



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

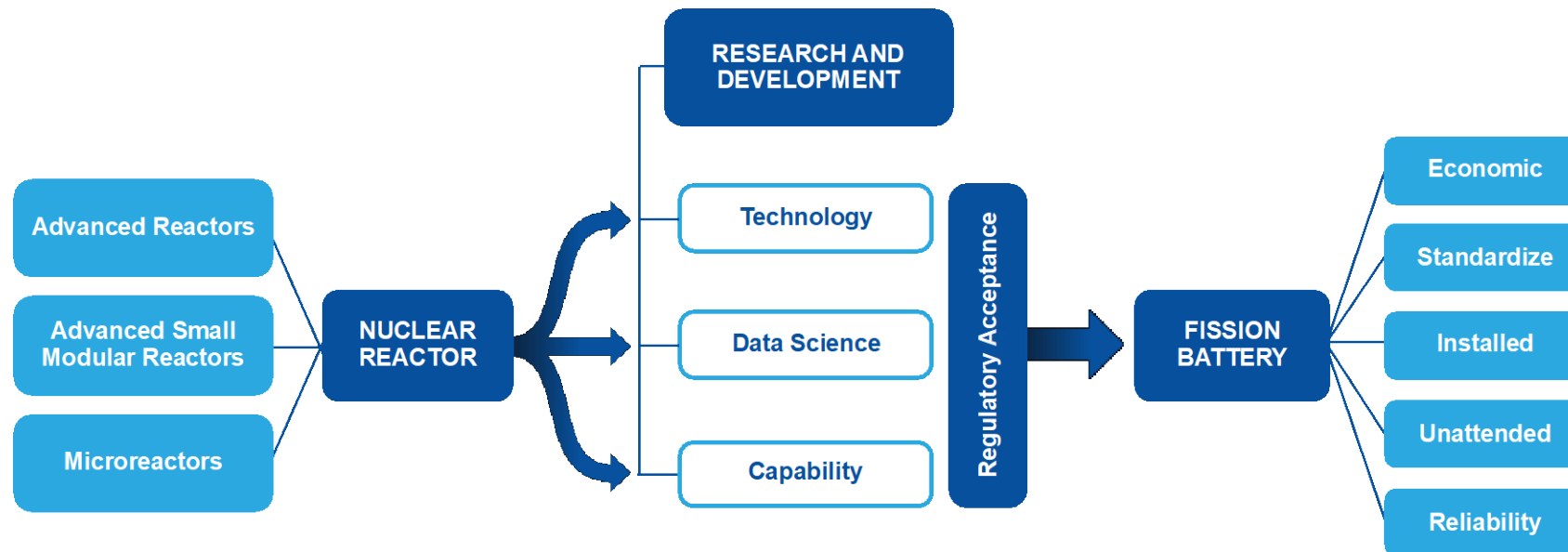


Idaho National Laboratory

Fission Battery Initiative

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

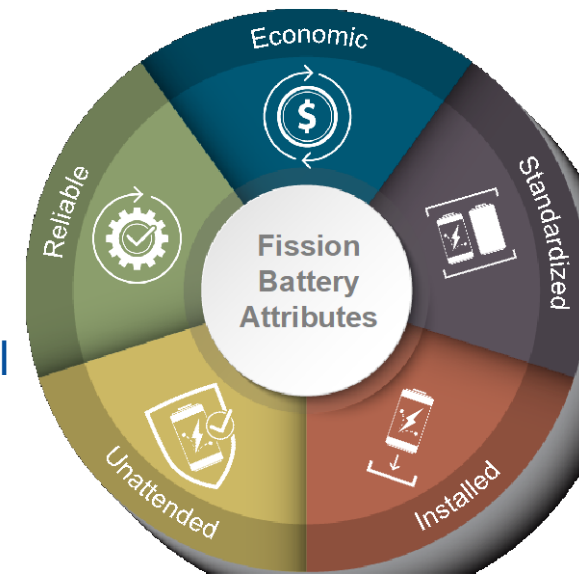
Outcome: Deliver on research and development needed to provide technologies that achieve key fission battery attributes and expand applications of nuclear reactors systems beyond concepts that are currently under development.



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 five 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



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



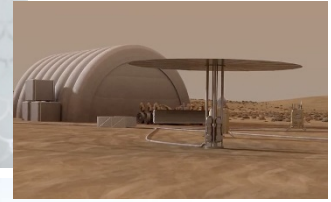
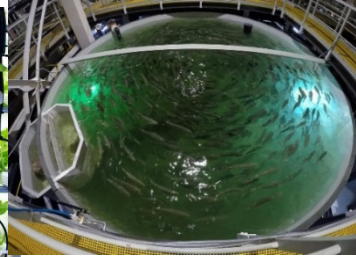
NSE
Nuclear Science
and Engineering

science : systems : society

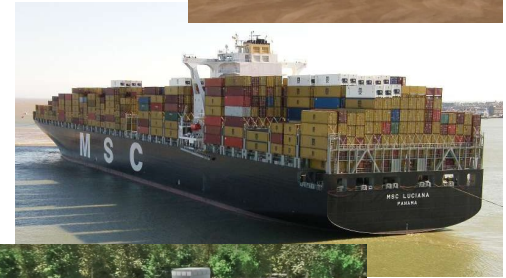
OBJECTIVES

- 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).

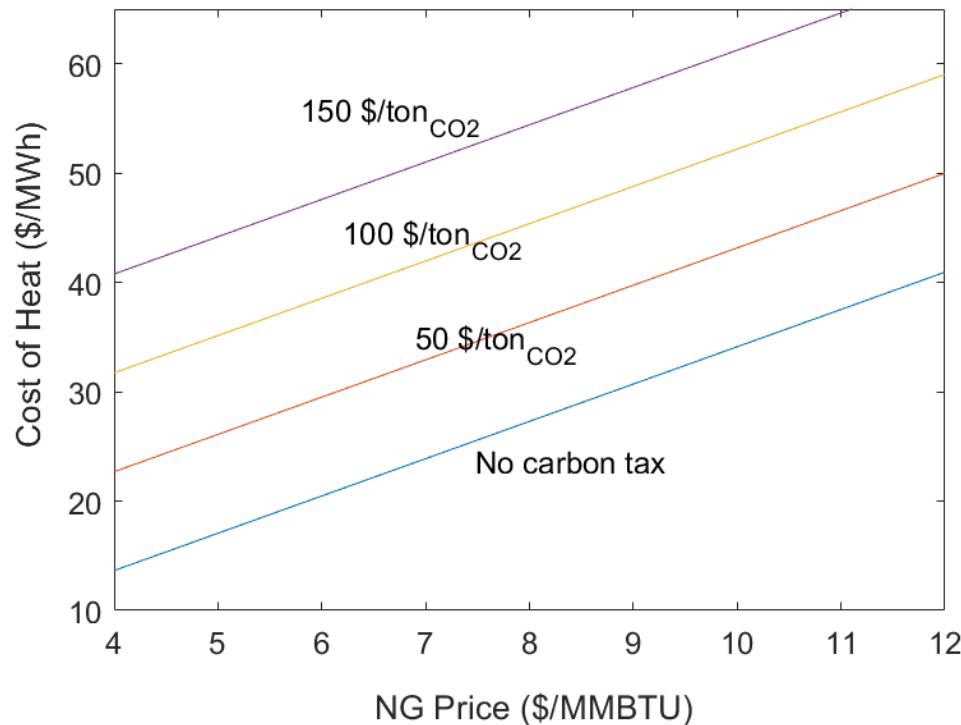
US Electricity Retail Prices 2019 (\$/MWh) (includes generation, transmission, distribution)

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 CO₂ 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 ₃ O 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

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

[\$/MWh]

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

[\$/MWh]

Baseline case results:

LCOE = 71 \$/MWh

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

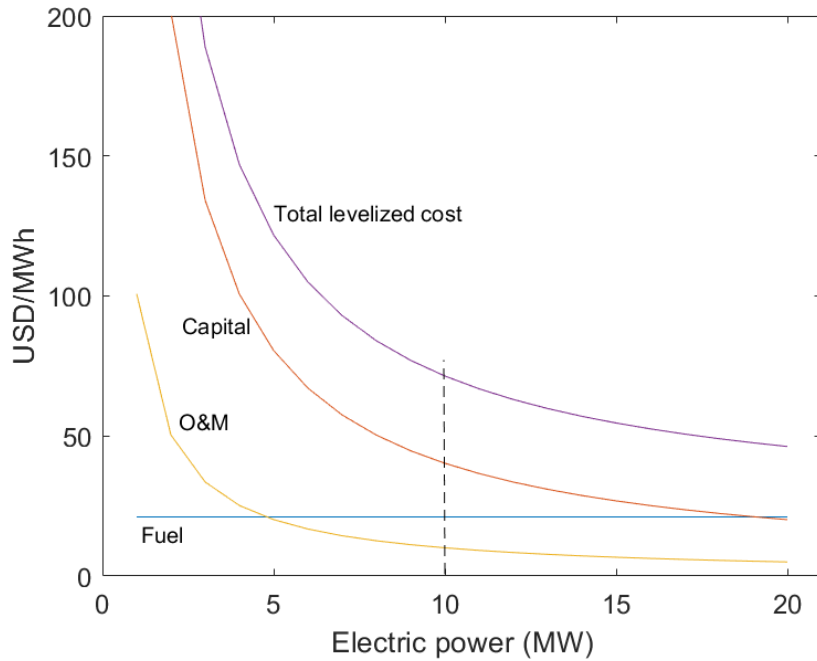
Depending on specific applications and business models, NB will be used for electricity only, heat only or cogeneration, requiring more sophisticated FOMs than LCOE and LCOH

LCOE PARAMETRIC STUDY

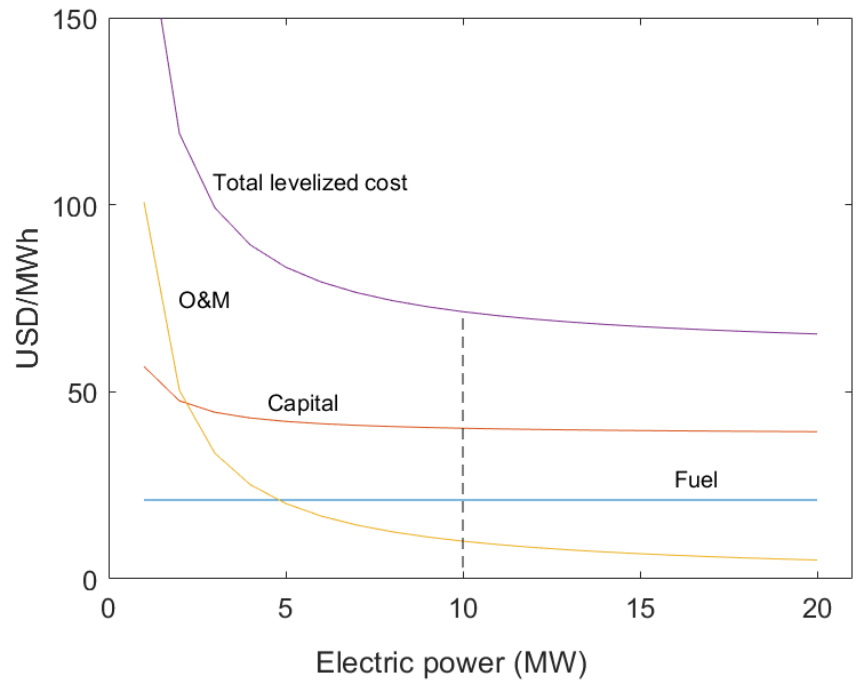
Parameters varied one at a time:

