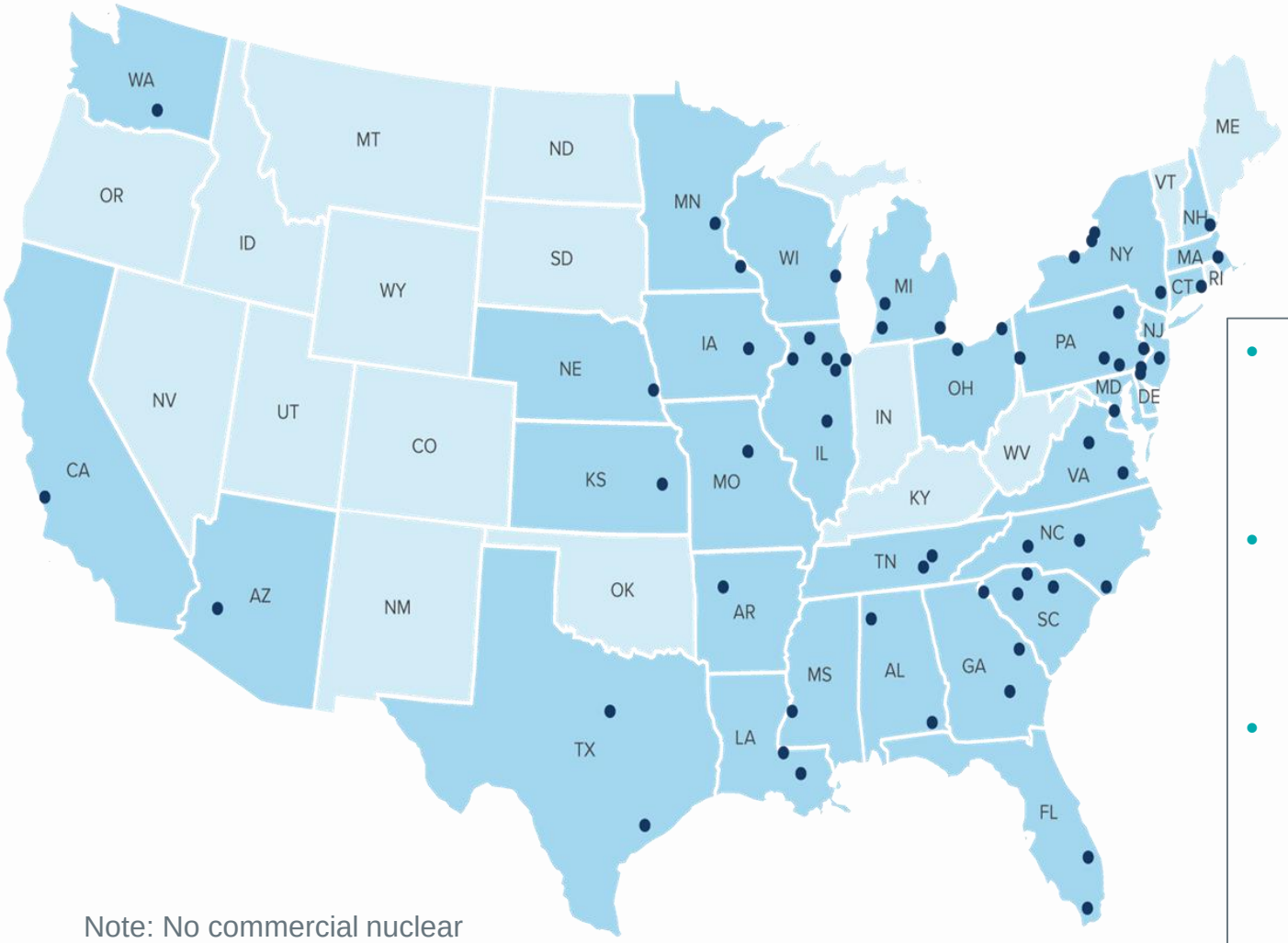
Getting to New Nuclear in the U.S.

John F. Kotek
Nuclear Energy Institute

NUCLEAR ENERGY INSTITUTE

October 16, 2019

NUCLEAR POWER IN THE U.S.



Note: No commercial nuclear power in Alaska or Hawaii

- 96 reactors at 57 sites, in 29 states
- 98 GWe of baseload capacity
- 19.3% of U.S. electricity generation in 2018

