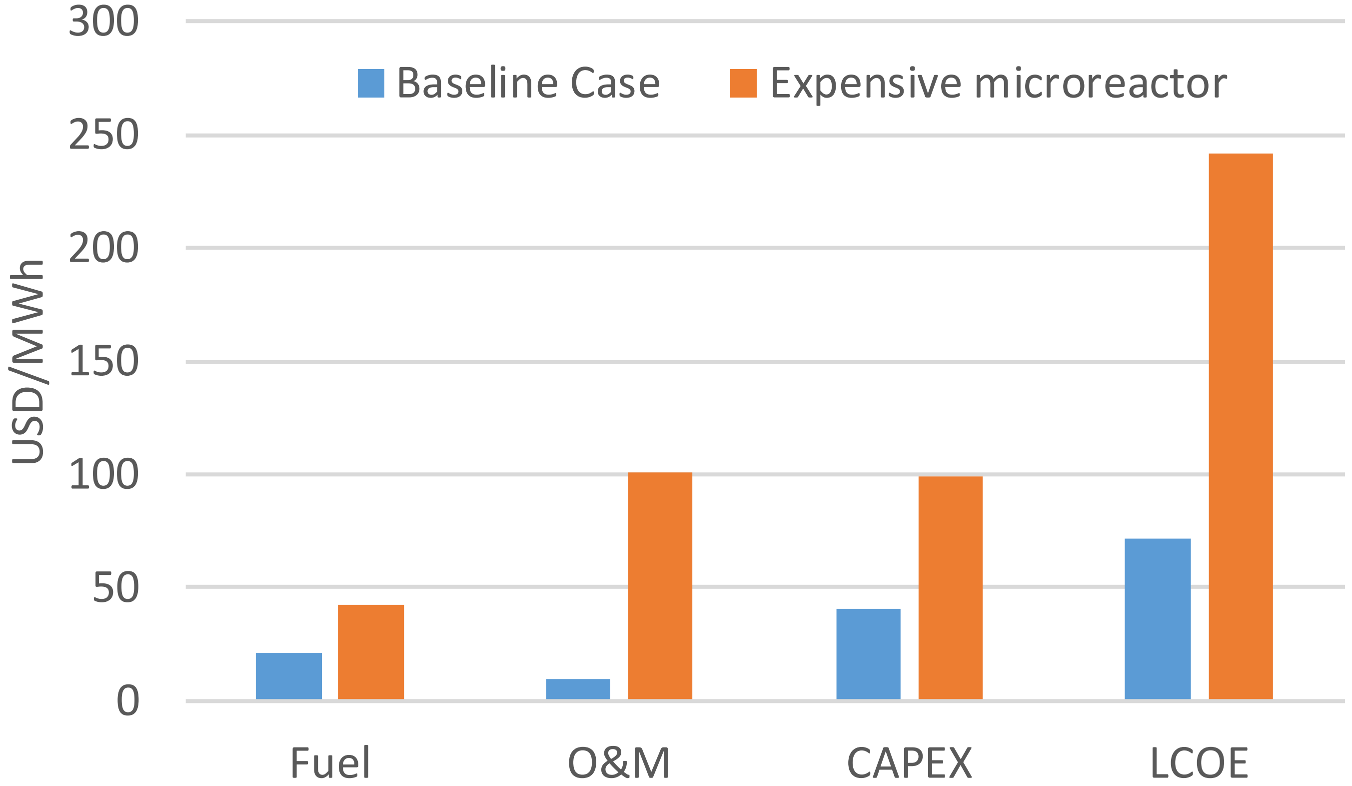


# COST CAN EASILY GET OUT OF HAND

**Notional example of “expensive design”**

Electric output: 2 MW
TRISO fuel: 2500 $/kg$_U$
Burnup: 50 MWd/kg$_U$
# of FTEs: 10

NB fabrication: 7000 $/kW
Enrichment: 15%
Refueling interval: 20 yrs



# TAKEAWAY MESSAGES

- Cost targets for Nuclear Batteries in large markets are 70-100 $/MWh for electricity, and 20-50 $/MWh or 6-15 $/MMBTU for heat

- It appears that NB can meet those targets, if:

  - Power output is maximized, within NB constraints (e.g., truck transportability, passive decay heat removal)
  - Staff is in the 0.5-1.5 FTE/MW range
  - Enrichment <10% and burnup >20 $MWd/kg_U$
  - NB fabrication cost (excluding fuel) <5000 $/kW
  - Discount rate <10 %/yr

- No cost incentive for very long refueling intervals (>10 yrs)

# BACKUP SLIDES

# SITE PREP AND INSTALLATION – ASSUMPTIONS

- Dig hole for micro-reactor vault: $150k at $200/cubic yard (Home Advisor 2020a)
- Prepare lot (assumed to be 300 $m^2$ per micro-reactor) (McClure 2013): $50k (Home Advisor 2020a)
- Cost of the micro-reactor vault: $1M, assumed to be equivalent to the cost of a SNF dry cask (Wald 2011)
- Electric transformer: $100k (Switchgear 2020)
- Office container: $5k (includes shipment) (Container Alliance ca 2017)
- Fence: $23k (high-end fences run at about $100/ft (Home Advisor 2020b)
- Shipment fresh micro-reactor: $50k, similar to fresh fuel shipment, conservatively calculated from recommended estimates in Feizollahi et al. (1995)
- Shipment spent micro-reactor: $200k, based on spent fuel shipment cost of $50/$kg_{HM}$ (NEA 1994)
- Micro-reactor installation, connection and on-site testing: $170k (crew of 5 × 14 days × 8 hours × $300/hour)

# LIKELY COST DRIVERS

- Core design: combo of fuel enrichment, specific power and burnup.

- Fabrication: materials availability in codes (Ni-based alloys, ferritic SS, Ti-alloys), supply chain, fabrication equipment suitability of desired size components (<10 ft, 3-4 tons forging), off-the-shelf BOP equipment.

- Transportability: weight and size compatible with standard ISO containers (<14'x14').

- Installation: requirements for onsite excavation, concrete structures, special crane or handling equipment.

- O&M: onsite manpower required for normal ops, unique daily ops requirements (e.g., chemistry monitoring/control), routine ops/maintenance with high exposure potential, unique sensing requirements (e.g., pump sensors/release monitoring for tritium), high replacement periodicity for any parts/materials, readily available sensors for remote or online monitoring and operations, safety systems hardened against cyber intrusion, diagnostic/prognostic/degradation algorithms availability.

# The Resilience Value Proposition

- Fission Battery Economics Workshop
- January 2021


- Paul E. Roege, P.E., Creative Erg, LLC

# Value

*The regard that something is held to deserve; the importance, worth, or usefulness of something*.

(Oxford)

# Historical manifestation

- Anthropological pattern - creation, guarding, barter, and conflict over items or services of "value"
- Currency systems facilitated negotiation and transactions
- Price (arbitrary) ≠ Value (fundamental)
- Value is exposed in a decision
- What's the value of
  - Pork bellies
  - Energy
  - Concert tickets?

Energy is now treated a commodity . . . *but*

*Value derives from application and circumstances of use!*

# to illustrate. . .

The military concept of *Energy-Informed Operations:*

*Using energy to the greatest net operational benefit.*

# Energy provides the operational edge

## *Dismounted Maneuver*

***Capability Priorities:***
- Increased Mobility, lethality
- Decreased Resupply and Operational Interruptions

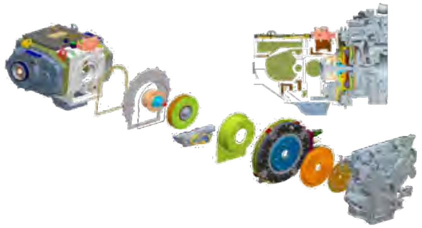
***Trend:***
- More Systems = Net increase in power demand
- Networked Communications to the Soldier level

Soldier-Worn Integrated Power Equipment System (SWIPES)

## *Mounted Maneuver*

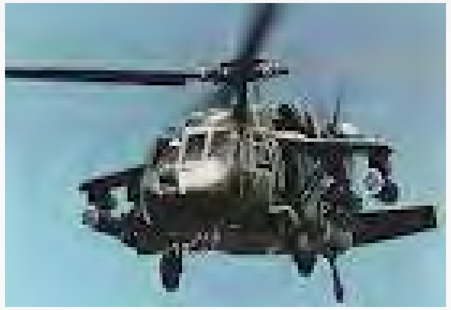
***Capability Priorities:***
- Flexibility for rapidly changing operating environment
- Endurance/sustainability

***Trend:***
- Diversification of threats
- Proliferation of onboard systems
- Networked energy concepts



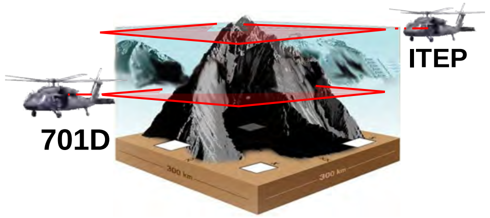
Integrated Starter-Generator (ISG)

## *Air Maneuver*



***Capability Priorities:***
- 424 Km Radius of Action without Refuel
- Operational coverage 6K/95°

***Trend:***
- Extended distances, remote locations
- Increasing Soldier load




Improved Turbine Engine Program (ITEP)

## *Contingency Basing*

***Capability Priorities:***
- Interoperate with systems, Soldiers, partners
- Increase efficiency to provide more resources for operations

***Trends:***
- Extended operations – quality of life improvements
- Increased use of contracted support

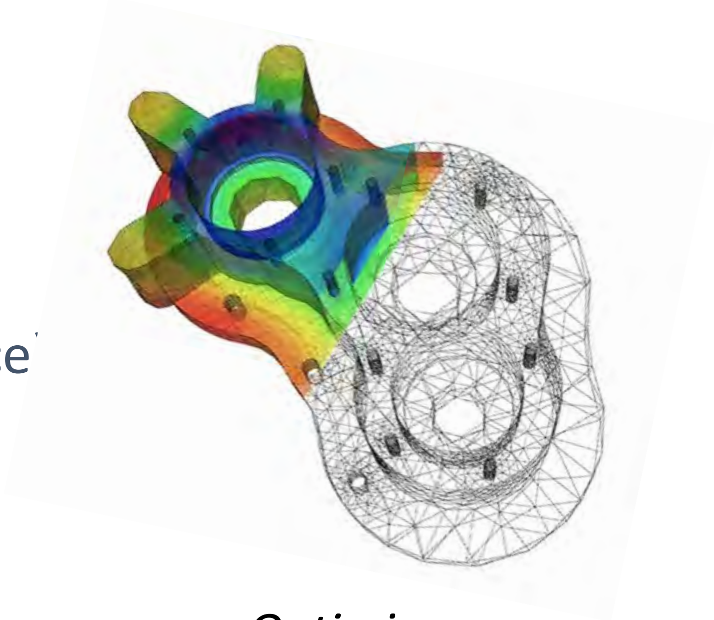
Microgrids

# Complicating the equation

*What if. . . ?*

# Factoring in Uncertainty (19th-20th Centuries)

- *Risk Management based upon confidence (or arrogance?)*
- Maximize Expected Value (EV)
- Decisions based upon actuarial information (predictability)
- Institutionalized indemnification (legal) / risk sharing (insurance)
- Life cycle strategy
  - Optimize system design for performance
  - Protect system as designed (*stasis*)