- 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



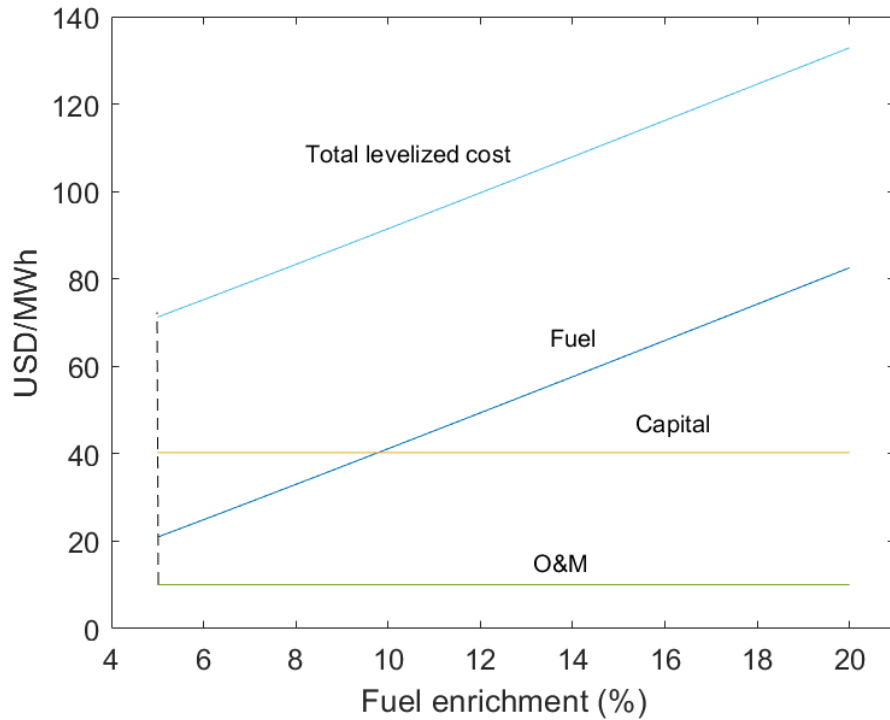
Zero scaling
(fixed fabrication cost, \$)



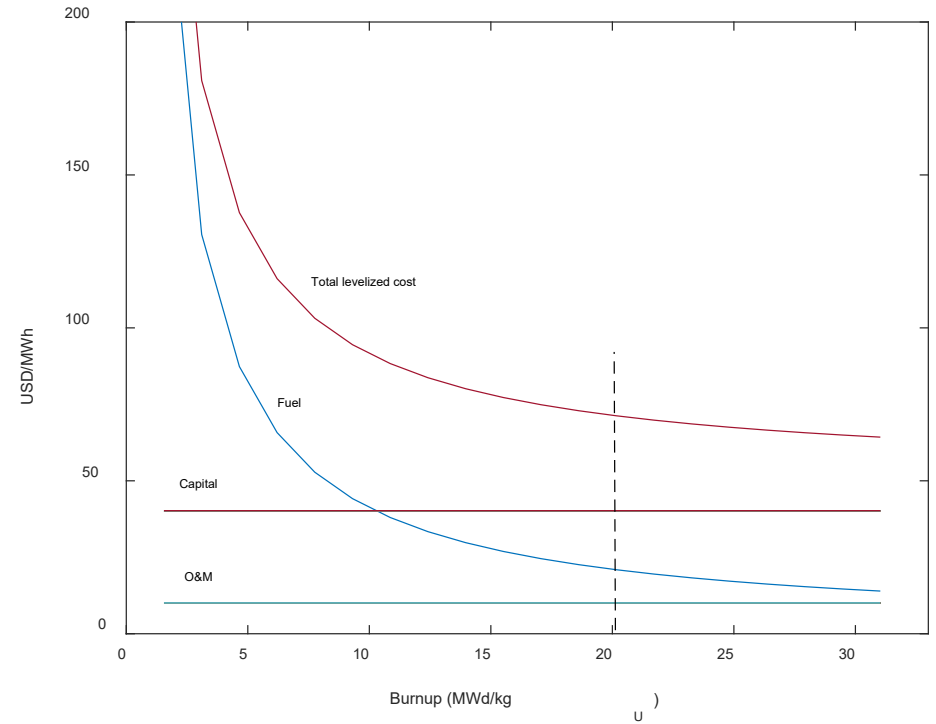
Linear scaling
(fixed *specific* fabrication cost, \$/kW)

Economy of scale applies also to micro-reactors!

THE EFFECT OF FUEL PARAMETERS

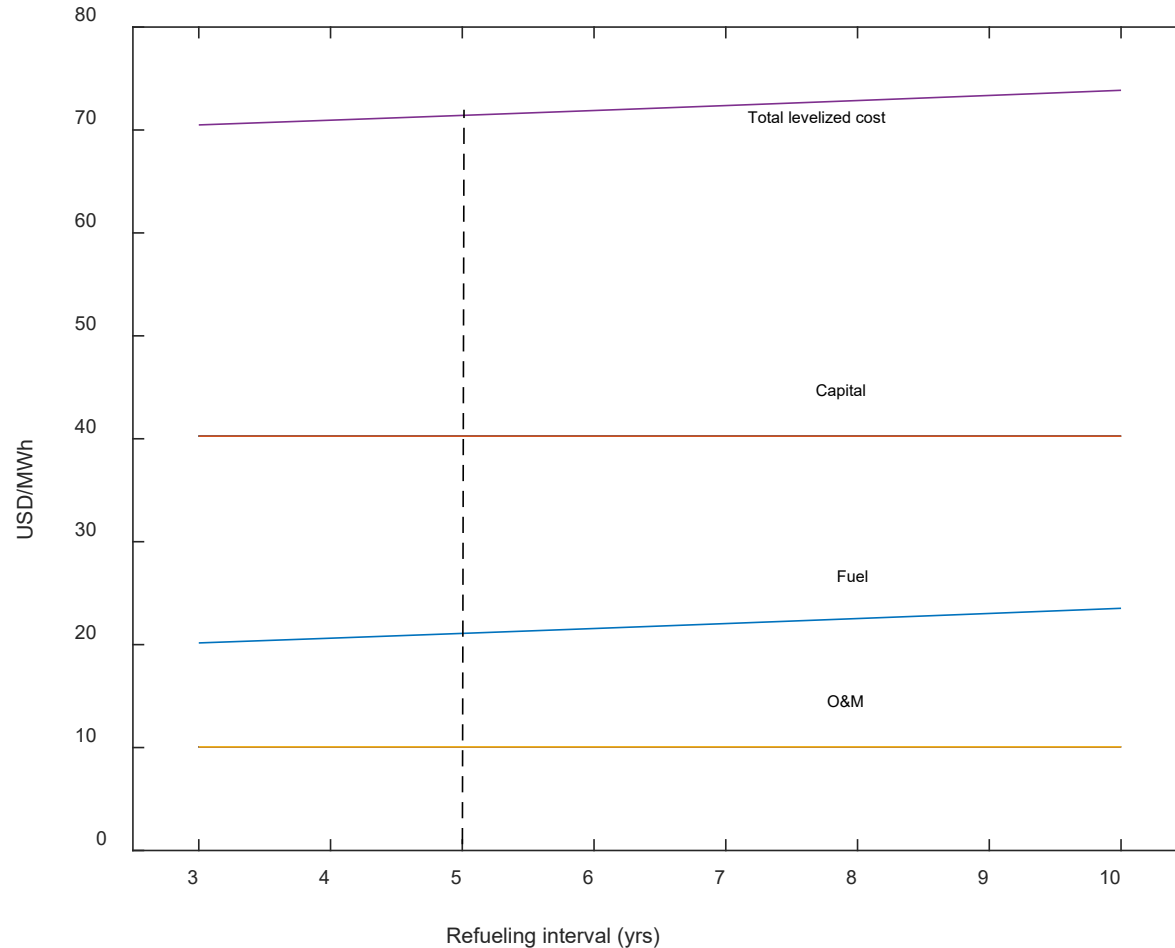


>5% enrichment requires relicensing of U.S. fuel cycle facilities



Fuel costs can quickly become unreasonable

THE EFFECT OF REFUELING INTERVAL

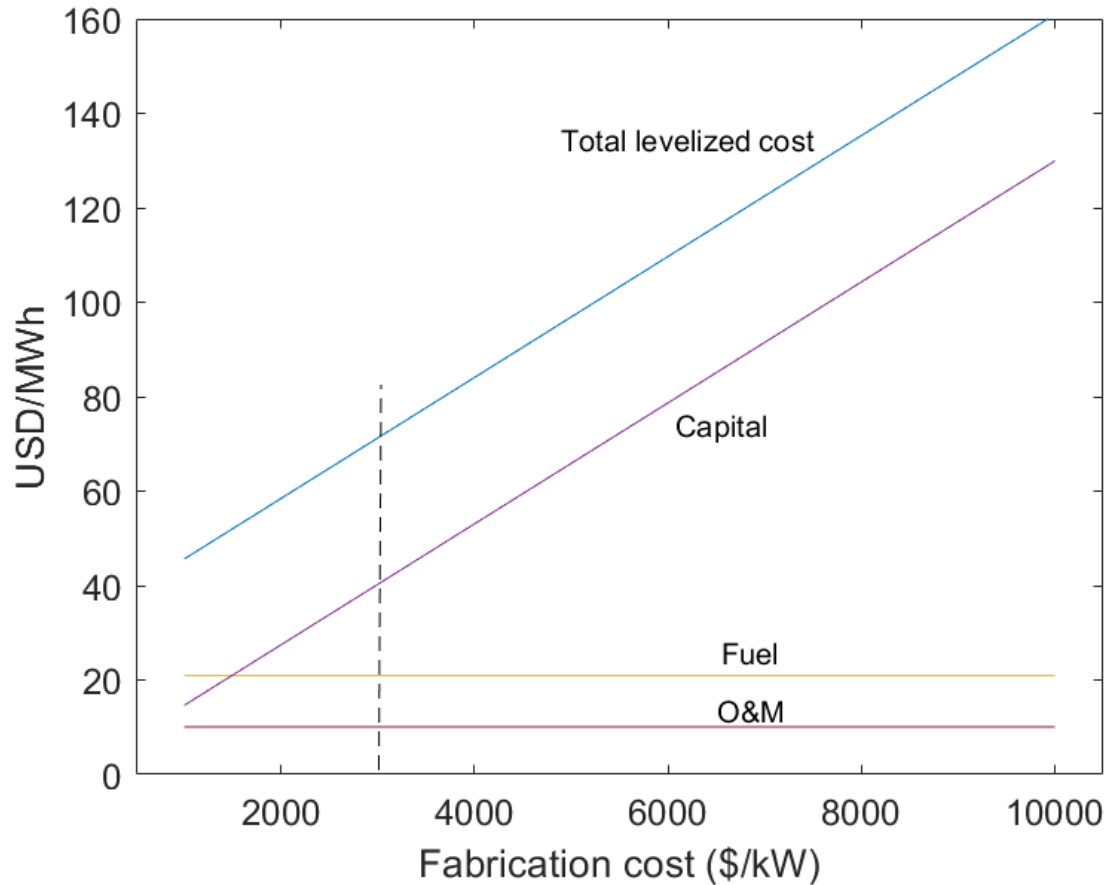


⇐ High power density

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

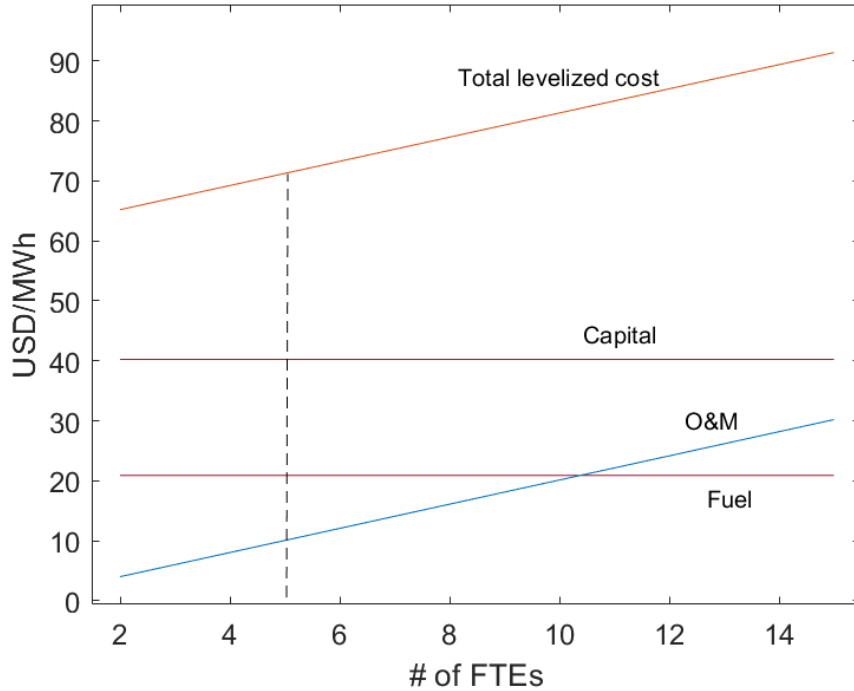


Fabrication cost makes a big difference, as expected

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.