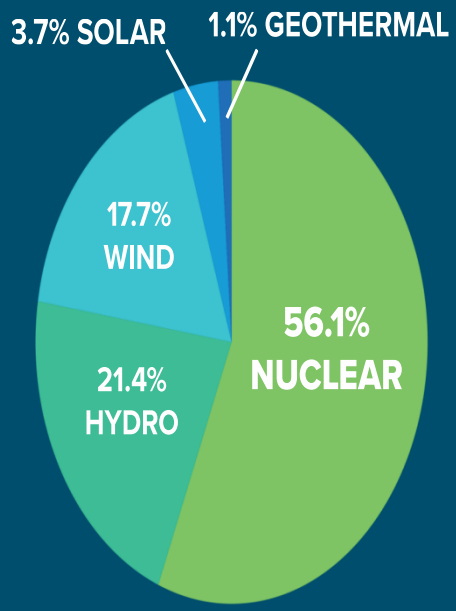
NUCLEAR CONTRIBUTIONS

AVOIDS **547.5 MILLION** METRIC TONS OF CARBON EMISSIONS EACH YEAR

+

PREVENTS **315,000** SHORT TONS OF **NOx** AND **374,000** SHORT TONS OF **SO2** EMISSIONS

—AVERAGE— **CAP FACTOR >90% SINCE 1999**



SUPPORTS **475,000** JOBS

SAVES CONSUMERS AN AVERAGE OF **6%** ON ELECTRICITY BILLS

ADDS **$60 BILLION** TO THE COUNTRY'S **GDP**

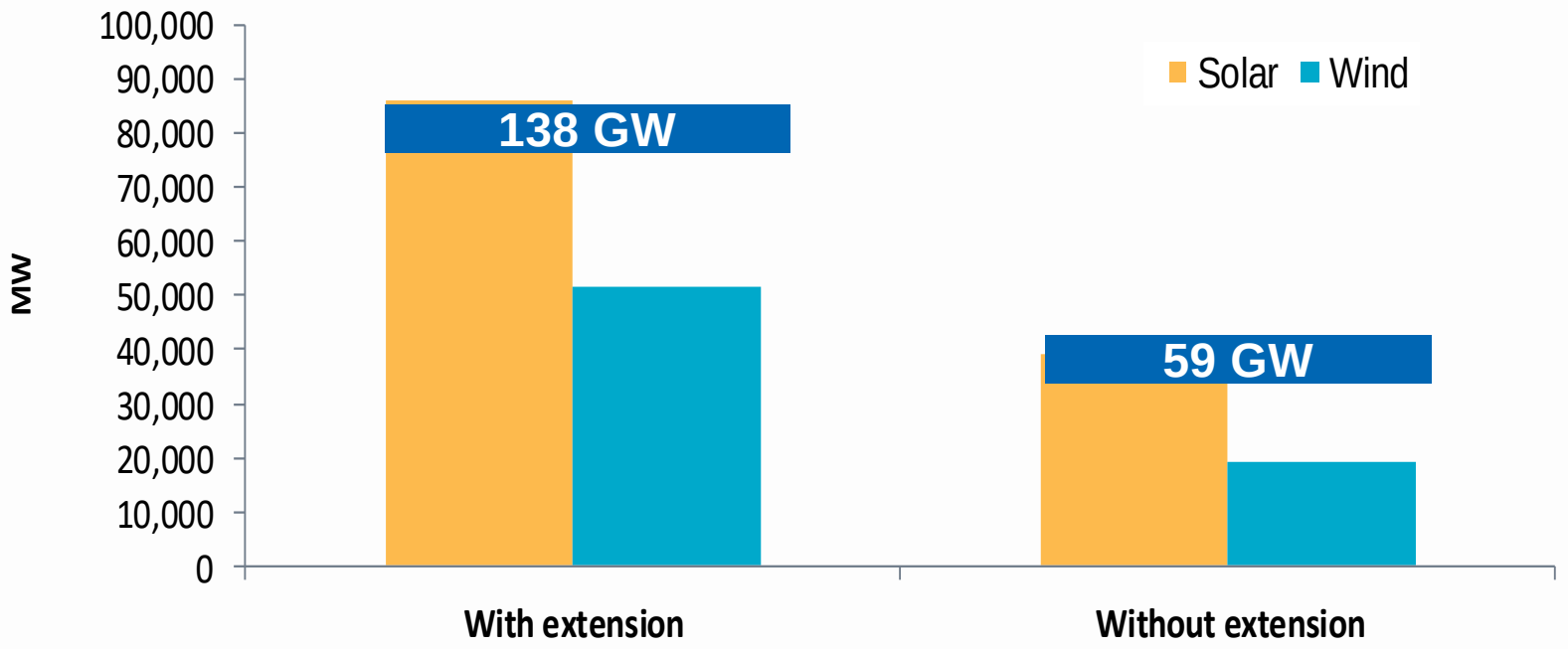
U.S. NUCLEAR POWER PLANT COSTS ($/MWH, IN 2018 DOLLARS)

Year	Fuel	Capital	Operating	Total Generating
2002	6.07	4.16	19.72	29.95
2004	5.60	5.99	19.66	31.25
2007	5.44	6.49	20.22	32.15
2010	7.17	9.71	21.89	38.76
2011	7.53	10.67	23.21	41.41
2012	7.96	11.48	22.91	42.36
2015	7.28	8.44	22.09	37.81
2016	7.07	7.05	21.38	35.50
2017	6.59	6.80	20.92	34.32
2018	5.98	6.14	19.71	31.83
2012 – 2018 Change	-25%	-46%	-14%	-25%