*Optimize . . .*

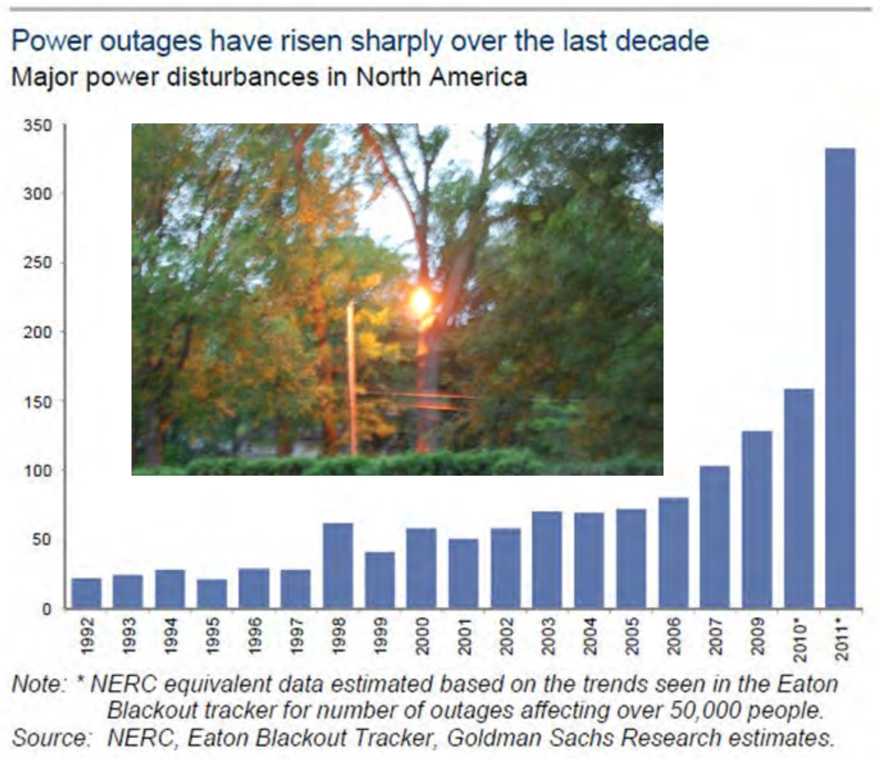
# Risk Management (the rest of human history)

- *Adaptive management based upon humility*
- Seek Resilience (capacity to thrive in face of change)
- Acknowledge change and unknowns
- Focus on desired outcome rather than the system
- Life cycle strategy
  - Balance effectiveness and agility for incremental improvement
  - Sense, respond, recover, and adapt

*Improvise!*

# Why resurrect Resilience?

- Increasingly dynamic and complex world
- New phenomenologies
- Recognition of knowledge gaps
- Shortcomings in EV model
- Growing dissatisfaction with outcomes



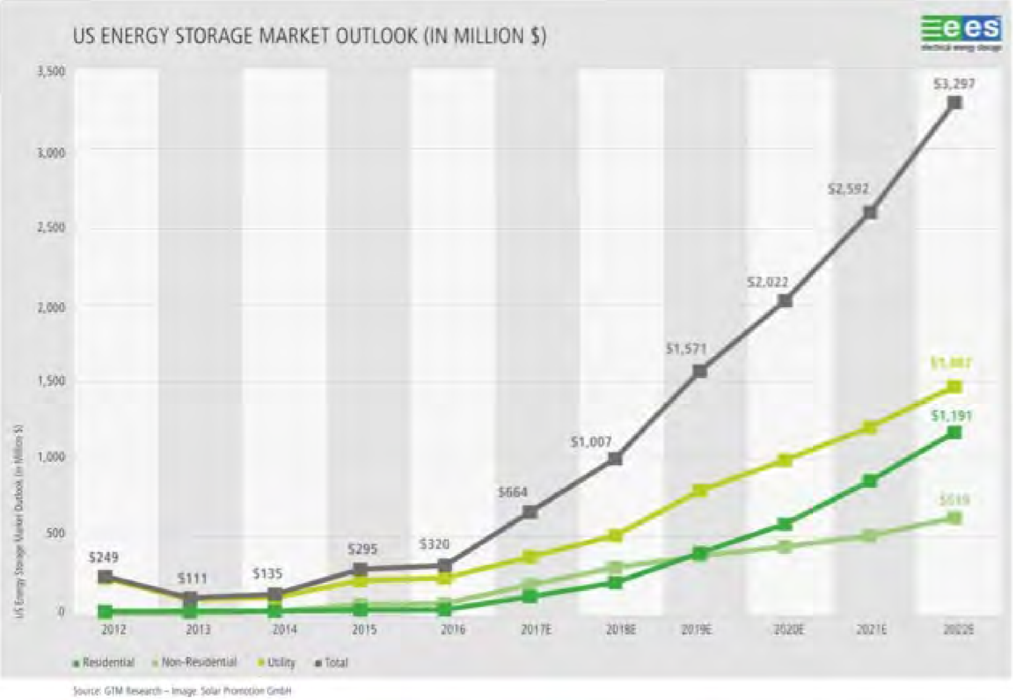
# Illustration – Fukushima tsunami

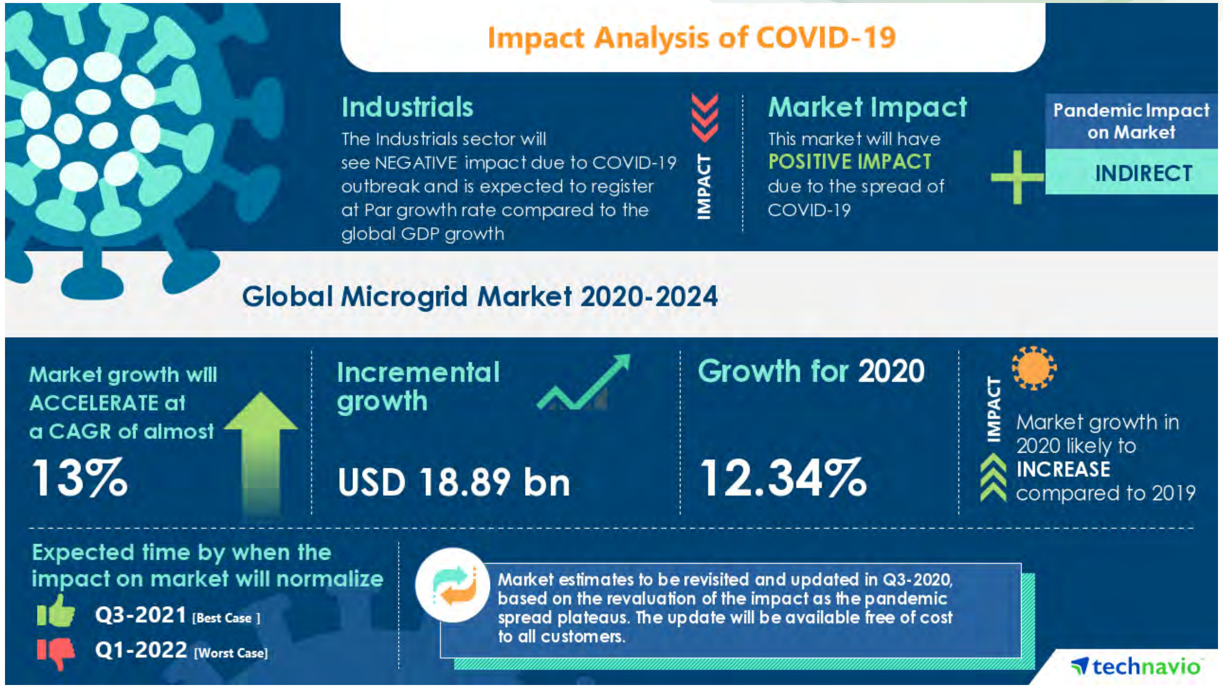
- Complex system
- Single-point vulnerabilities
- Extraordinary consequences
- Mitigated by operator initiative

# Illustration – Puerto Rico hurricane

- Centralized system
- Limited local capacities
- Service restoration 1 >yr
- Consequences mitigated by local initiative

# Indicators of change




*Energy storage and microgrid investment growth – not driven by "lowest LCOE."*

# How can we value (and afford) Resilience?

- Shift focus from maintaining system stasis to assuring outcomes
- Reform design emphasis from point optimization to agility
- Adopt systemic resilience metrics
- Cultivate proactive, entrepreneurial posture
- Expand decision processes to address real value

# Alternative design approaches

## Deterministic

- Optimize @design condition
- Maximize expected return
- Anticipated stressors
- System features
  - Protective barriers
  - Deterministic control
  - Prescriptive procedures

## Resilient

- Characterize via contingency & sensitivity analyses
- Embrace sensing, stability, flexibility, adaptability
- System features
  - Open architecture
  - Alternative configurations
  - Intelligent systems
  - Situational awareness
  - Operational options

LEGO® Model – INL Photo

# Resilience Metrics (model)

| Domain | Prepare | Absorb | Recover | Adapt |
| --- | --- | --- | --- | --- |
| Physical | | | | |
| Information | | | | |
| Cognitive | | | | |
| Social | | | | |

*Develop specific measures based upon system/objectives*

From Roege, P.E. et al., Metrics for energy resilience, Energy Policy (2014), http://dx.doi.org/10.1016/j.enpol.2014.04.012

# Philosophical shift required

- Reform value proposition
- Adopt abundance mentality
- Accept humble attitude
- Embrace change
- Encourage/empower entrepreneurship