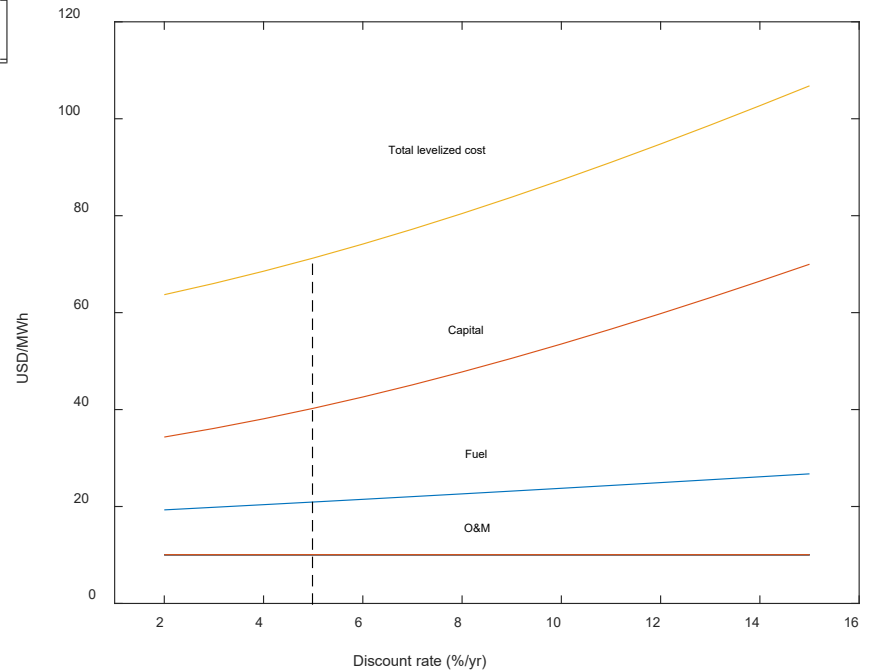


THE EFFECT OF STAFF SIZE AND DISCOUNT RATE



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.

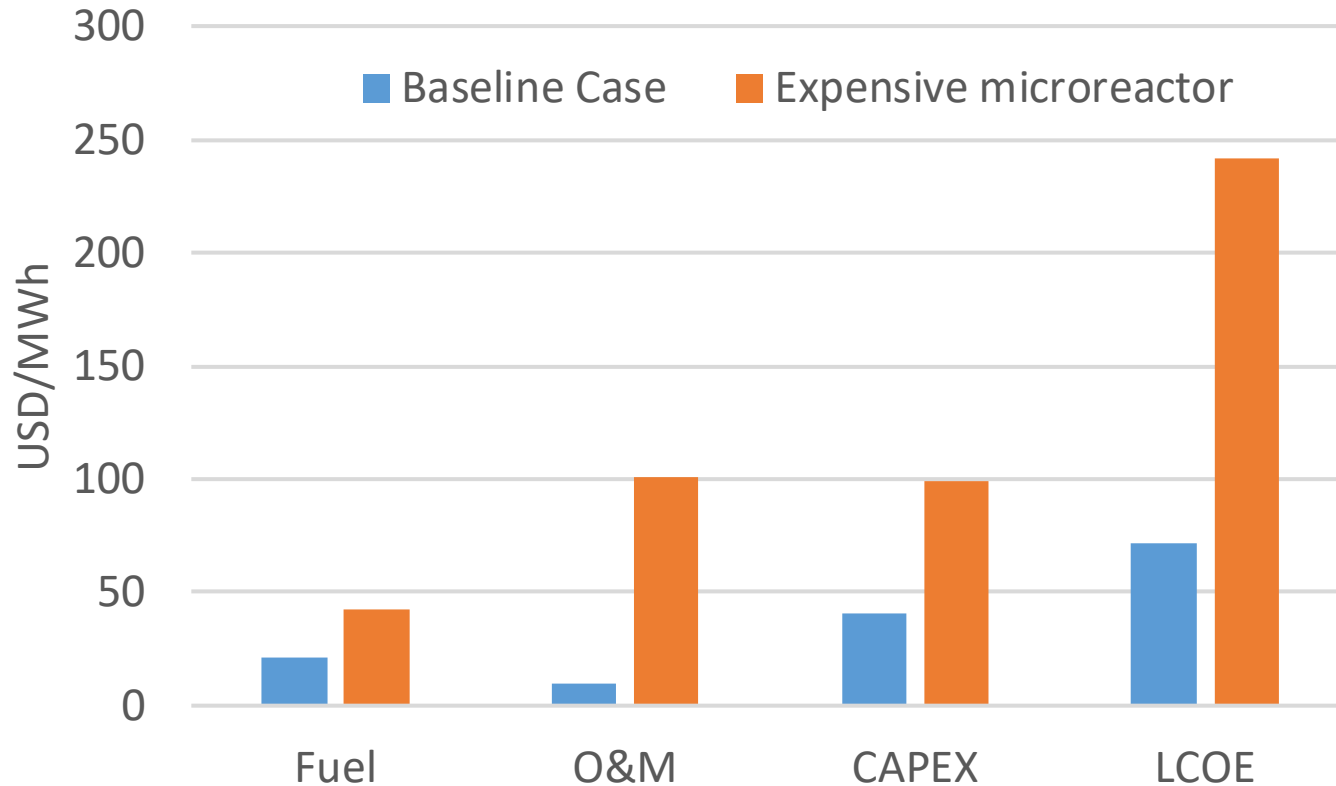


COST CAN EASILY GET OUT OF HAND

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 m² 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) \neq 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

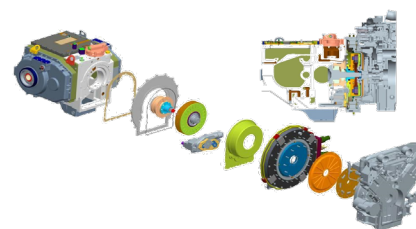


Capability Priorities:

- 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

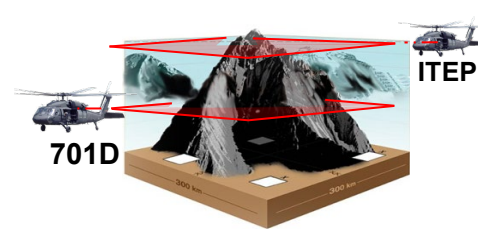


Capability Priorities:

- 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



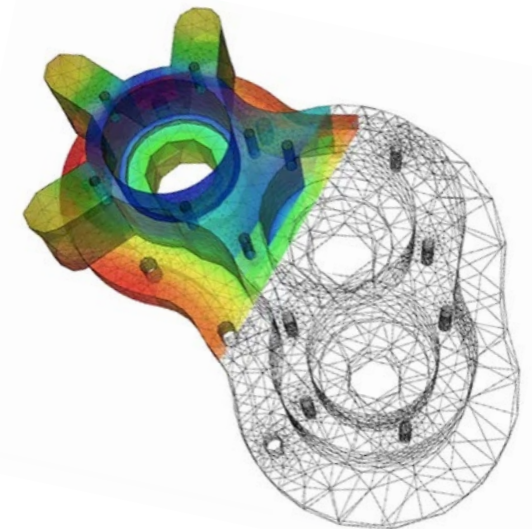
Microgrids

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

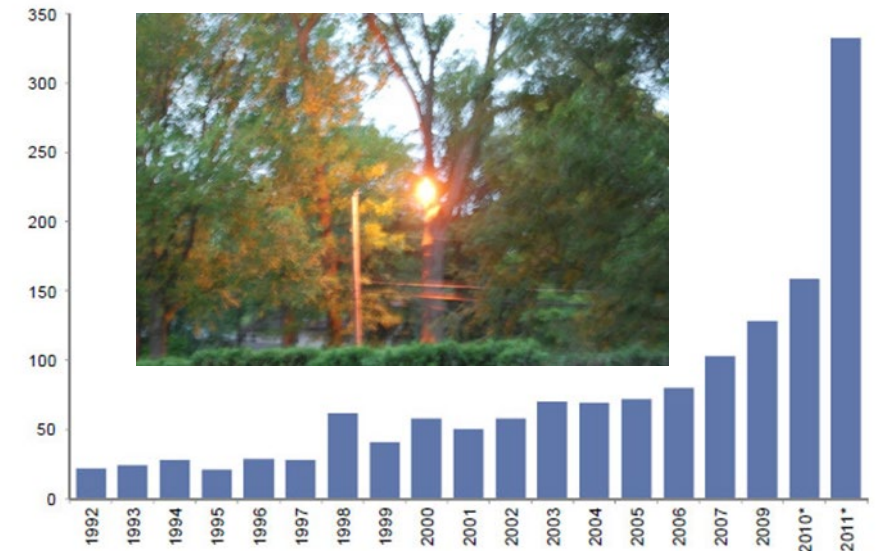


Improvise!

Why resurrect Resilience?

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

Power outages have risen sharply over the last decade
Major power disturbances in North America



Note: * NERC equivalent data estimated based on the trends seen in the Eaton Blackout tracker for number of outages affecting over 50,000 people.
Source: NERC, Eaton Blackout Tracker, Goldman Sachs Research estimates.