Source: Electric Utility Cost Group
Updated: February 2019

IMPACT OF FEDERAL POLICIES

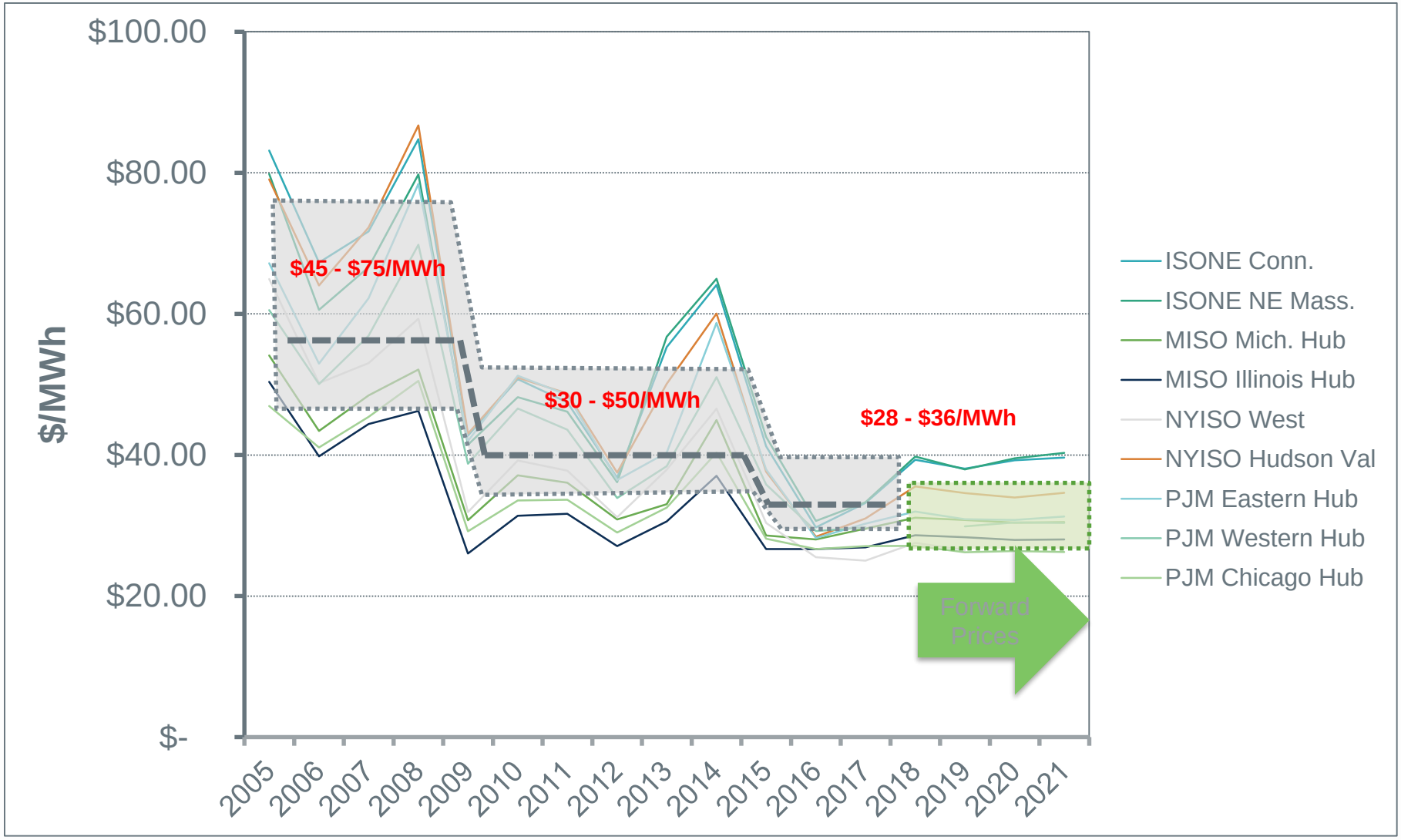
IHS outlook for cumulative wind and solar build with and without tax credit extension, 2016–22



Notes: Solar represents AC capacity.
Source: IHS

The extension of tax credits is expected to more than double combined wind and solar build from 2016 to 2022, from about 60 GW to about 140 GW