# Leasing Nuclear Batteries: Opportunities and Considerations


**Elina Teplinsky**
**Partner**
***Pillsbury Winthrop Shaw Pittman LLP***

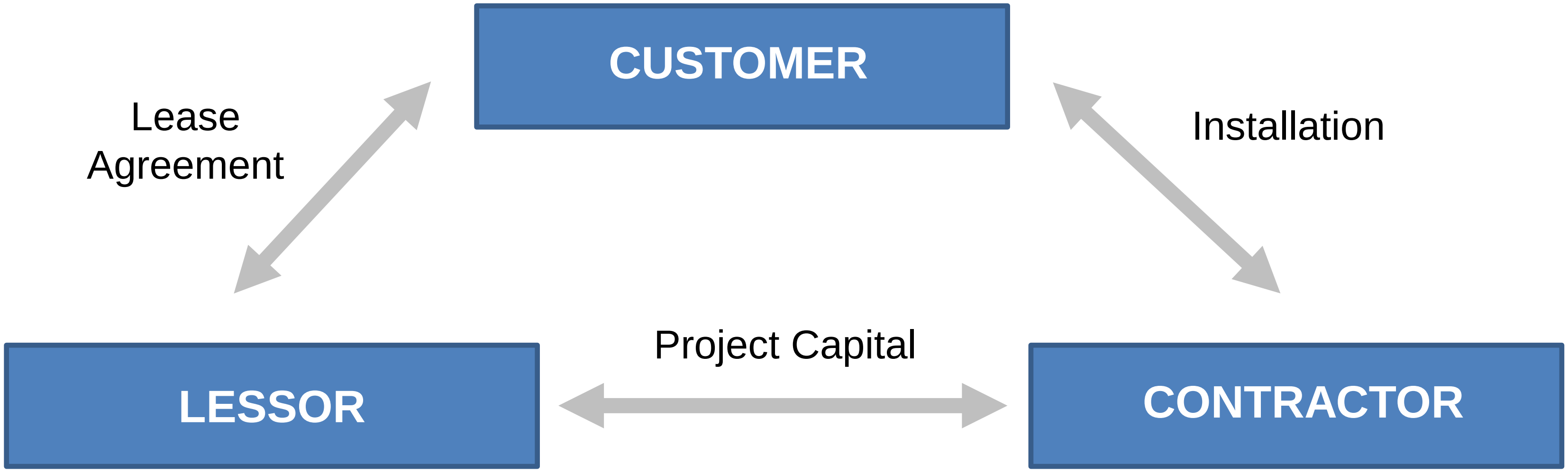

*presented at*

**Workshop on Markets and Economic Requirements for Fission Batteries and Other Nuclear Systems**

**January 27, 2021**

# Leasing in the Energy Sector: An Overview

- **Lease:** financing structure that allows a customer to use equipment without purchasing it outright
  - Commonly used for solar systems and battery storage
  - Simpler than a PPA + possible tax & accounting benefits
  - Terms flexible – 3-15+ years

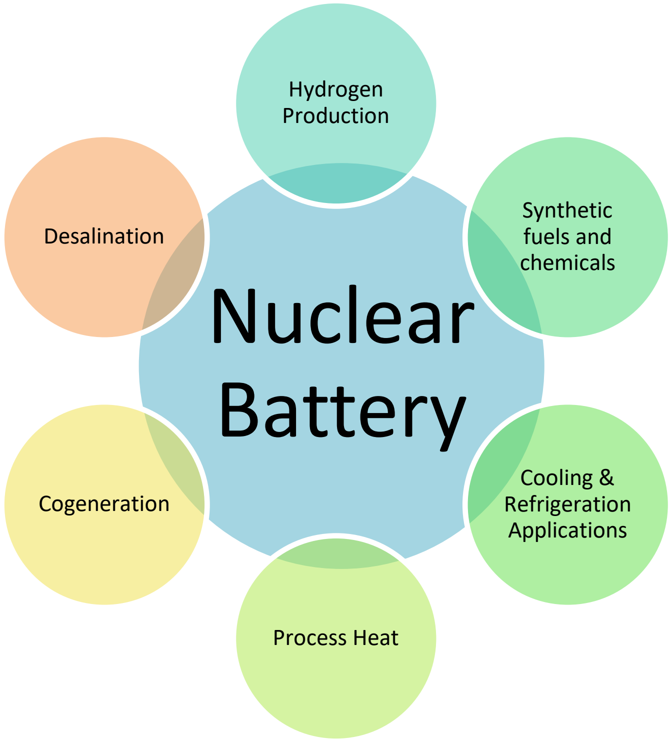


# Types of Leases

| Type of Lease | Key Aspects |
| --- | --- |
| **Capital or Finance Lease** (similar to bank loan) | • Customer owns equipment, lessor takes security interest<br>• Equipment = asset, lease payments = liability<br>    • Customer can depreciate the equipment as an asset to provide a tax benefit<br>• Customer can purchase equipment for discounted price at end of lease term |
| **Operating Lease** | • Lessor owns equipment, customer rents at a fixed monthly payment<br>• Rental payments = operating expenses, tax deductible<br>• End of lease term -> customer can extend lease, purchase equipment for fair market value, or return equipment |
| **Solar Lease** | • Similar to operating lease<br>• Different options of down payment<br>• Tax incentives / rebates normally are retained by developer |

# Leases in the Context of Nuclear Batteries

- Primary customers will be industrials – purchasing heat, not electricity
  - Diverse customer base relative to utilities
  - No interest in licensing and operating nuclear facilities
- Leases v. PPAs
- Highly manufactured content and short deployment times may allow for involvement of additional players, such as financial institutions



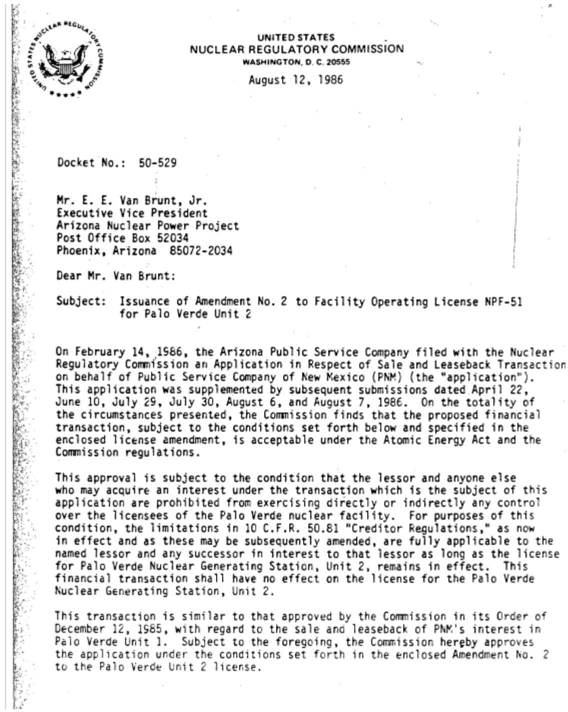
# Feasibility of Leasing Nuclear Batteries

- **NRC Creditor Regulations at 10 CFR §50.81:**
  - The Commission consents, without individual application, to the creation of any mortgage, pledge, or other lien upon any production or utilization facility not owned by the United States which is the subject of a license or upon any leasehold or other interest in such facility: Provided:
    - (1) That the rights of any creditor so secured may be exercised only in compliance with and subject to the same requirements and restrictions as would apply to the licensee pursuant to the provisions of the license, the Atomic Energy Act of 1954, as amended, and regulations issued by the Commission pursuant to said Act; and
    - (2) That no creditor so secured may take possession of the facility pursuant to the provisions of this section prior to either the issuance of a license from the Commission authorizing such possession or the transfer of the license.

# History of Regulation of Nuclear Leasing in the U.S.

- **1970s and 80s: various "sale leaseback" transactions**
  - Nuclear power plant owners in the United States sold facilities to equity investors, leased back same interest sold
  - Refinancing and tax equity transactions – sale of credits to institutional investors

- **NRC applied 10 CFR §50.81 to these transactions:**
  - Approved the applications with no impact on licenses, but with conditions:
    - Facilities to operate in conformity with applications
    - Lessor and anyone else who may acquire an interest under the transaction are **prohibited from exercising directly or indirectly any control over the licensees**
    - Licensees required to notify NRC of any changes in the sale leaseback agreements



UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

August 12, 1986

Docket No.: 50-529

Mr. E. E. Van Brunt, Jr.
Executive Vice President
Arizona Nuclear Power Project
Post Office Box 52034
Phoenix, Arizona 85072-2034

Dear Mr. Van Brunt:

Subject: Issuance of Amendment No. 2 to Facility Operating License NPF-51 for Palo Verde Unit 2

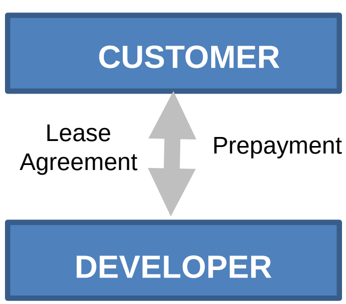
On February 14, 1986, the Arizona Public Service Company filed with the Nuclear Regulatory Commission an Application in Respect of Sale and Leaseback Transaction on behalf of Public Service Company of New Mexico (PNM) (the "application"). This application was supplemented by subsequent submissions dated April 22, June 10, July 29, July 30, August 6, and August 7, 1986. On the totality of the circumstances presented, the Commission finds that the proposed financial transaction, subject to the conditions set forth below and specified in the enclosed license amendment, is acceptable under the Atomic Energy Act and the Commission regulations.

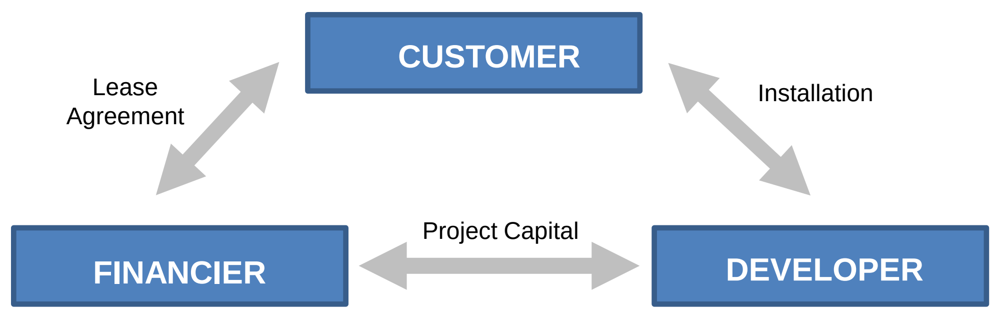
This approval is subject to the condition that the lessor and anyone else who may acquire an interest under the transaction which is the subject of this application are prohibited from exercising directly or indirectly any control over the licensees of the Palo Verde nuclear facility. For purposes of this condition, the limitations in 10 C.F.R. 50.81 "Creditor Regulations," as now in effect and as these may be subsequently amended, are fully applicable to the named lessor and any successor in interest to that lessor as long as the license for Palo Verde Nuclear Generating Station, Unit 2, remains in effect. This financial transaction shall have no effect on the license for the Palo Verde Nuclear Generating Station, Unit 2.

This transaction is similar to that approved by the Commission in its Order of December 12, 1985, with regard to the sale and leaseback of PNM's interest in Palo Verde Unit 1. Subject to the foregoing, the Commission hereby approves the application under the conditions set forth in the enclosed Amendment No. 2 to the Palo Verde Unit 2 license.