Illustration – Fukushima tsunami



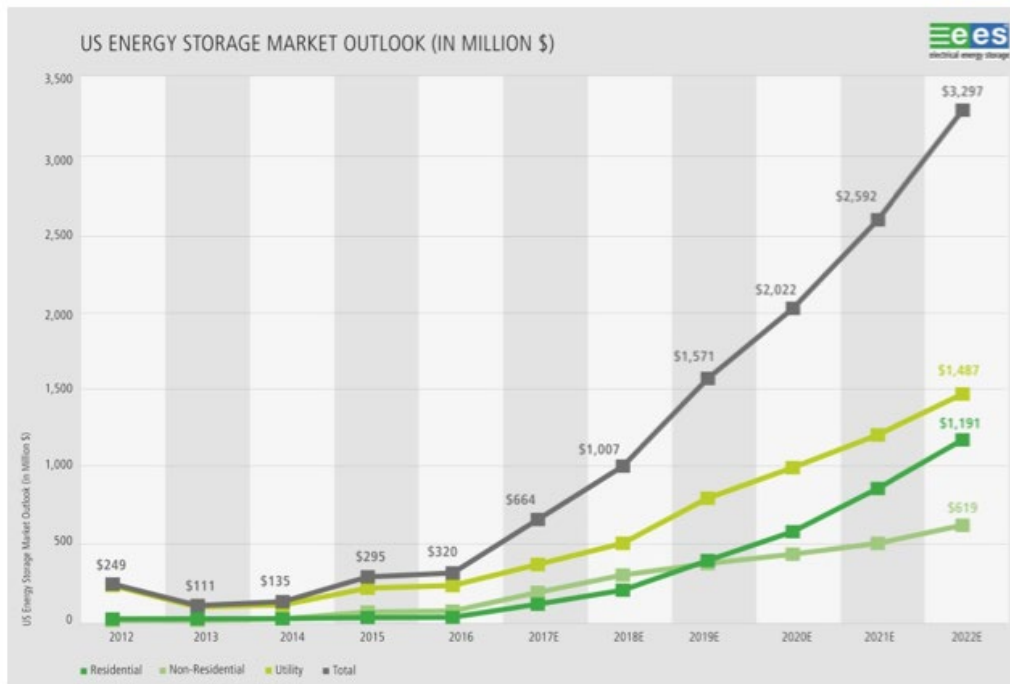
- Complex system
- Single-point vulnerabilities
- Extraordinary consequences
- Mitigated by operator initiative

Illustration – Puerto Rico hurricane



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

Indicators of change



Impact Analysis of COVID-19

Industrials
The Industrials sector will see **NEGATIVE** impact due to COVID-19 outbreak and is expected to register at Par growth rate compared to the global GDP growth

Market Impact
This market will have **POSITIVE IMPACT** due to the spread of COVID-19

Pandemic Impact on Market
INDIRECT

Global Microgrid Market 2020-2024

Market growth will **ACCELERATE** at a CAGR of almost **13%**

Incremental growth
USD 18.89 bn

Growth for 2020
12.34%

IMPACT Market growth in 2020 likely to **INCREASE** compared to 2019

Expected time by when the impact on market will normalize

Q3-2021 [Best Case]

Q1-2022 [Worst Case]

Market estimates to be revisited and updated in Q3-2020, based on the revaluation of the impact as the pandemic spread plateaus. The update will be available free of cost to all customers.

technavio

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	<i>Develop specific measures based upon system/objectives</i>			
Cognitive				
Social				

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

pillsbury

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

PILLSBURY NUCLEAR.

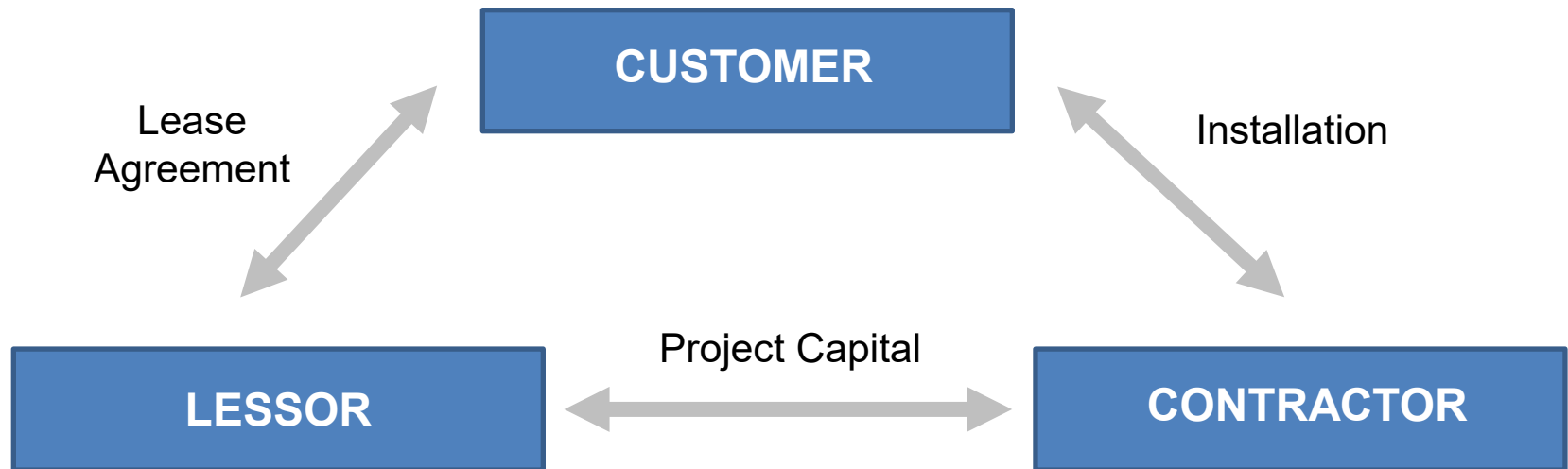
50 years advising the nuclear industry. 20 dedicated nuclear lawyers. 360° advice on nuclear projects.

AUSTIN BEIJING HONG KONG HOUSTON LONDON LOS ANGELES MIAMI NEW YORK N. VIRGINIA PALM BEACH
SACRAMENTO SAN DIEGO SAN FRANCISCO SHANGHAI PALO ALTO TAIPEI TOKYO WASHINGTON DC



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

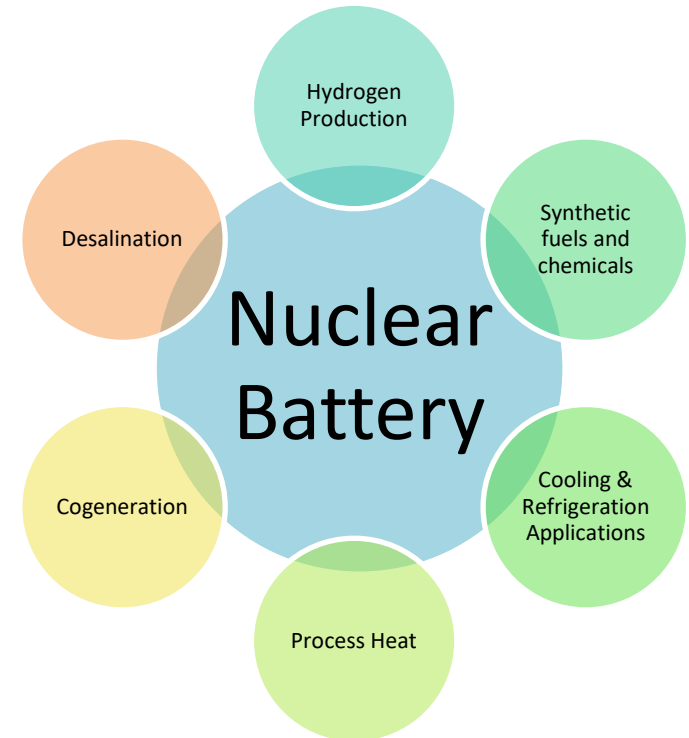


Type of Lease	Key Aspects
Capital or Finance Lease (similar to bank loan)	<ul style="list-style-type: none">• Customer owns equipment, lessor takes security interest• Equipment = asset, lease payments = liability<ul style="list-style-type: none">• Customer can depreciate the equipment as an asset to provide a tax benefit• Customer can purchase equipment for discounted price at end of lease term
Operating Lease	<ul style="list-style-type: none">• Lessor owns equipment, customer rents at a fixed monthly payment• Rental payments = operating expenses, tax deductible• End of lease term -> customer can extend lease, purchase equipment for fair market value, or return equipment
Solar Lease	<ul style="list-style-type: none">• Similar to operating lease• Different options of down payment• 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



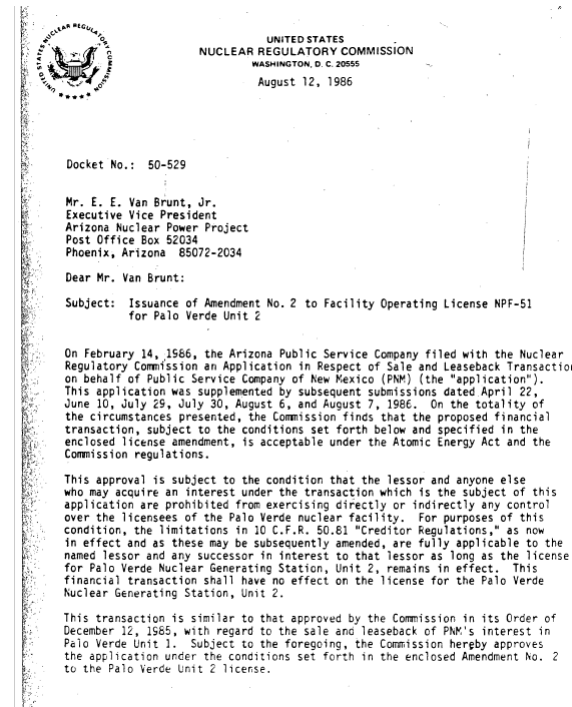
Feasibility of Leasing Nuclear Batteries

- **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.



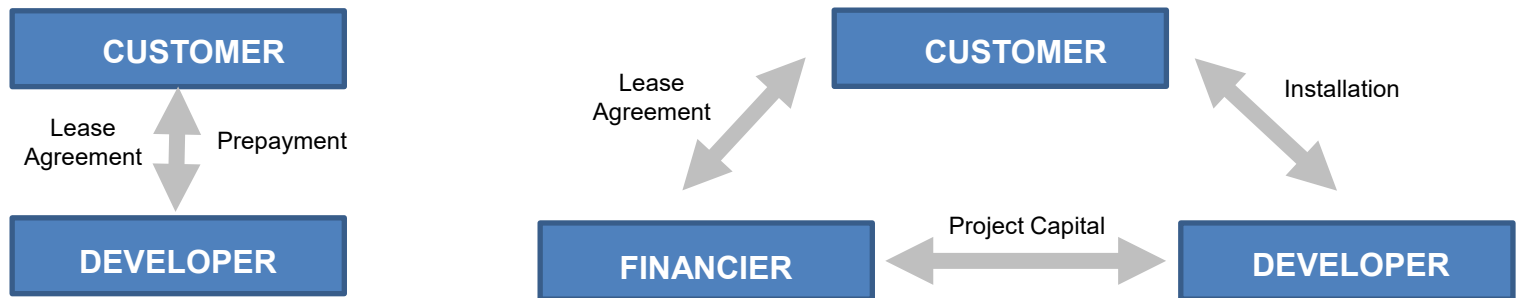
History of Regulation of Nuclear Leasing in the U.S.