DECLINING ELECTRICITY PRICES



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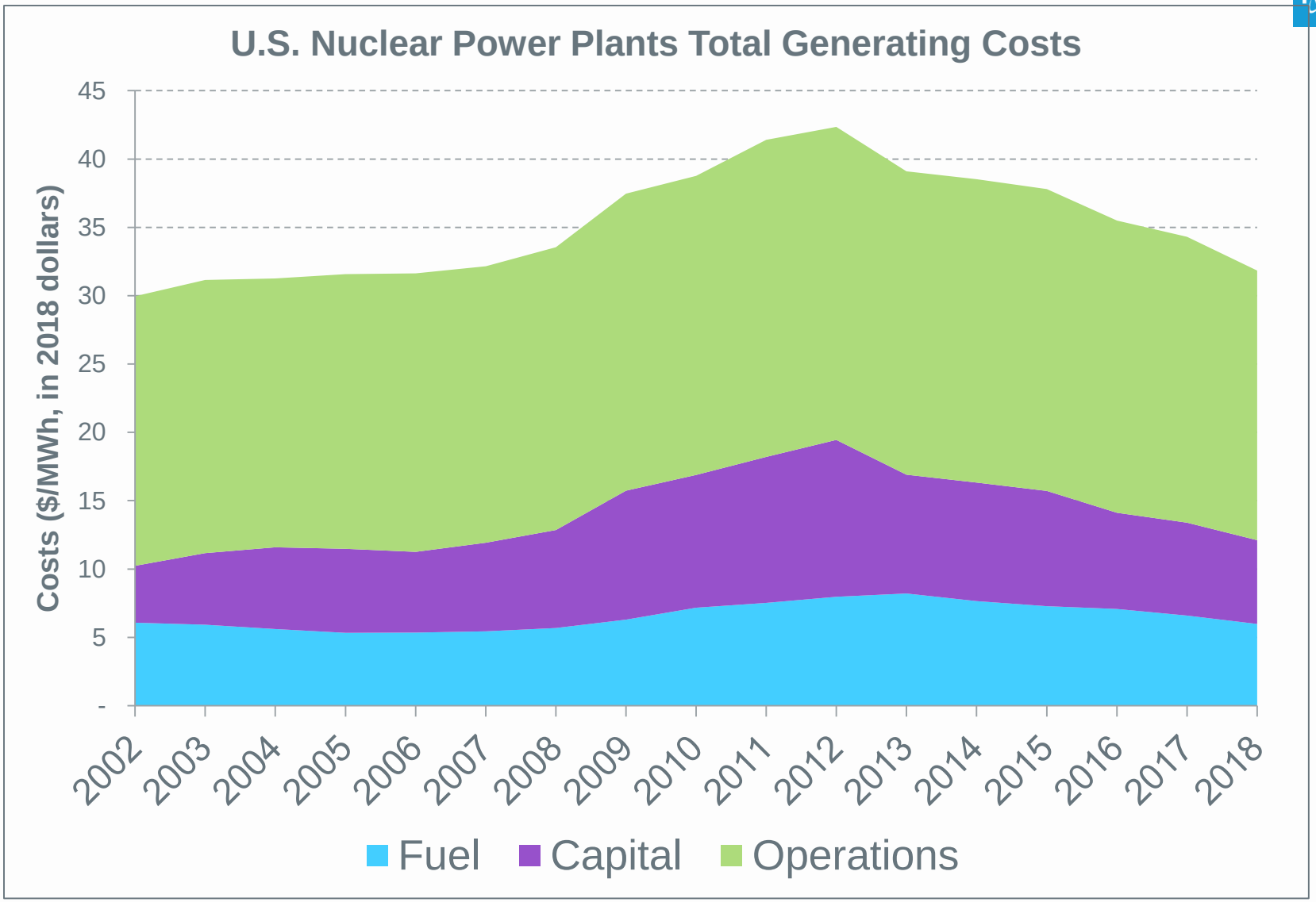
U.S NUCLEAR POWER PLANT COSTS ($/MWh, in 2018 dollars)



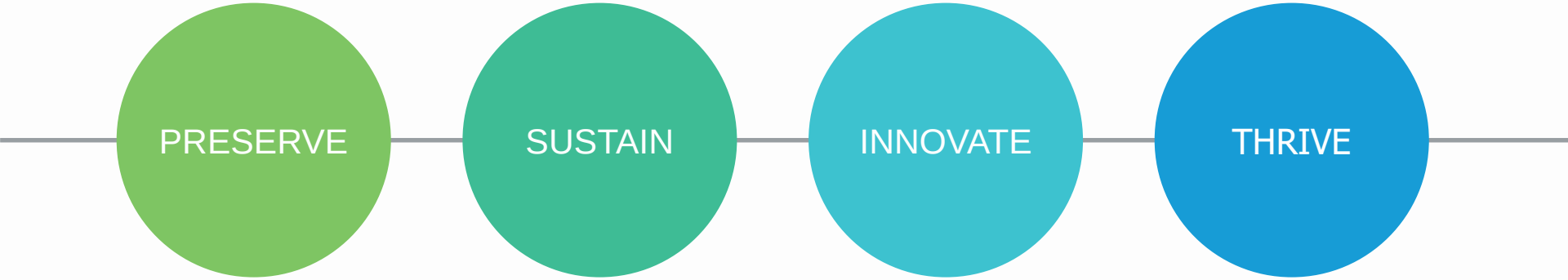
Source: Electric Utility Cost Group
Updated: February 2019

Nuclear Plants: Premature Closures and Announced Shutdowns

Plant	State	Capacity (MWe)	Closure Year	Latest Year Generation (billion kWh per year)	Latest Year CO2 Avoided (Million tons per year)
Crystal River 3	Florida	860	2013	7.0	4.8
San Onofre 2 & 3	California	2,150	2013	18.1	8.0
Kewaunee	Wisconsin	566	2013	4.5	4.4
Vermont Yankee	Vermont	620	2014	4.8	2.4
Fort Calhoun	Nebraska	478	2016	3.5	3.4
Oyster Creek	New Jersey	625	2018	5.4	4.0
Pilgrim	Massachusetts	679	2019	4.4	2.0
Three Mile Island 1	Pennsylvania	803	2019	7.3	5.0
TOTAL		**6,781**		**55.1**	**33.9**
Duane Arnold	Iowa	601	2020	4.9	4.6
Indian Point 2 & 3	New York	2,057	2020-2021	16.3	7.6
Beaver Valley 1 & 2	Pennsylvania	1,808	2021	14.7	10.1
Palisades	Michigan	804	2022	5.5	4.6
Diablo Canyon 1 & 2	California	2,240	2024-2025	18.2	7.3
TOTAL		**7,510**		**59.6**	**34.2**

Source: Emissions avoided are calculated using regional and national fossil fuel emissions rates from the **U.S. Environmental Protection Agency** and latest plant generation data from the **U.S. Energy Information Administration**.
Updated: September 2019.