# Framework for Leasing

- Facility licensed and operated by project developer
- Easiest structure from NRC licensing perspective is operating lease – facility owner by developer, customer rents at fixed periodic payment
- Capital lease may be possible, but likely subject to significant NRC scrutiny – may not be compatible with large-scale deployment model, unless blanket approval of concept can be secured
- Lessor can be project developer (build, own, operate, lease) or financial institution (if a derisked project)
  - In absence of financier involvement, partial pre-payment or downpayment of lease will help offset capital costs

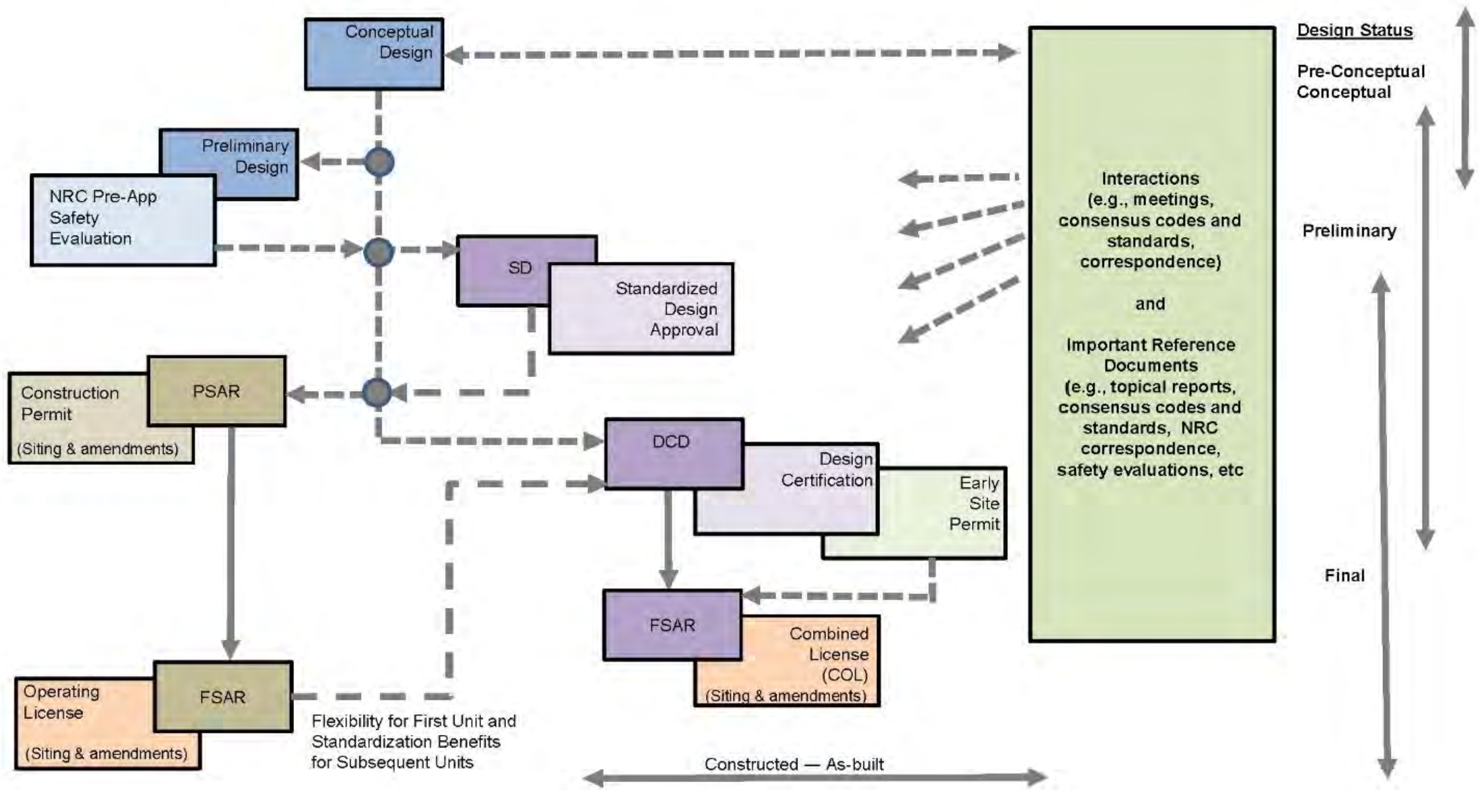


# Licensing Challenge

Current NRC licensing framework is not designed for large-scale deployment of nuclear batteries

Licensing solutions necessary to enable this large-scale deployment – key to success of leasing model from a market perspective



# Licensing Challenge – Possible Solutions

- **Manufacturing Licenses**
  - allows for pre-fabrication of nuclear power plants and then installation and operation at separately approved sites
  - Appendix N to Parts 50 and 52 provides for construction and operation of nuclear power reactors of identical design at multiple sites
- **Non-power reactors (NPRs)**
  - Simplified licensing process
  - NUREG-1537, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors" – includes Standard Review Plant for licensing NPRs
  - Although nuclear batteries may not be nonpower reactors, regulations could be changed in the future to allow them to be licensed in a manner similar to NPRs
  - NRC has already included suggested modifications to NUREG-1537 Part 1 in a report titled "Regulatory Review of Micro-Reactors – Initial Considerations"
- **Part 53**
  - Performance-based licensing regime with technology-inclusive framework
  - Significant engagement with NRC required to provide for a licensing framework allowing for large-scale deployment of nuclear batteries

# Leasing Model – Liability Considerations
## *Price-Anderson Act (PAA) Key Principles*

**Omnibus coverage protects all who may be liable**

- The owner
- Contractors, vendors and suppliers
- Anyone else with liability

**Covers <u>any legal liability</u> arising from a nuclear incident**

- Negligence
- Gross negligence
- Willful misconduct

**Economically channels all liability to the plant owner**

- Owner holds insurance policies

**Provides cap on liability equal to the coverage**

- Total amount of primary + secondary insurance

# Requirements for Reactors with Rated Capacity of > 100MWe

- Must have two tiers of nuclear liability security:
  - Primary nuclear liability insurance of $450 million
  - Must participate in a secondary retrospective insurance plan
- Modular units of 100 MWe to 300 MWe at single site with combined capacity up to 1300 MWe treated as single unit

**Primary nuclear liability insurance:**
$450M

+

**Secondary retrospective insurance:**
$131M / reactor / incident

# Requirements for Reactors with Rated Capacity <100 MWe

- Maintain primary insurance as required by NRC
  - Required amount ranges from $1-$74M, depending on capacity or established by a formula
  - Requirement does not apply to non-profit university reactors
- No secondary retrospective premiums are required
- Government indemnification required where licensee maintains financial protection of less than $560M
  - Maximum amount of indemnification is $500M; amount reduced by the amount licensee's financial protection exceeds $60M
  - Indemnity in excess of $250M available for non-profit university reactors

**Primary nuclear liability insurance:**
$1-74M

+

**NRC indemnification**

# Leasing Model and Liability

- Operating lease model fully compatible with Price Anderson framework
  - Owner holds insurance policies, lessor covered under the policies, lessor has no control over facility or owner
- Capital lease model would require discussion with NRC
- Some industry recommendations:
  - Threshold for requiring maximum primary financial protection and participation in the secondary financial protection program (100 MWe too low)
  - Changing the existing 300 MWe threshold for treating a combination of facilities as a single facility for financial protection purposes;
  - Developing variable requirements for primary and/or retrospective premiums (e.g., a sliding scale for reactors with output between 100 MWe and 500 MWe)
  - Creating new thresholds for non-electricity generating reactors; and
  - Changing the amount of property insurance required under 10 CFR 50.54(w).

# Conclusions

- Leasing models widely used in the energy sector
- NRC precedent for treatment of financial transactions
- Leasing models need to be developed with input from regulators and financial community
- Licensing presents the biggest challenge
- Liability framework works with leasing model, but financial requirements should be better adapted to nuclear batteries

# QUESTIONS?

## *Thank you for your attention*


**Contact Information:**
Elina Teplinsky
Partner
Pillsbury Winthrop Shaw Pittman LLP
elina.teplinsky@pillsburylaw.com
+1.202.663.9009 (office)
+1.202.277.9547 (mobile)


American Forest & Paper Association

# *AF&PA's Energy Profile*

## January 27, 2020

### Workshop: Markets and Economic Requirements for Fission Batteries and Other Nuclear Systems

BETTER PRACTICES BETTER PLANET 2020
Continuing AF&PA's Commitment to Sustainability

# *Overview*

- AF&PA
- Description of Industry
- Energy Profile Today
  - Energy Sources
  - Costs
  - Key Attributes
- Where Are We Going?
  - Industry Commitments/Trends
  - Technology Development
  - 2050

# *AF&PA's Mission*

Advance a sustainable U.S. pulp, paper, packaging and wood products manufacturing industry through fact-based public policy and marketplace advocacy.

# *Our Industry Supports Nearly One Million Jobs Nationwide*

## WE ARE AMERICAN

### MANUFACTURING JOBS

Forest products manufacturers are an important source of year-round, well-paying jobs in many rural American communities and often serve as economic-development engines for entire regions. Given the industry's size, the economic vitality of forest products companies is essential to these local communities and regions, as well as to the nation's manufacturing base and overall economy.

### NATIONAL EMPLOYER

The industry employs approximately

**950,000**

workers in the U.S.

### TOP 10

The forest products industry is among the top 10

**45**

manufacturing sector employers in 45 states.

### GDP

The industry represents approximately

**4%**

of U.S. manufacturing GDP.

### ADDED WEALTH

The industry meets a payroll of approximately

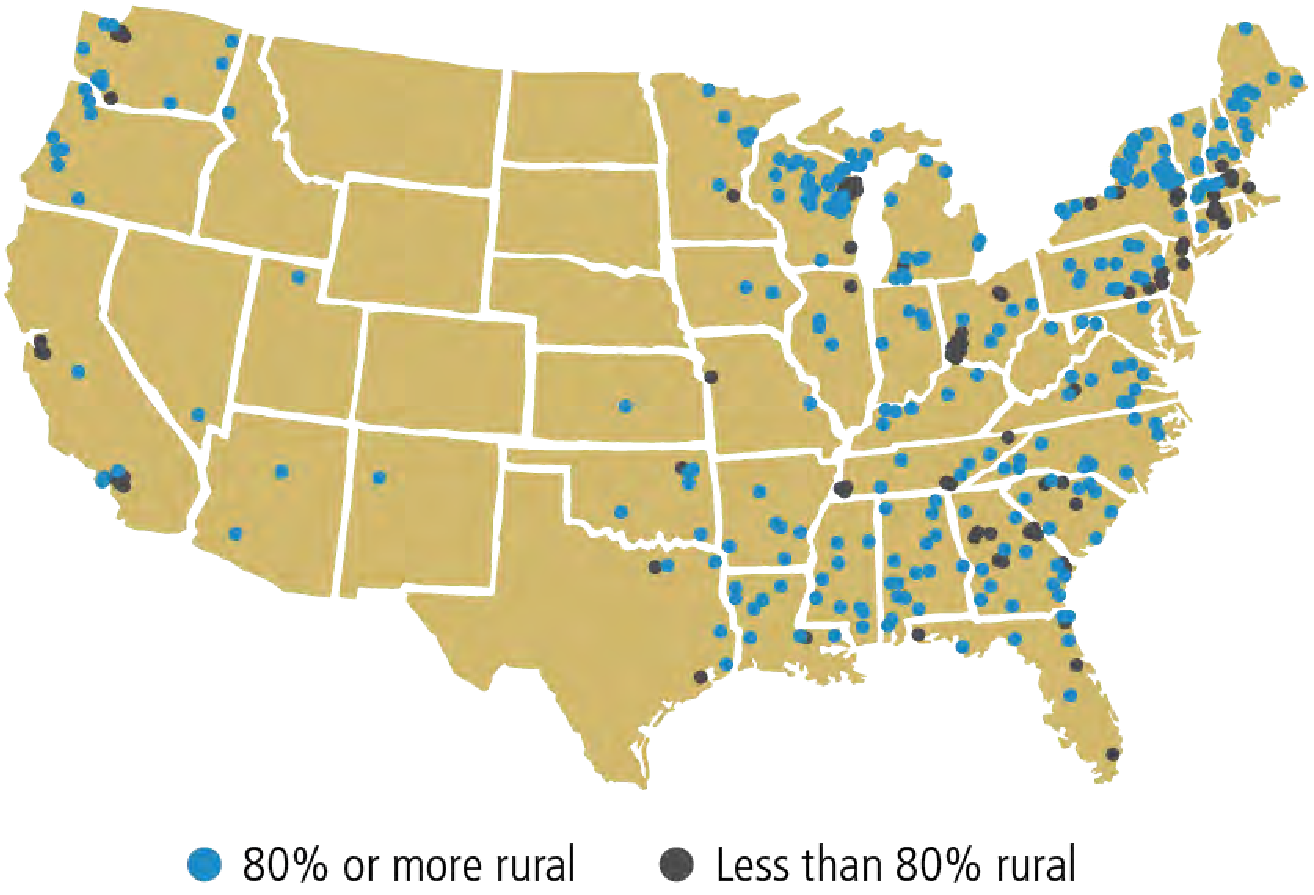
**$55 BILLION**

annually among its employees.