- **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



Framework for Leasing

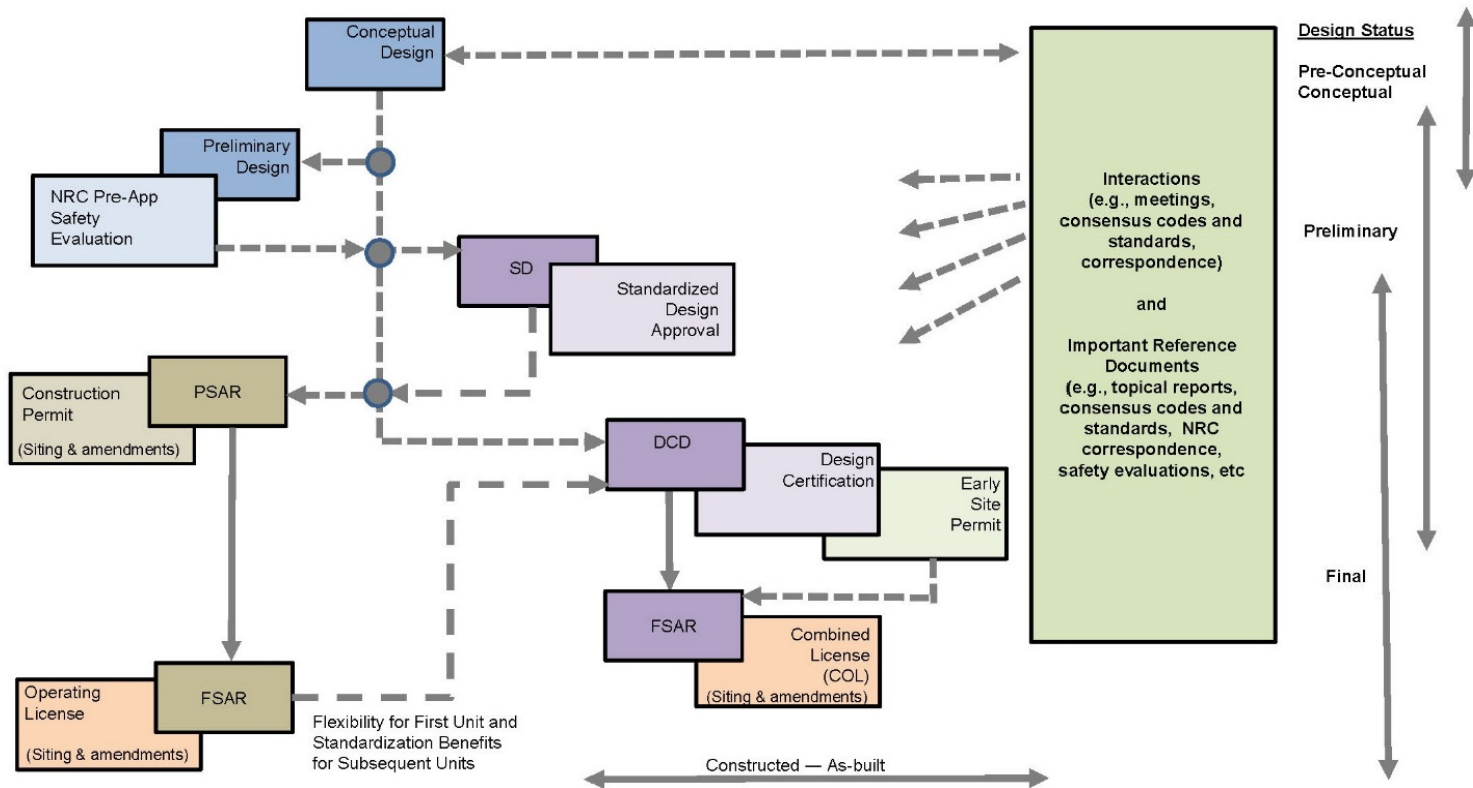
- Facility licensed and operated by project developer
- Easiest structure from NRC licensing perspective is operating lease – facility owner by developer, customer rents at fixed periodic payment
- Capital lease may be possible, but likely subject to significant NRC scrutiny – may not be compatible with 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



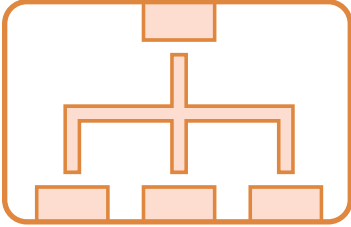
Licensing Challenge – Possible Solutions



- **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



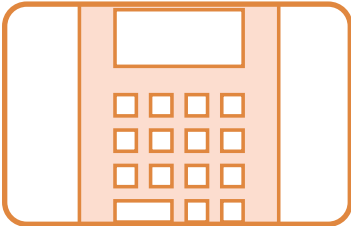
Omnibus coverage protects all who may be liable

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



Covers any legal liability 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

A photograph of a nuclear power plant cooling tower emitting steam, set against a clear sky and a body of water in the foreground.

- 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

pillsbury

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PILLSBURY NUCLEAR.

50 years advising the nuclear industry. 20+ dedicated nuclear lawyers. 360° advice on nuclear projects.

AUSTIN BEIJING HONG KONG HOUSTON LONDON LOS ANGELES MIAMI NEW YORK N. VIRGINIA PALM BEACH

SACRAMENTO SAN DIEGO SAN FRANCISCO SHANGHAI PALO ALTO TAIPEI TOKYO WASHINGTON DC



AF&PA's Energy Profile

January 27, 2020

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

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

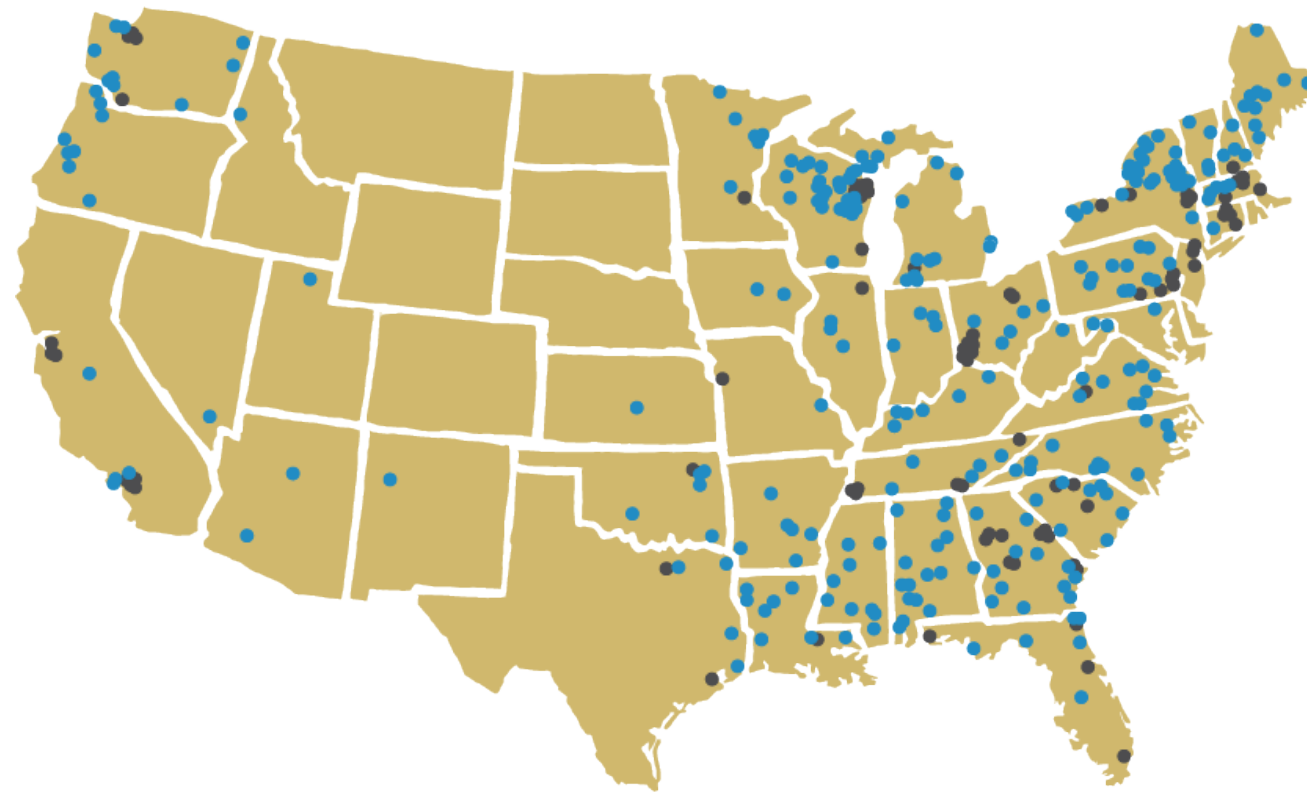
The industry meets a payroll of approximately

\$55 BILLION

annually among its employees.



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



● 80% or more rural ● Less than 80% rural

U.S. Forest Products Industry



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

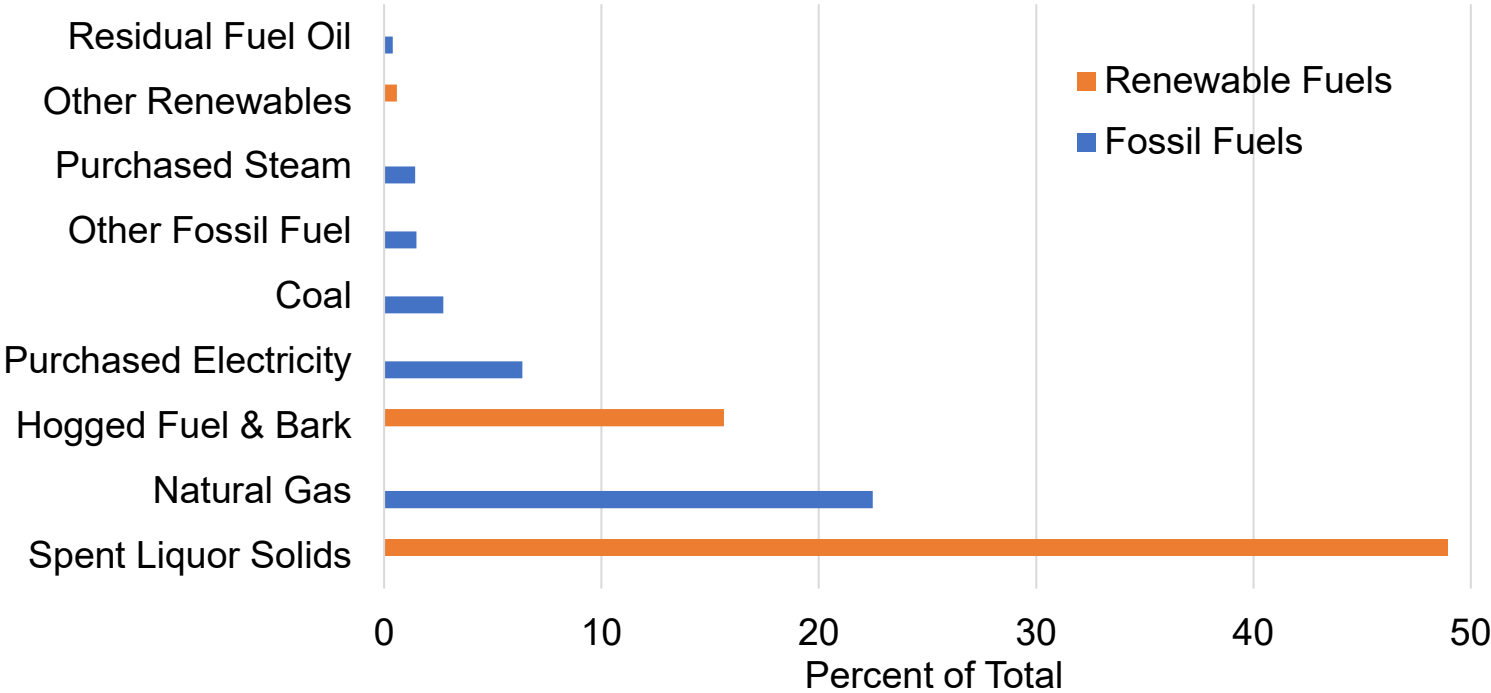
Data Sources

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

Pulp and Paper Mill Energy Sources—AF&PA Members

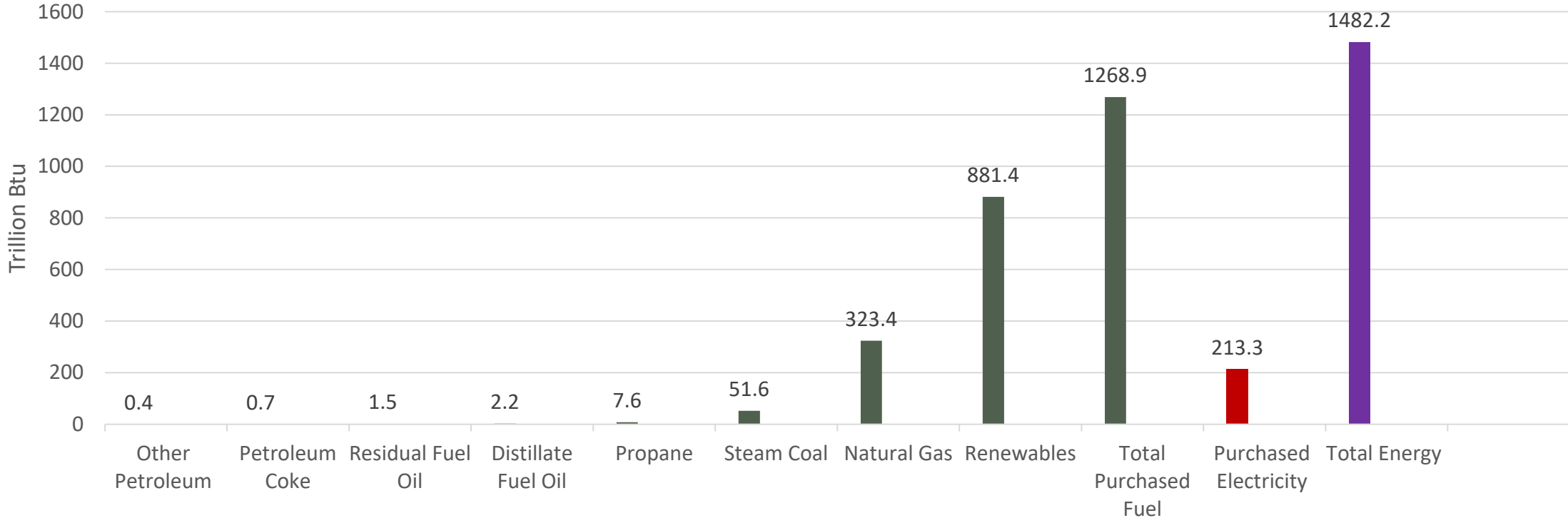
Meet About 2/3 of Overall Energy Demand with Carbon Neutral Biomass