National Nuclear Energy Strategy



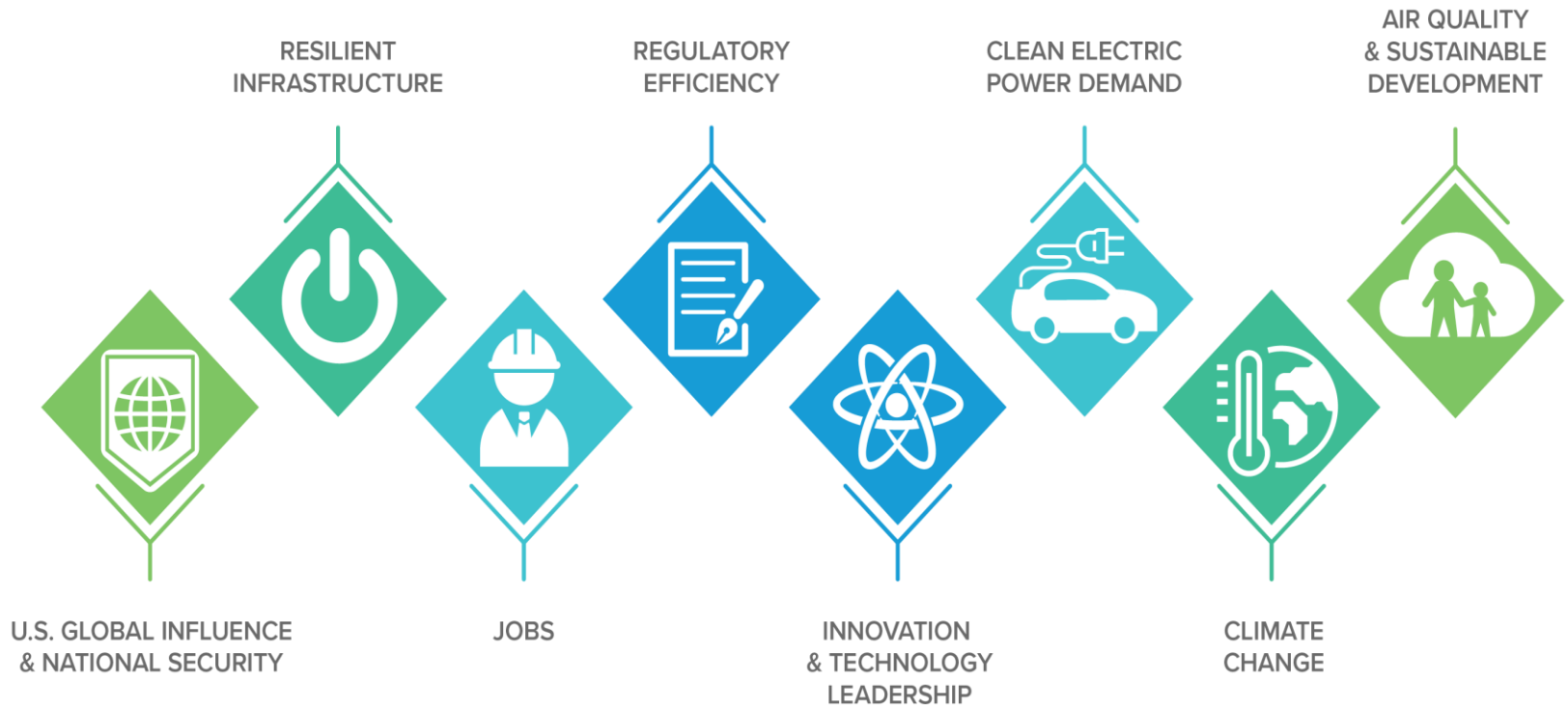
Appropriately value nuclear generation

Create sustainability via improved regulatory framework and reduced burden

Innovate, commercialize, and deploy new nuclear

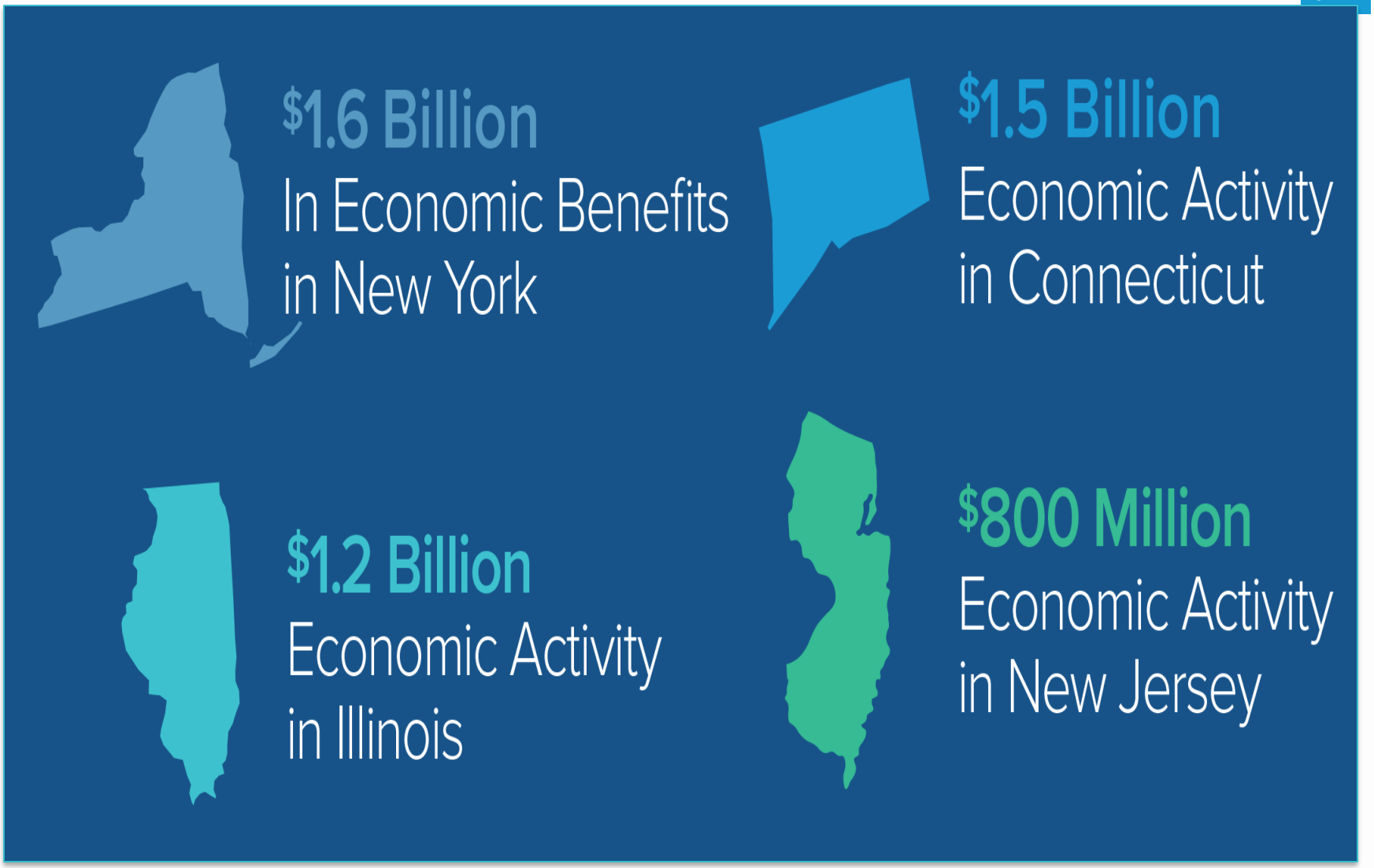
Compete globally

NUCLEAR ENERGY IMPERATIVES



PRESERVE

STATES RECOGNIZE NUCLEAR'S VALUE



THE EMISSIONS REDUCTION IMPERATIVE

The Nuclear Power Dilemma

Declining Profits, Plant Closi
of Rising Carbon Emissions

Steve Clemmer
Jeremy Richardson
Sandra Sattler
Dave Lochbaum

November 2018

Union of Concerned Scientist

Google

Moving toward 24x7 Carbon-Free Energy at Google Data Centers: Progress and Insights

Introduction

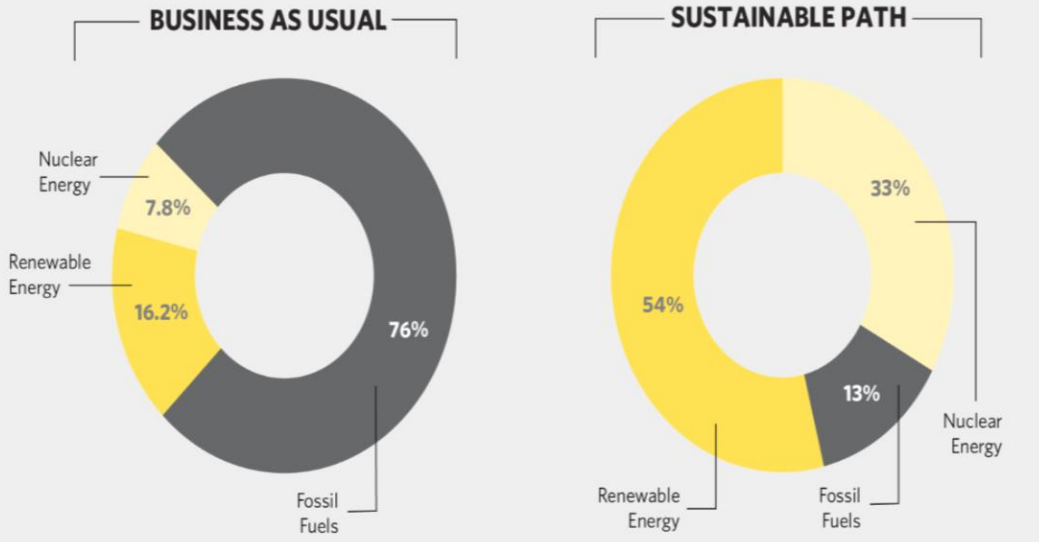
In recent years, Google has become the world's largest corporate buyer of renewable energy. In 2017 alone, we purchased more than seven billion kilowatt-hours of electricity (roughly as much as is used y the state of Rhode Island[1]) from solar and wind farms that ilt specifically for Google. This enabled us to match 100% of ual electricity consumption through direct purchases of le energy; we are the first company of our size to do so.

g our 100% renewable energy purchasing goal was an nt milestone, and we will continue to increase our purchases vable energy as our operations grow. However, it is also just nning. It represents a head start toward achieving a much longer-term challenge: **sourcing carbon-free energy for our ns on a 24x7 basis.**

this challenge requires sourcing enough carbon-free energy h our electricity consumption *in all places, at all times*. Such oach looks markedly different from the status quo, which, our large-scale procurement of renewables, still involves based power. Each Google facility is connected to its regional rid just like any other electricity consumer; the power mix in gion usually includes some carbon-free resources (e.g. wind, dro, nuclear), but *also* carbon-based resources like coal, gas, and oil. Accordingly, we rely on those carbon-based es — particularly when wind speeds or sunlight fade, and also s where there is limited access to carbon-free energy. Carbon-ot, around-the-clock electricity is the fuel that enables us to busly deliver Google search results, YouTube video plays, Cloud Platform services, and much more without interruption.