American Forest & Paper Association

# More Than 75 Percent Of All U.S. Pulp And Paper Mills Are Located In Rural Counties






American Forest & Paper Association

# *U.S. Forest Products Industry*



American Forest & Paper Association

# Typical Pulp and Paper Mill

# *In the Mill*

PCA's Wallula mill in Washington state and Greif's Riverville mill in Virginia.
Photo Credit: AF&PA

# *Data Sources*

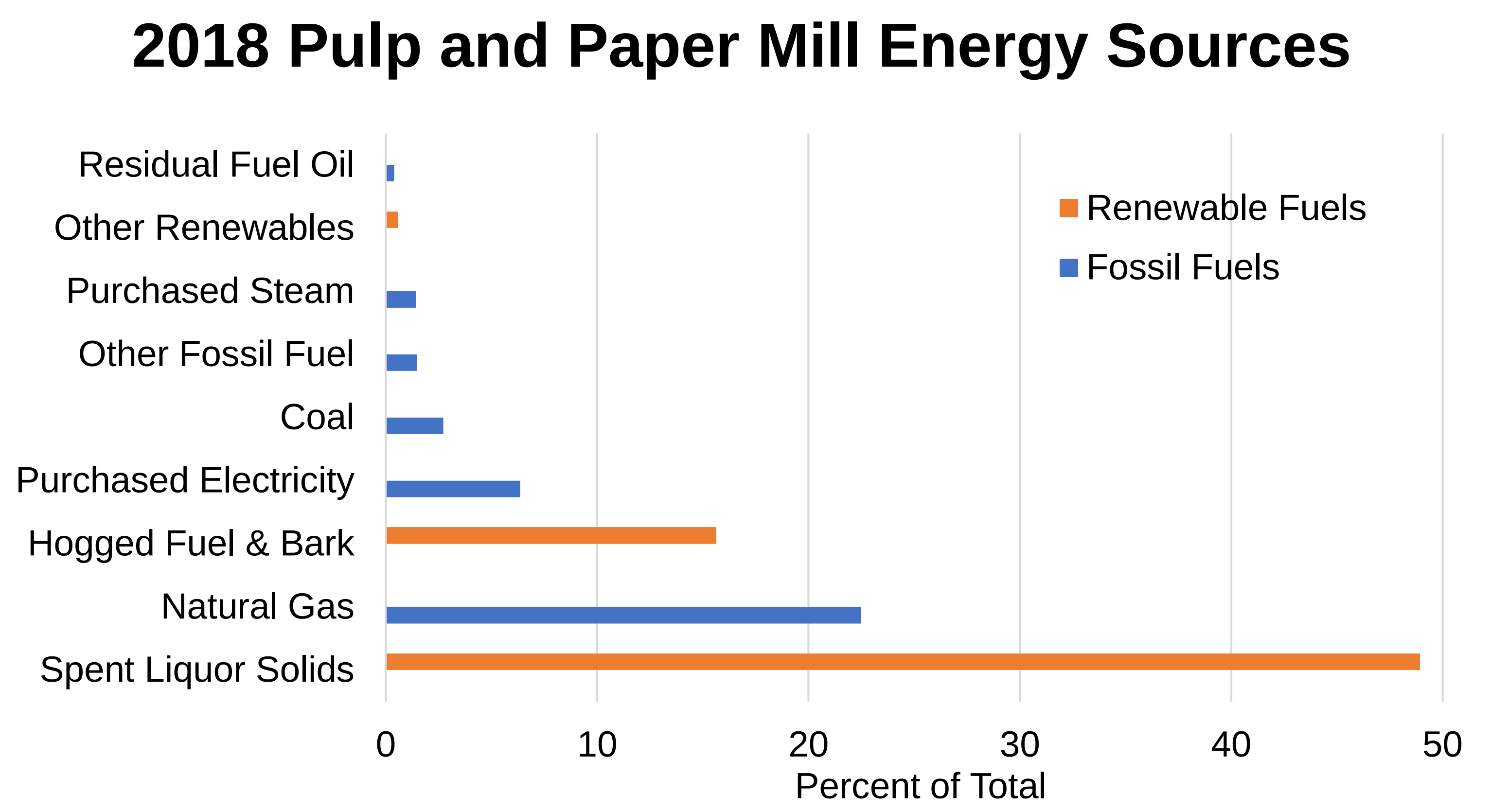
- AF&PA—For members in 2018
- U.S. Government—As indicated



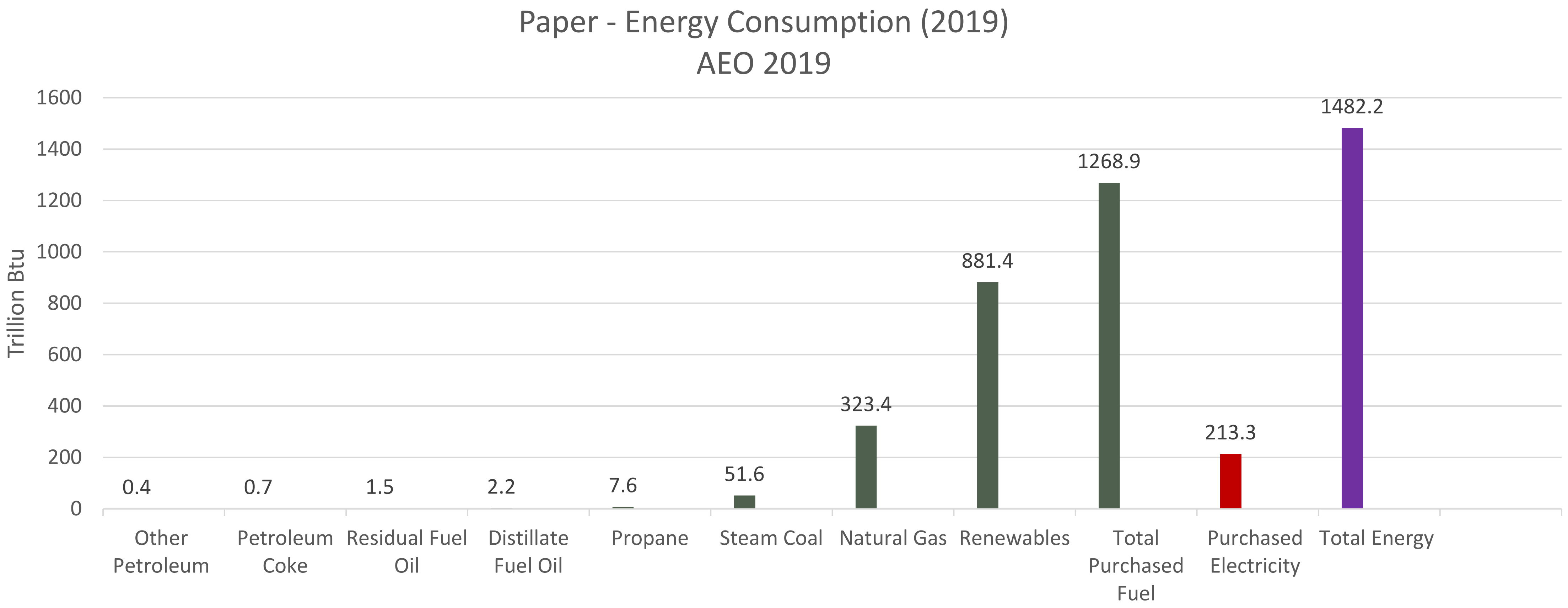
American Forest & Paper Association

# Pulp and Paper Mill Energy Sources—AF&PA Members

## Meet About 2/3 of Overall Energy Demand with Carbon Neutral Biomass



# *Paper Industry Energy Consumption*



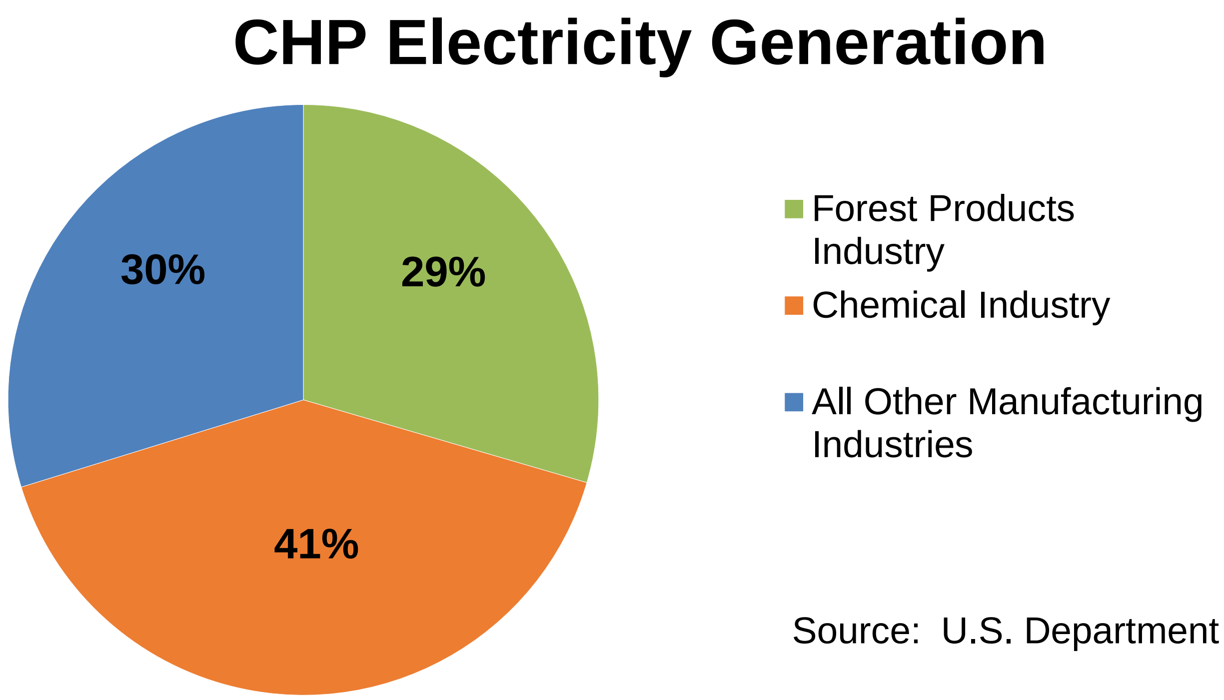



American Forest & Paper Association

# *Combined Heat & Power (CHP) Electricity Generation*

98.9% of electricity produced in 2018 by the paper and wood products industry was generated using CHP technology