2018 Pulp and Paper Mill Energy Sources



Paper Industry Energy Consumption

Paper - Energy Consumption (2019)
AEO 2019

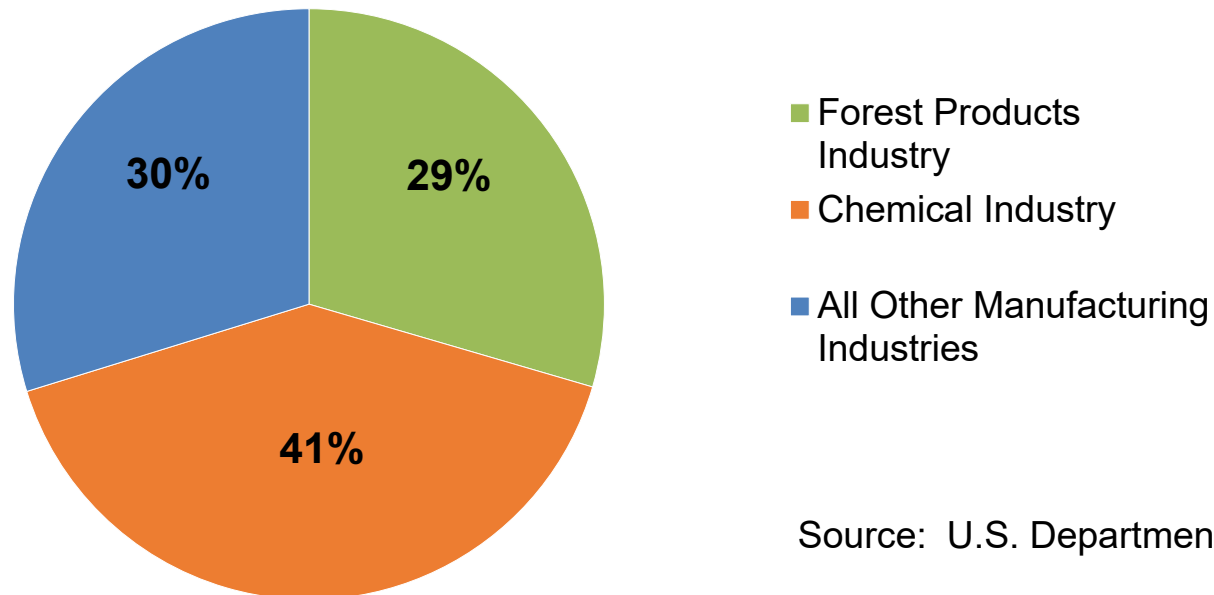


Combined Heat & Power (CHP) Electricity Generation

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

CHP Electricity Generation



Source: U.S. Department of Energy

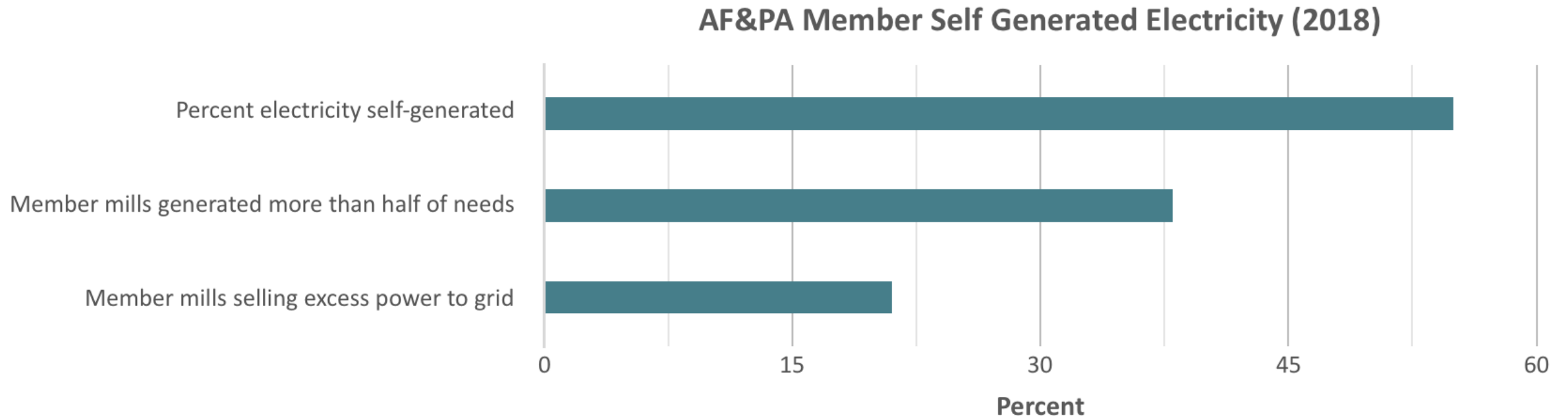
AF&PA Member CHP Capacity

- 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

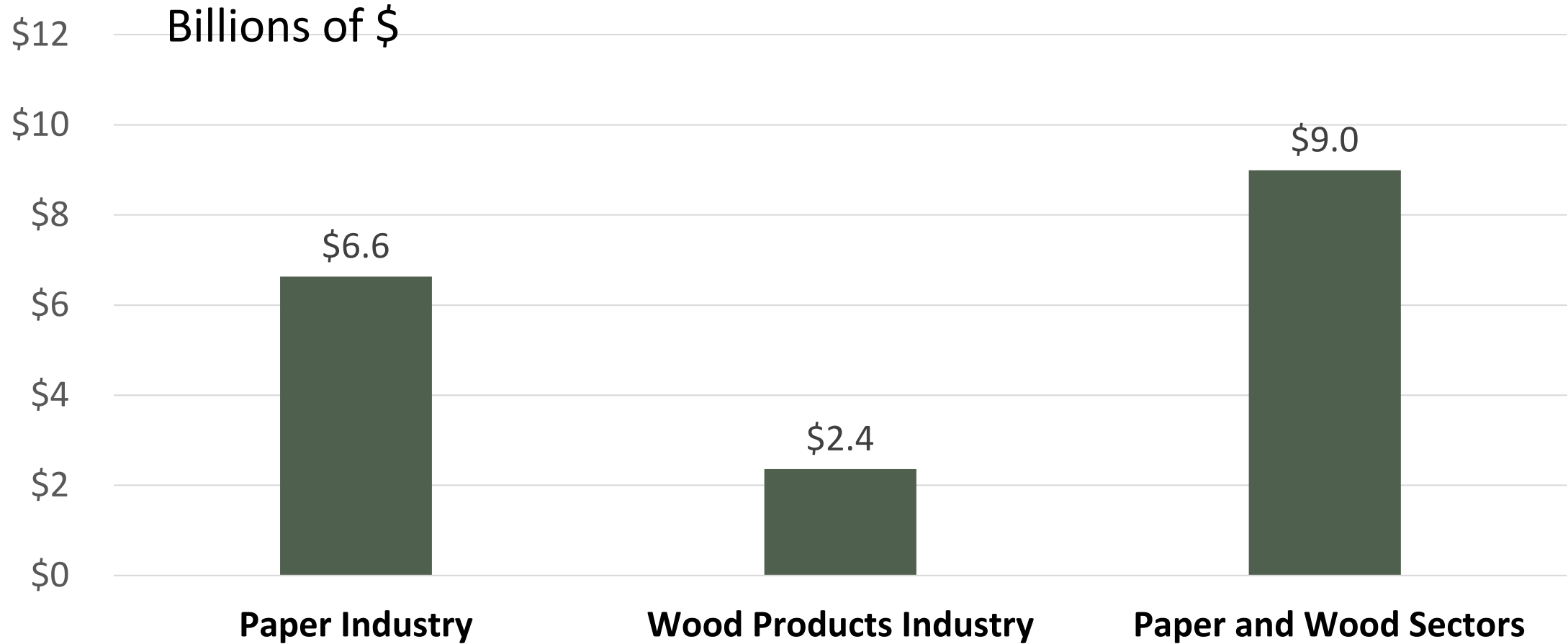
CHP Benefits

- 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

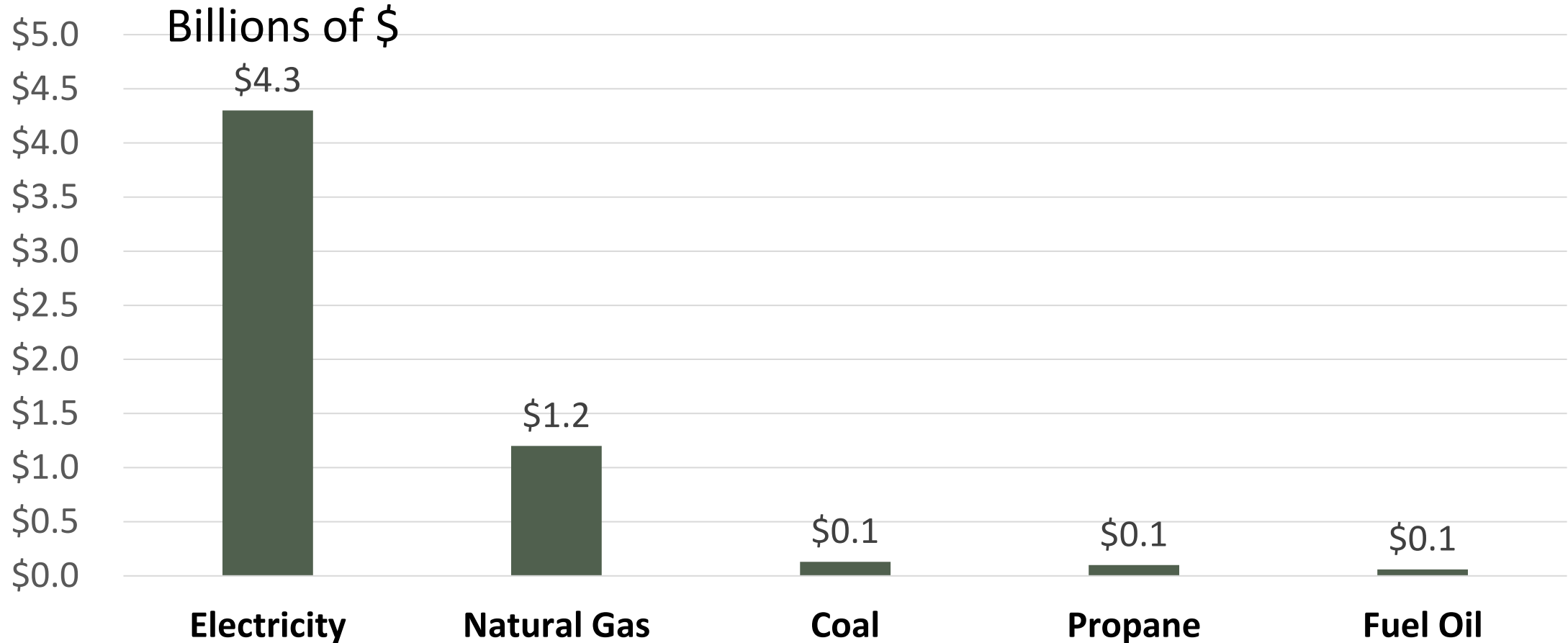
AF&PA Pulp And Paper Mills Self-generated 55% Of Electricity Needed To Power Mills In 2018