A Changing Energy Portfolio

In order to both meet increased energy demand and keep the climate in safe boundaries, we'll need to alter our energy makeup to curtail emissions of carbon and other harmful chemicals.



Source: The Nature Conservancy, The Science of Sustainability, 2018

The Emissions Reduction Imperative

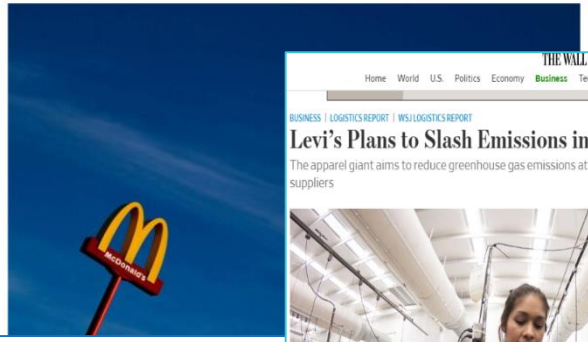
REUTERS

ENVIRONMENT MARCH 20, 2018 / 10:29 AM / A YEAR AGO

McDonald's sets greenhouse gas reduction targets

Lisa Baertlein 3 MIN READ

(Reuters) - McDonald's Corp on Tuesday announced an approved, science based target to cut greenhouse gas emissions and battle climate change, saying it is the first restaurant company to do so.



Supply chains + Add to myFT

Blue chips act to cut supply chain greenhouse gas emissions

Rolls-Royce, Nestlé and Panasonic among larger companies taking action

Michael Pooler JANUARY 29, 2018 2

The number of large companies taking serious action to tackle greenhouse gas emissions in their supply chains has doubled, according to research by an

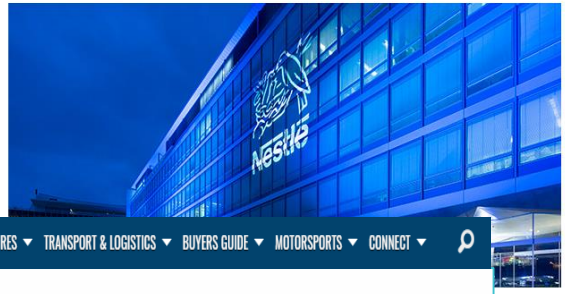
CLIMATE

Nestlé commits to net-zero target by 2050

E&E NEWS PM

Haley Weiss, E&E News reporter

Published: Monday, September 16, 2019



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Levi's Plans to Slash Emissions in Global Supply Chain by 2025

The apparel giant aims to reduce greenhouse gas emissions at a sprawling set of factories and mills in 39 countries, sta… suppliers

Levi's will start its effort to cut greenhouse gas emissions through energy-efficiency programs at factories run by vendors in the first tier of its supply chain, such as this supplier facility in Mexico. PHOTO: PHOTO COURTESY OF LEVI STRAUSS & CO.

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Toyota wants zero carbon emissions in all factories by 2050

Marcus De Guzman

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Clean, zero emission Toyota factories may soon be a reality

Toyota

May 31, 2019 09:41

Advertisement

Let's face it, manufacturing cars is no easy feat. Aside from the fact that you have to build a whole fleet of them, you'll also need plenty of resources and energy to manufacture batches of them. But using energy means you're also producing CO_2 emissions, which is never good.

That's right, aside from automobiles, car factories also use plenty of energy that result in more CO_2 emissions that harm the environment and add more greenhouse gases that pollute the air. So how does Toyota plan to combat that? By setting a goal of achieving 35% reduced CO_2 emissions in global plants worldwide by 2030, and having zero CO_2 emissions in all manufacturing plants by 2050.

Part of the "Toyota Environmental Challenge 2050", the automaker is looking at not just reducing their carbon footprint from their cars, but also from their manufacturing facilities. To do this, Toyota has been finding ways of recycling and using alternative means of generating energy.