29% of industrial CHP was generated by the paper and wood products industry




Source: U.S. Department of Energy



American Forest & Paper Association

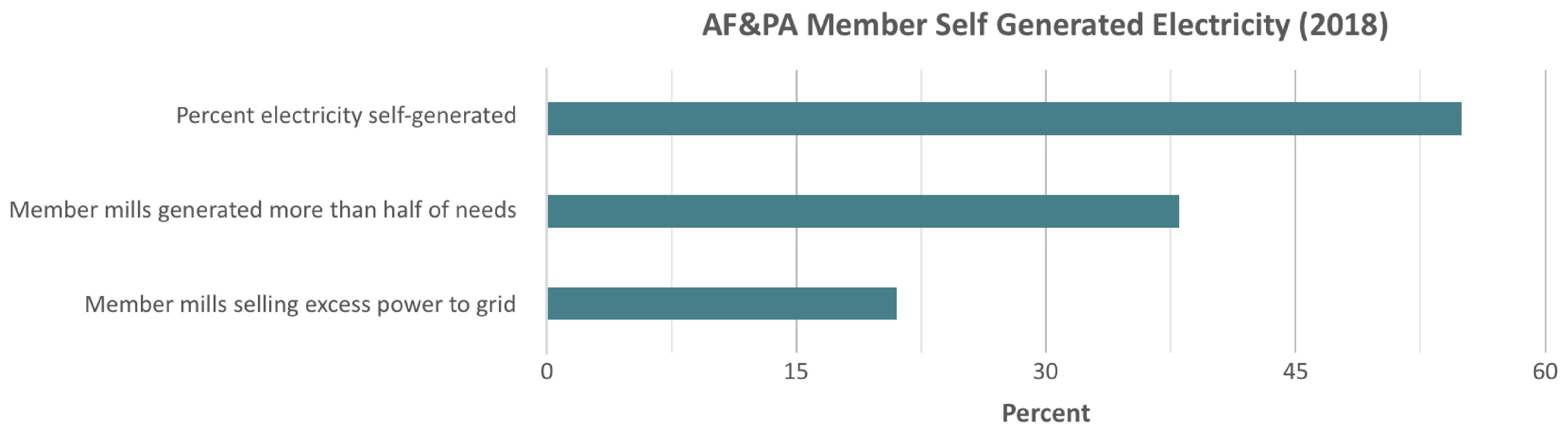
# AF&PA Member CHP Capacity

- About 300 units (note one facility can have more than one generator).
- Range:  from less than 1 MW to about 90MW
- Median: 22 MW
- Average: 26 MW

# *CHP Benefits*

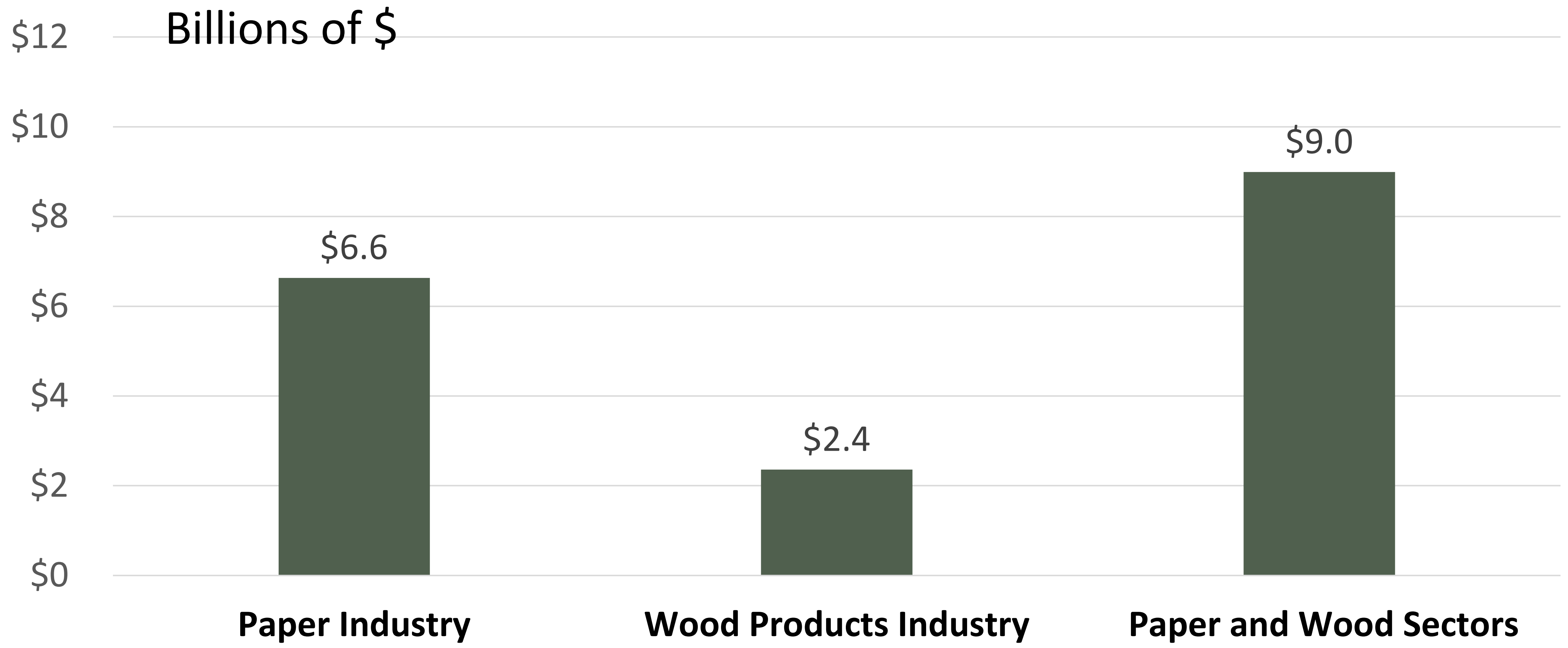
- Power is byproduct for industrial CHP; main product for other QFs
- Integral to pulp and paper manufacturing
- CHP provides benefits to society through higher efficiency, lower emissions, resilience,  transmission relief (distributed generation), more competitive manufacturing and jobs