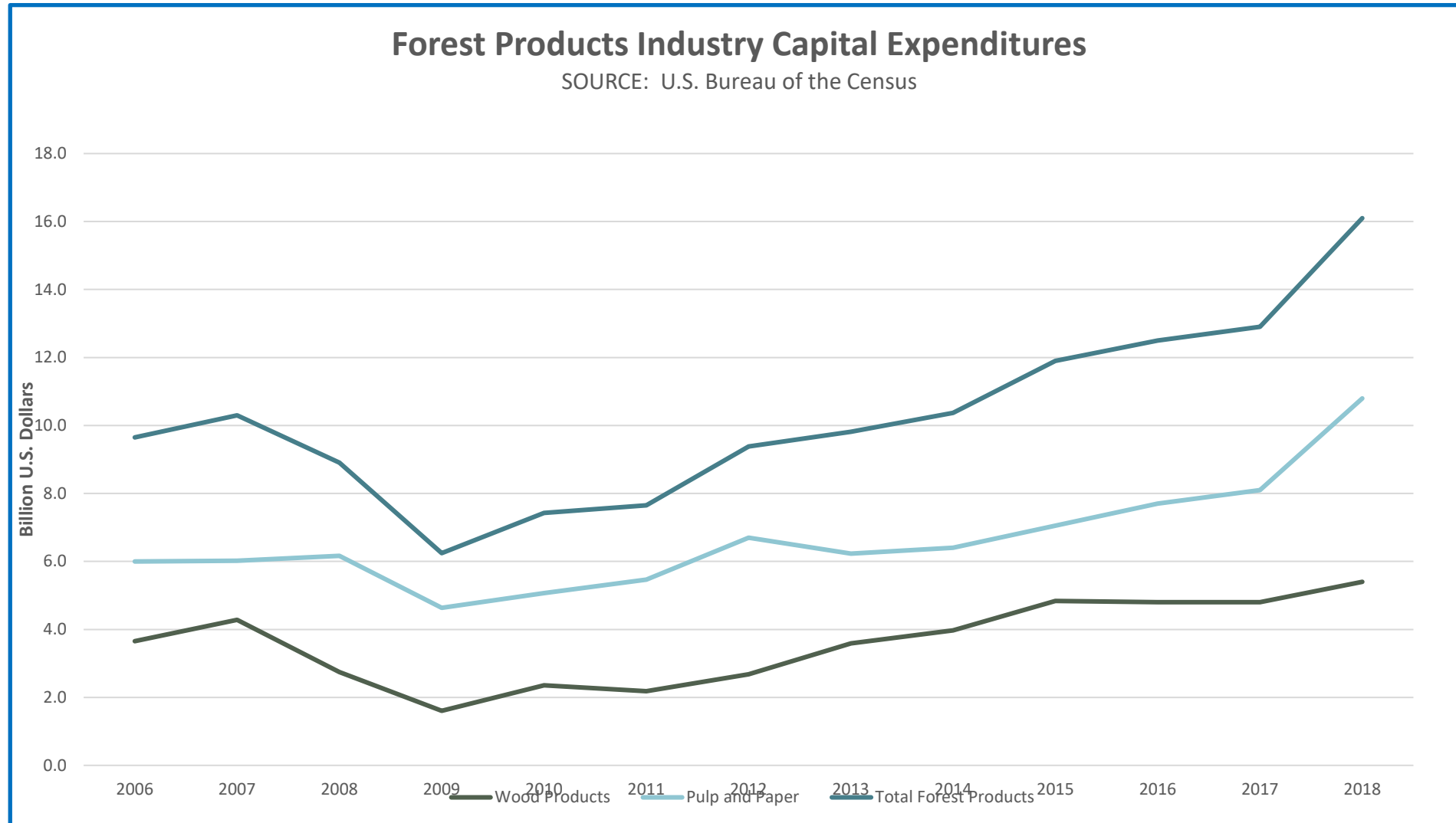
Annual Energy Expenditures - 2018



Paper Industry Energy Expenditures by Category

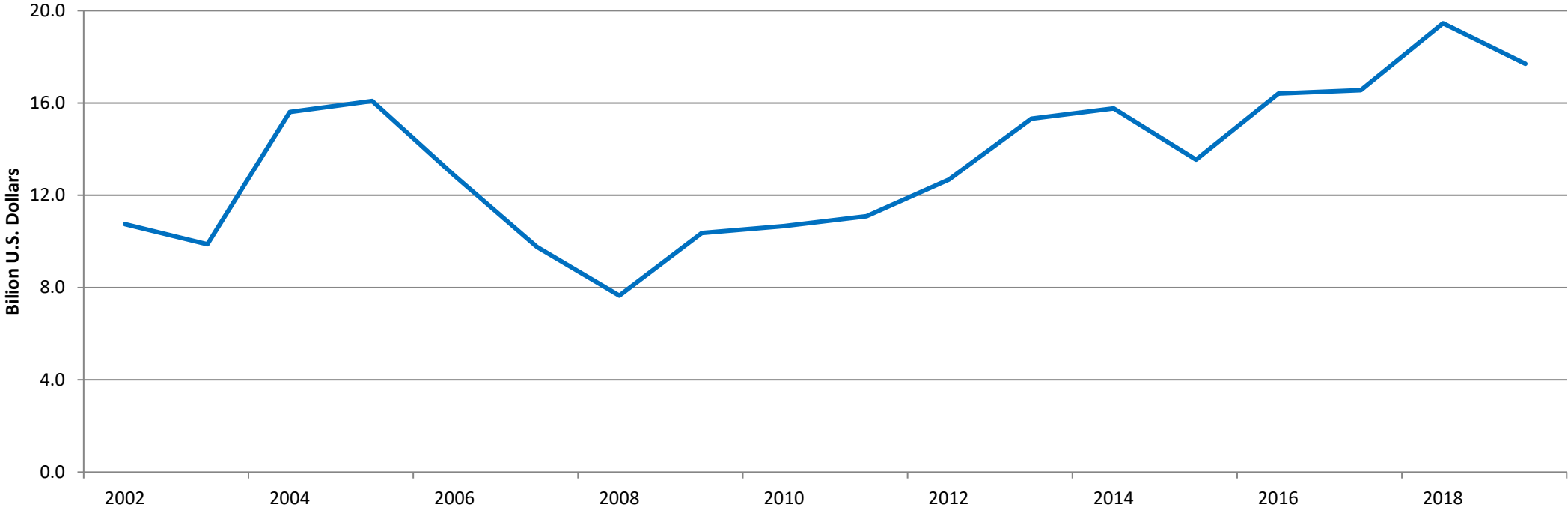


Economics-Capital Expenditures



Economics-Profits

Forest Industry Profits

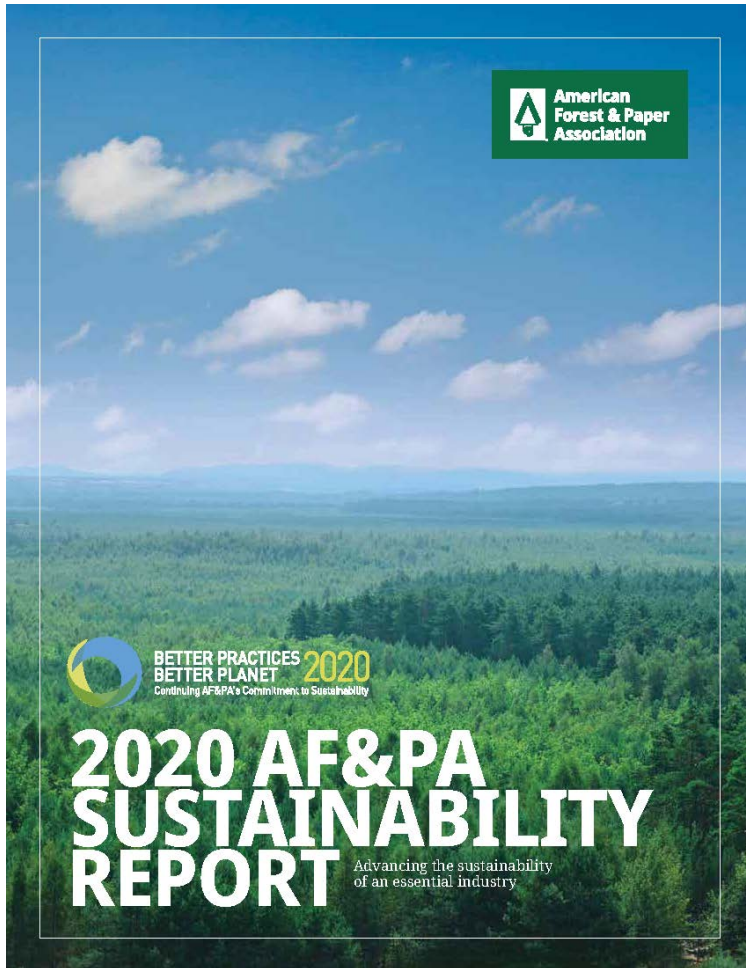


Source: Quarterly Financial Report (QFR)
Manufacturing, Mining, Trade, and Selected Service Industries