# AF&PA Pulp And Paper Mills Self-generated 55% Of Electricity Needed To Power Mills In 2018



# *Annual Energy Expenditures - 2018*

`



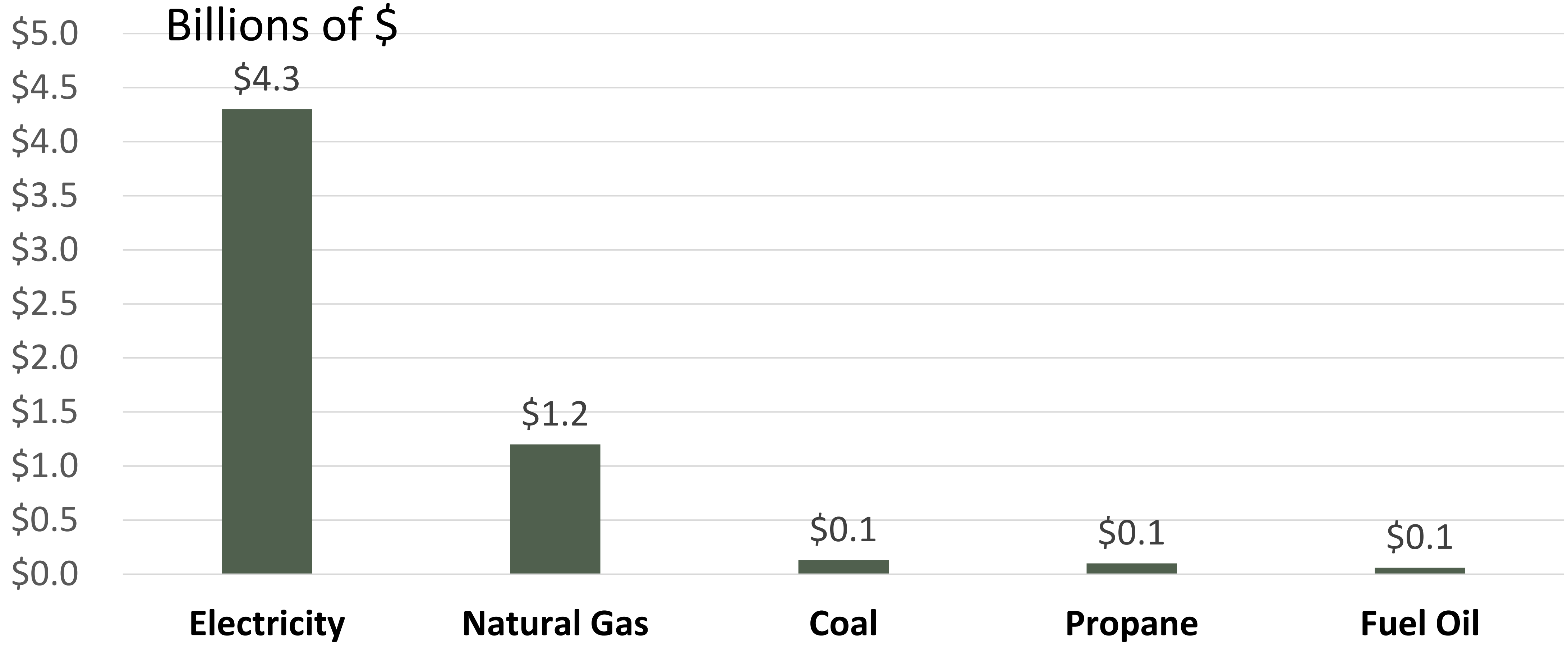

Source: Annual Survey of Manufactures



American Forest & Paper Association

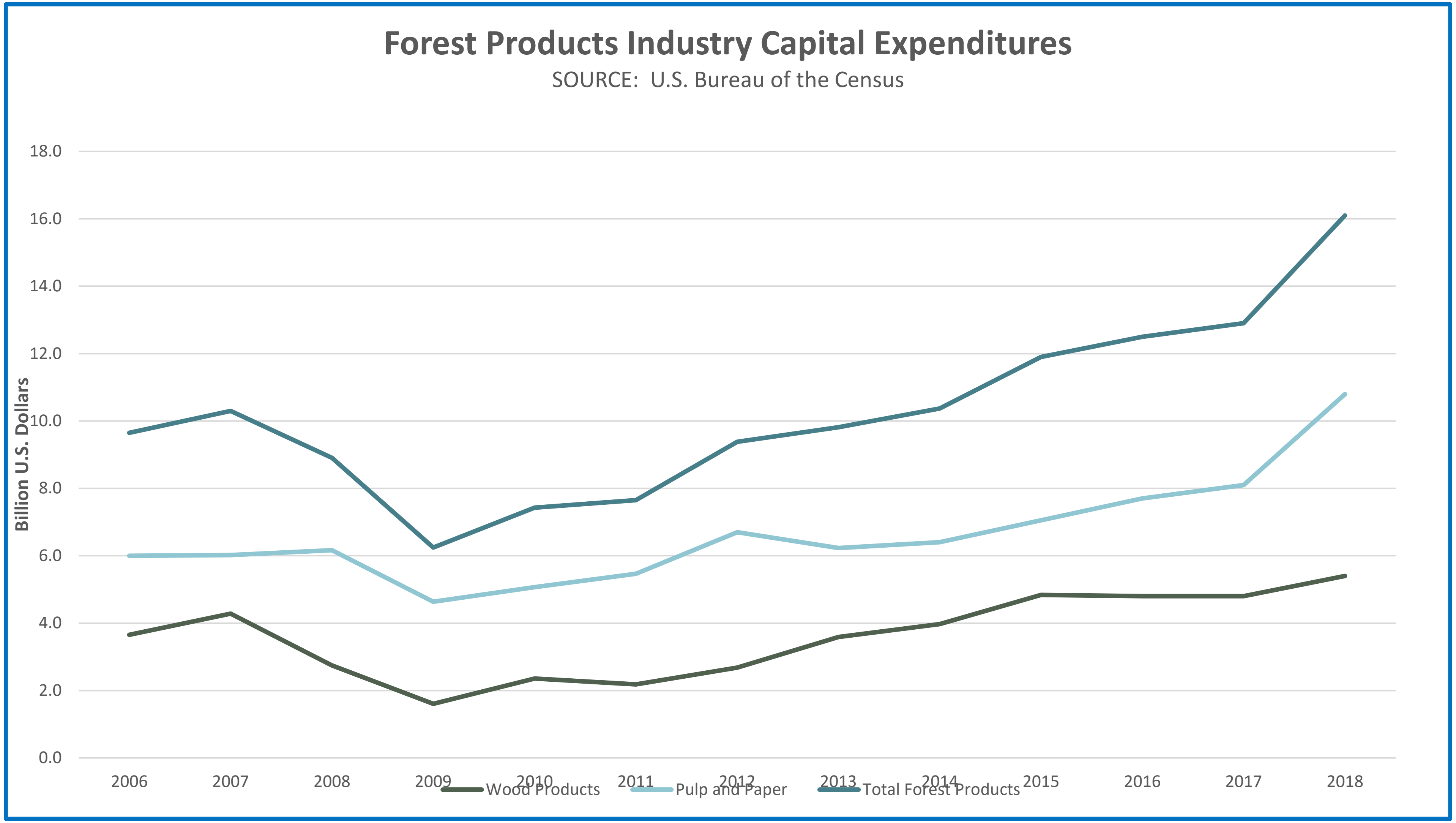
# Paper Industry Energy Expenditures by Category

`




Source: Estimated based on 2019 Energy Information Administration data

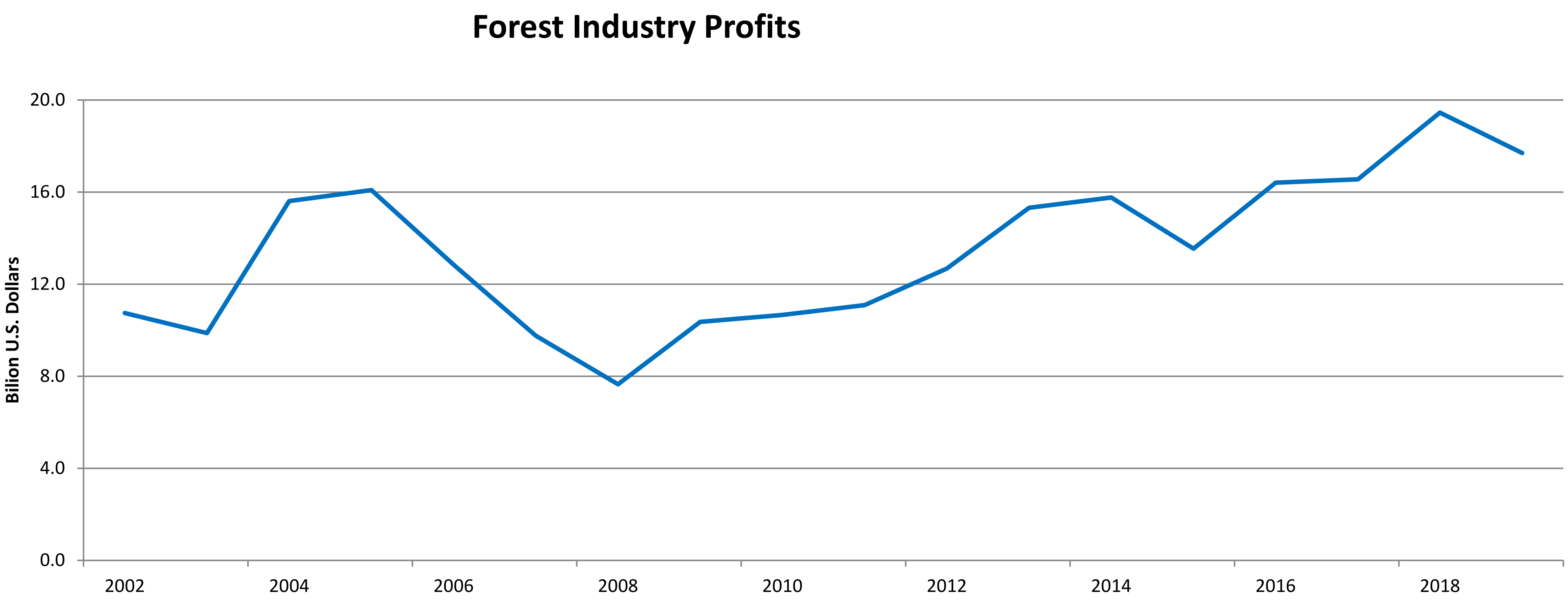
# Economics-Capital Expenditures






American Forest & Paper Association

# *Economics-Profits*

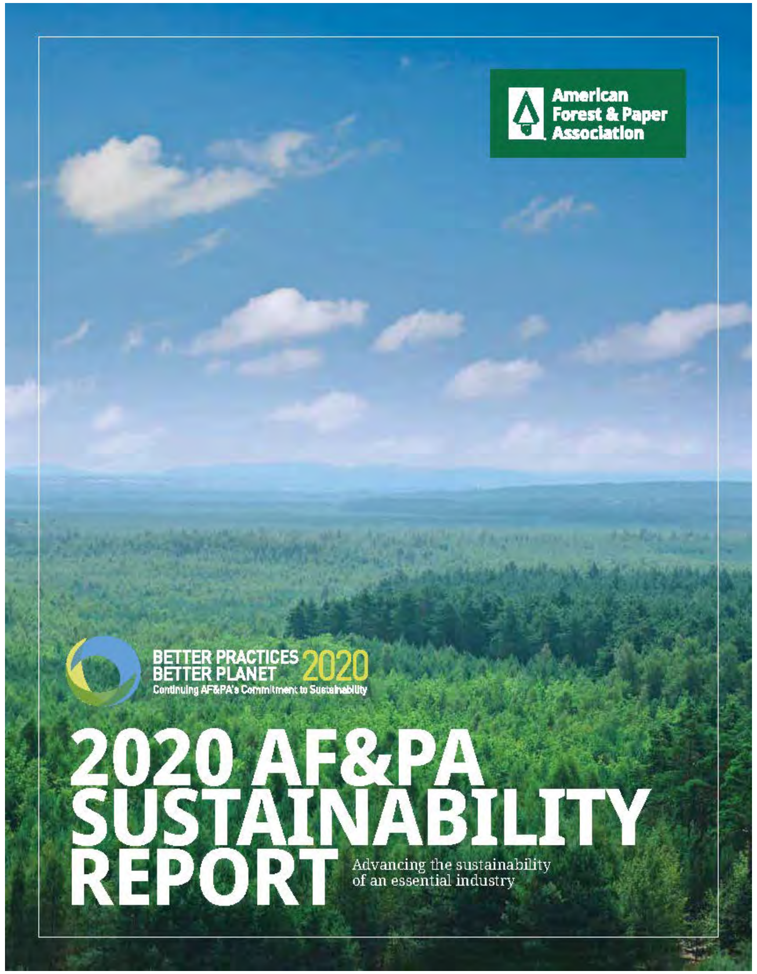



Source: Quarterly Financial Report (QFR)
Manufacturing, Mining, Trade, and Selected Service Industries

# *Industry Needs v Initiative Key Attributes*

- Economic
- Standardized
- Installed
- Unattended
- Reliable

# Better Practices, Better Planet 2020




## PROGRESS BY THE NUMBERS

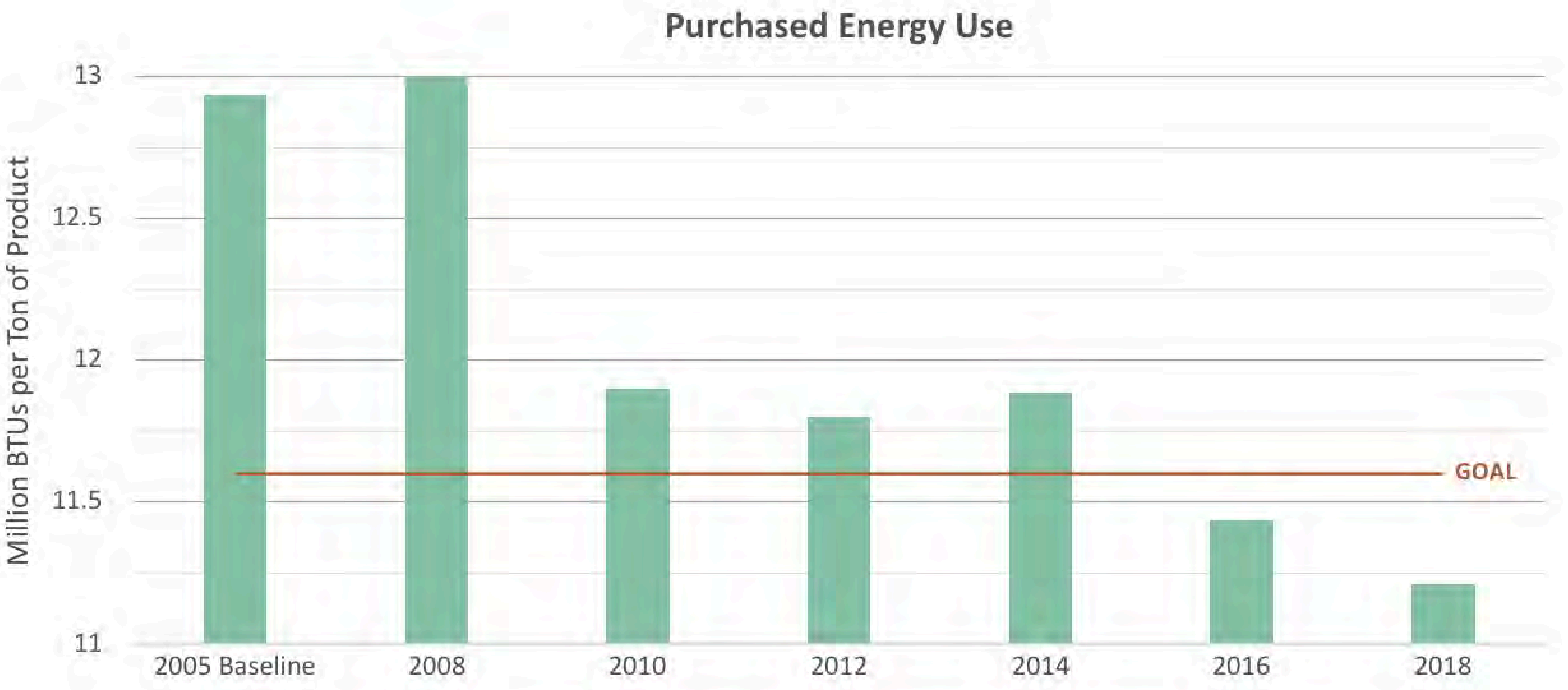
| AF&PA Sustainability Goal | 2018 Performance* | Baseline (2005*) | Progress from baseline year |
|---|---|---|---|
| Improve safety incidence rate by 25%, while working to achieve zero injuries | 1.617 recordable cases per 200,000 hours worked | 2.625 recordable cases per 200,000 hours worked (2006) | 38.4% improvement in recordable incidence rate GOAL SURPASSED |
| Increase wood fiber procurement from certified forestlands and certified fiber sourcing programs; decrease illegal logging | 99% from certified fiber sourcing programs; 28.1% from certified forestlands | 87% from certified fiber sourcing programs; 23% from certified forestlands | 12 percentage point improvement from certified sourcing programs; 5.1 percentage point improvement from certified forestlands GOAL ACHIEVED |
| Improve purchased energy efficiency by at least 10% | 11.21 million BTUs per ton of product | 12.94 million BTUs per ton of product | 13.3% decrease in purchased energy GOAL SURPASSED |
| Reduce greenhouse gas emissions by at least 20% | 0.636 ton $CO_2$eq per ton of product | 0.828 ton $CO_2$eq per ton of product | 23.2% decrease in GHG emissions GOAL SURPASSED |
| Reduce pulp and paper mill water use by at least 12% | 10,503 gallons per ton of product | 11,281 gallons per ton of product | 6.9% reduction in water use |
| Exceed 70% paper recovery for recycling | 66.2% (2019) | 51.5% | 14.7 percentage point increase in paper recycling rate |

** unless otherwise indicated*



American Forest & Paper Association

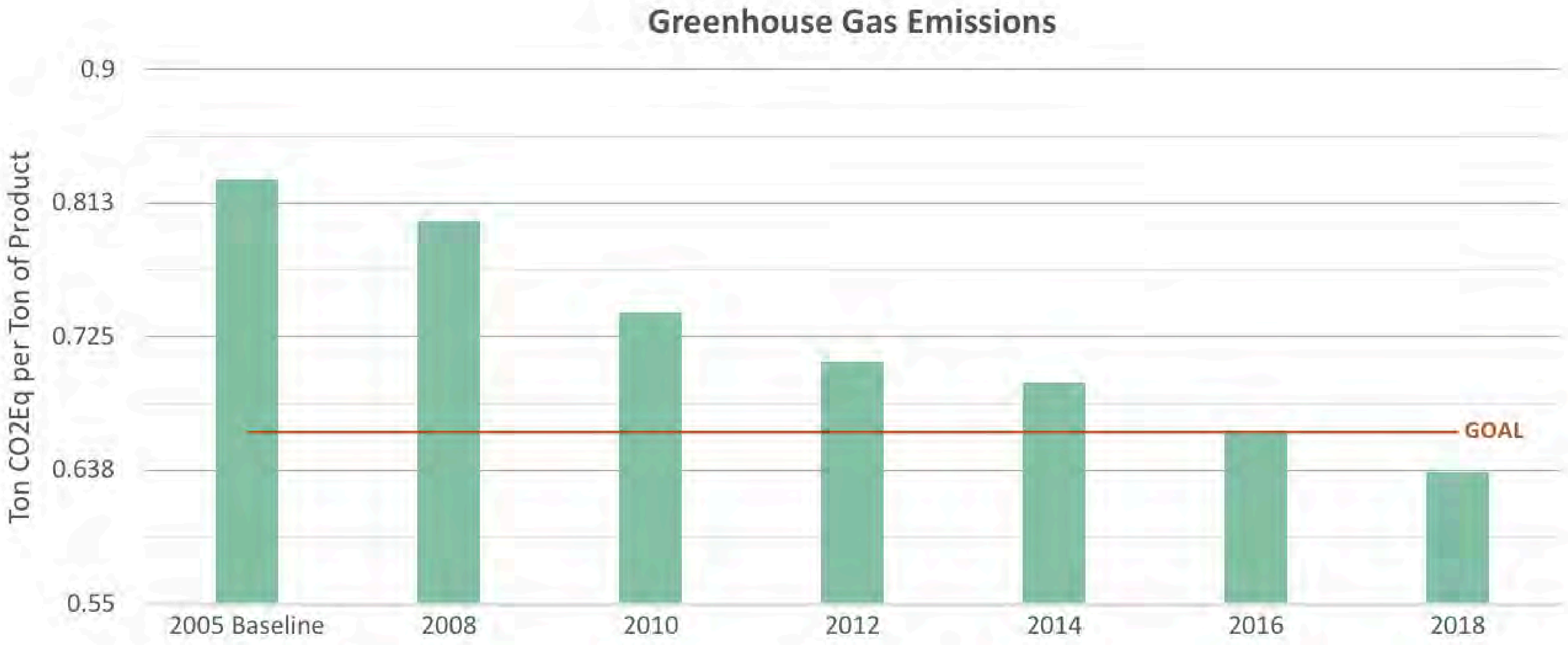
# Energy Efficiency: 13.3% decrease in purchased energy (Goal Surpassed)






American Forest & Paper Association

# Greenhouse Gas Emissions: 23.2% reduction (Goal Surpassed)






American Forest & Paper Association

# Alliance for Pulp & Paper Technology Innovation

**Mission:**

- Promote development of advanced manufacturing technologies for the pulp and paper industry and platforms to enable new revenue streams from forest-based biomass

| Identify | Communicate | Deliver |
| --- | --- | --- |
| • Technology needs<br>• R&D priorities | • Funding entities<br>• Solution providers | • Projects<br>• Partnerships |

# *Next-Generation Pulping*

**Goal** **Reduce total energy 25%. Increase yield 5 percentage points.**

Value $900 MM, Energy 70 trillion BTU
($6MM/yr 1000 tpd mill)

# Black Liquor Concentration

**Goal** **Develop a more energy-efficient method to remove water from kraft black liquor**

Value $95 MM, 23 trillion BTU ($2-3 MM per year for a 2,000 tpd mill)



*Transforming Manufacturing Through Innovation*

American Forest & Paper Association

# *Drier Web before Dryer Section*

**Goal** **Increase dryness of paper webs entering dryer section by ~ 30%** ***(from 45-55% up to 65%)***

Value $250 MM, 80 TBTU



*Transforming Manufacturing Through Innovation*

# *Reuse of Process Effluents*

**Goal** **Reduce average water usage by half**

Value ~ 5K gal/ton, >$300MM, 45 TBTU, 480B Gal



*Transforming Manufacturing Through Innovation*

American Forest & Paper Association

# *2050—Industrial Decarbonization*

2030 Goals

2050?

# American Forest & Paper Association

BETTER PRACTICES
BETTER PLANET 2020
Continuing AF&PA's Commitment to Sustainability

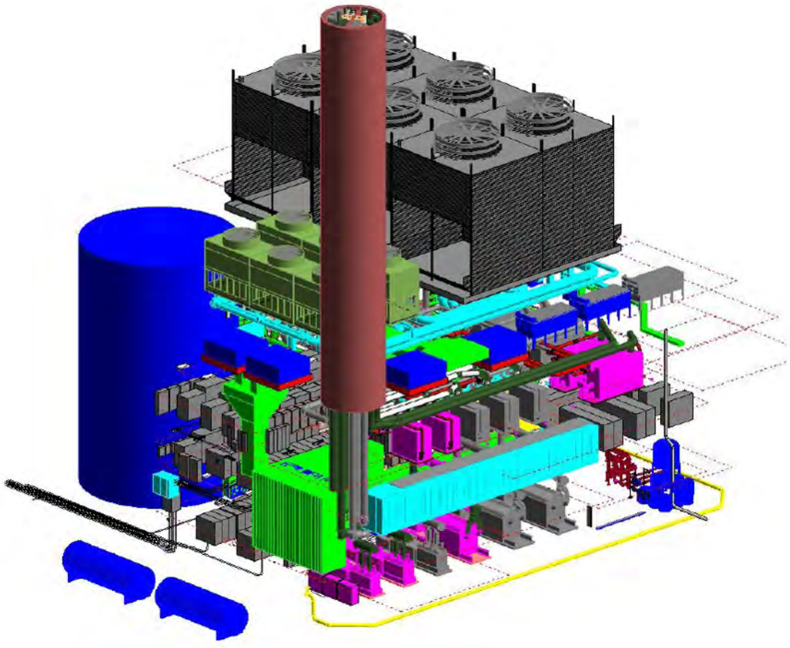
# BUSINESS MODELS, FINANCING MODELS

**JOHN PARSONS**
January 27, 2021
Fission Battery Initiative Workshop, INL

# WHO WILL BUY A NUCLEAR BATTERY?

# CAN MULTIPLE USERS SHARE AN ASSET?

# Harvard’s New District Energy Facility



# City of Boston – Major Parcel Development

**7 years ago, new district heating systems were a part of Boston's climate plan.**



**No longer. Fear of stranded NG asset.**
**But also…developer opposition to central sys.**

# Central AC is More Efficient, but…

# Why is One a Campus and Not the Other?

**It's not because one is a university.**



**Boston has a medical campus with a district heating system.**

# On the other hand…

# OWNERSHIP AND FINANCING ARE ADAPTABLE TO OPERATIONAL CONTEXT

# Project Financing: Carlsbad Desalination Plant

- $1 billion investment
- 82% debt financed
- County water authority pays for the plant on an installment plan

- The asset is dedicated and cannot be repurposed.

# Ownership is Flexible: Battery Installations


- Owned by special purpose entity--financier.
- Managed by specialist company.
- Hosted by building owner.
- Utility pays a fee.

# THANK YOU