Industry Needs v Initiative Key Attributes

- Economic
- Standardized
- Installed
- Unattended
- Reliable

Better Practices, Better Planet 2020

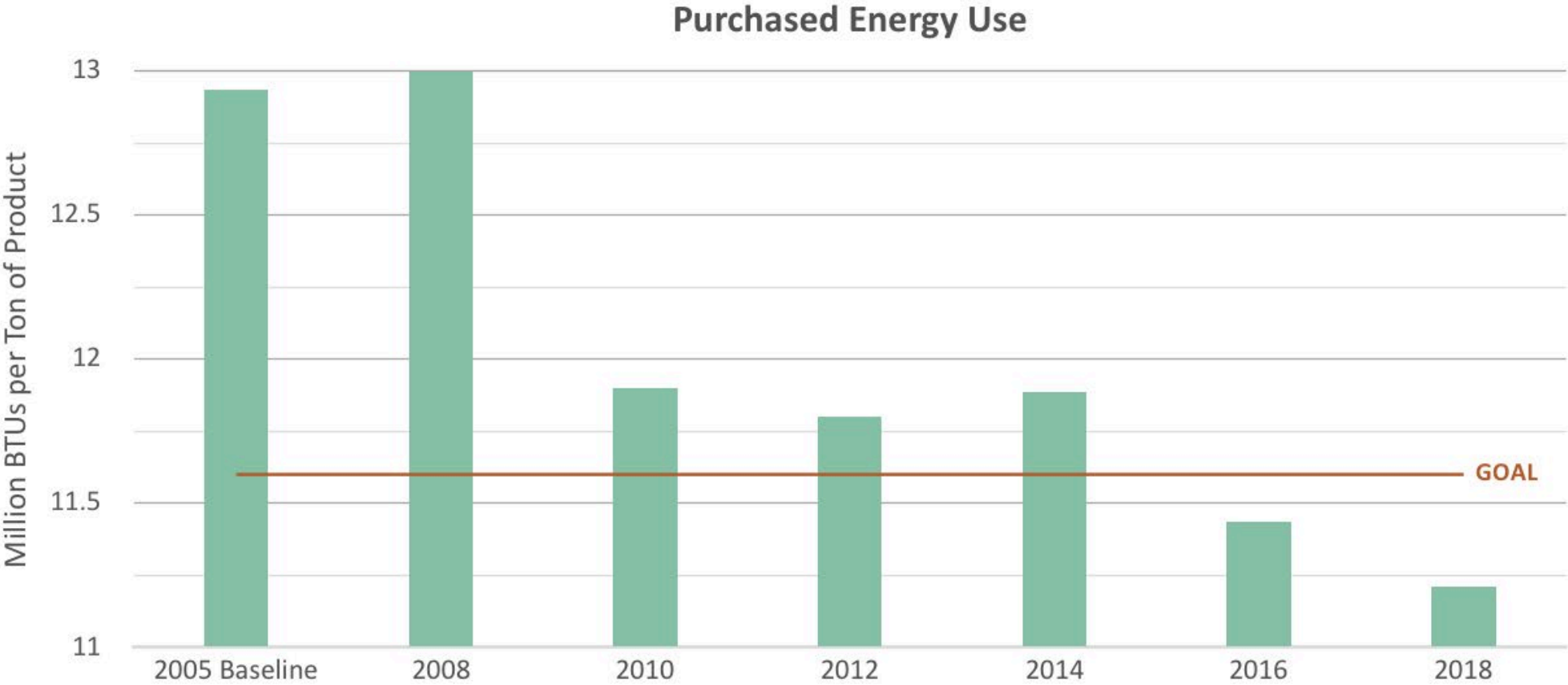


PROGRESS BY THE NUMBERS

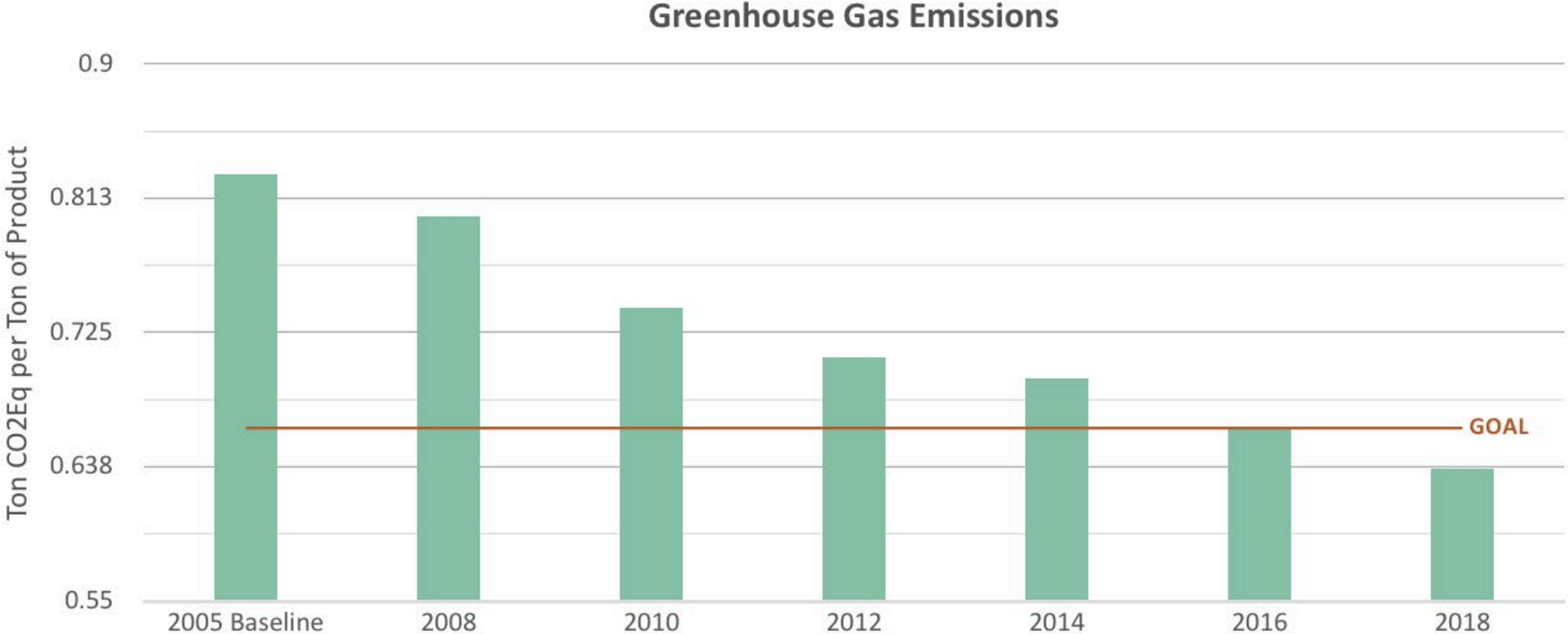
AF&PA Sustainability Goal	2018 Performance*	Baseline (2005*)	Progress from baseline year
 Improve safety incidence rate by 25%, while working to achieve zero injuries	1.617 recordable cases per 200,000 hours worked	2.625 recordable cases per 200,000 hours worked (2006)	38.4% improvement in recordable 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

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



Greenhouse Gas Emissions: 23.2% reduction (Goal Surpassed)



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

- Technology needs
- R&D priorities

Communicate

- Funding entities
- Solution providers

Deliver

- Projects
- 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)



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



Reuse of Process Effluents

Goal **Reduce average water usage by half**
Value ~ 5K gal/ton, >\$300MM, 45 TBTU,
 480B Gal



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

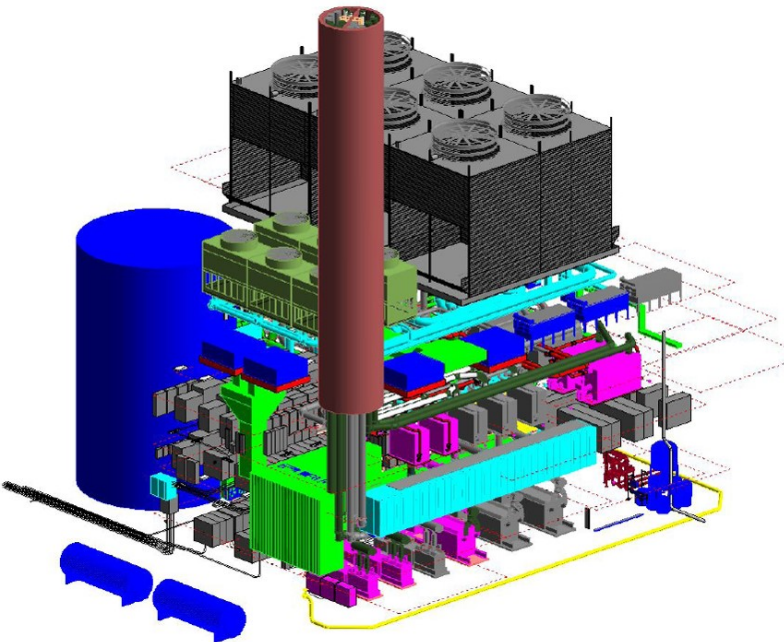
Fission Battery Initiative Workshop, INL

**WHO WILL BUY A NUCLEAR
BATTERY?**

**CAN MULTIPLE USERS SHARE
AN ASSET?**



Harvard's New District Energy Facility



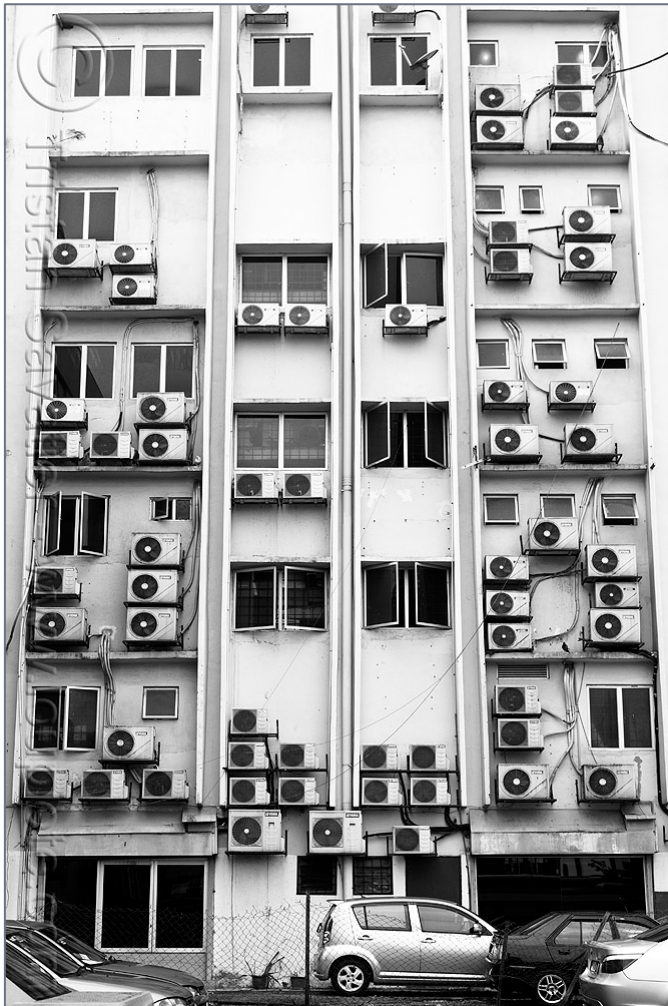
City of Boston – Major Parcel Development

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.**

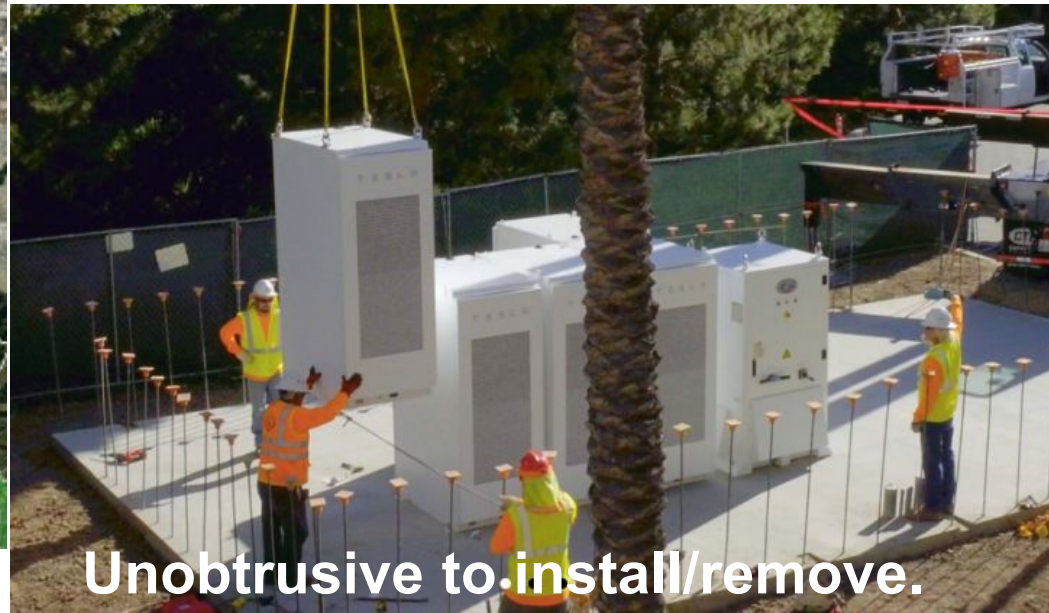


Ownership is Flexible: Battery Installations

Located at commercial buildings, behind the meter, throughout SCE territory.



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



Unobtrusive to install/remove.

THANK YOU