NEI

NUCLEAR PLANTS SAVED FROM PREMATURE CLOSURE

More than 9,100 direct jobs saved through State actions

Plant	State	Capacity (MWe)	Projected Closure Year	Electricity Generated (billion kWh in 2018)	CO_2 Emissions Avoided (Million tons per in 2018)
Clinton	Illinois	1,060	2017	8.3	8.1
Davis-Besse	Ohio	894	2020	7.4	5.1
Fitzpatrick	New York	851	2017	6.5	3.1
Ginna	New York	582	2017	4.7	2.2
Hope Creek	New Jersey	1,172	~2020	9.5	6.6
Millstone 2 & 3	Connecticut	2,088	~2020	16.9	7.6
Nine Mile Point 1 & 2	New York	1,916	2017-2018	15.4	7.2
Quad Cities 1 & 2	Illinois	1,819	2018	15.5	10.6
Perry	Ohio	1,240	2020	10.9	7.5
Salem 1 & 2	New Jersey	2,328	~2020-2021	18.9	13.0
TOTAL		**13,950**		**114.1**	**70.9**

This is nearly **twice** the electricity generation from U.S. utility solar in 2018

Source: Emissions avoided are calculated using regional and national fossil fuel emissions rates from the **U.S. Environmental Protection Agency** and latest plant generation data from the **U.S. Energy Information Administration**.
Updated: July 2019.

SUSTAIN

NEI REGULATORY EFFORTS

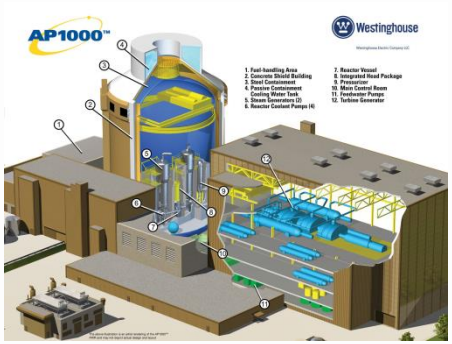
Enable meaningful reductions in costs associated with existing regulatory requirements

Minimize the burden associated with any new/evolving challenges and regulatory requirements

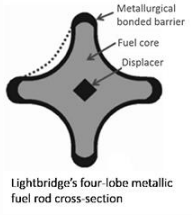
Reduce the total costs associated with industry-controlled activities

INNOVATE

Continuum of Innovation



Evolutionary LWR Fuels



Lightbridge's four-lobe metallic fuel rod cross-section

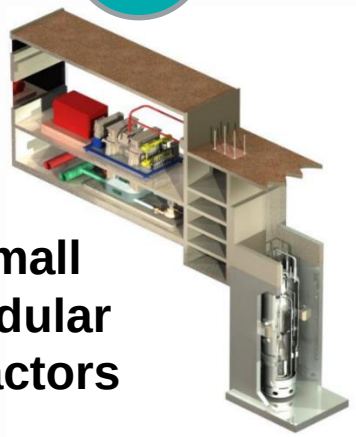
Advanced Non-LWRs

- Hi-temp gas
- Liquid metal
- Molten salt
- Micro-reactors

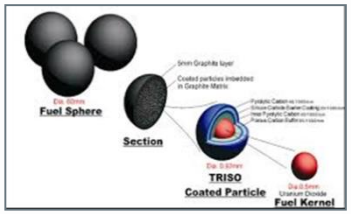
2016 — 2020 — 2025 — 2030

Large LWRs

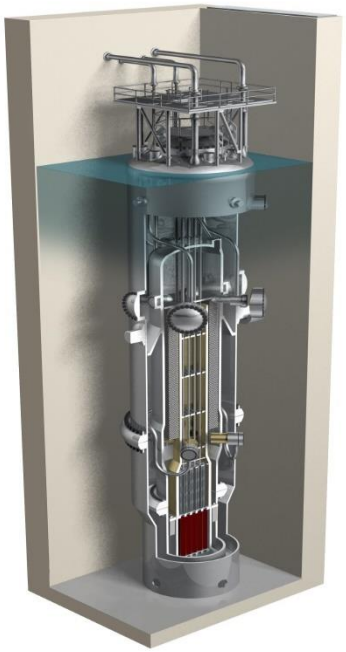
NuScale Power Module



Small Modular Reactors

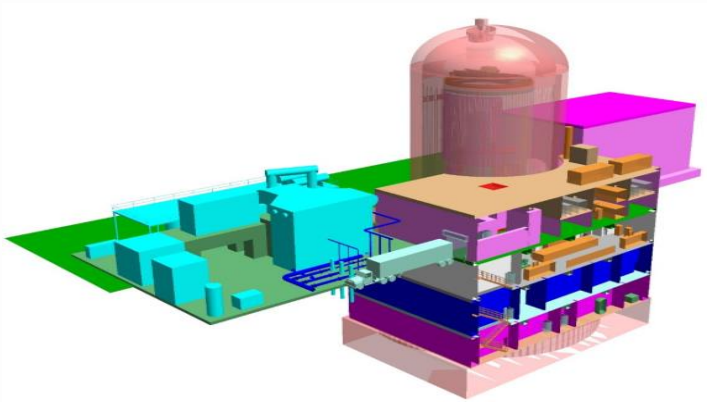


Small Modular LWRs



NuScale Power Module

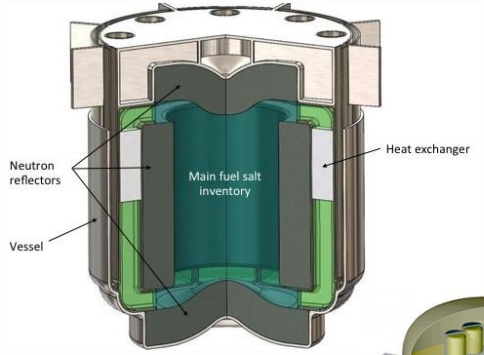
GEH BWRX-300



Holtec SMR-160

Non-Water Cooled Reactors

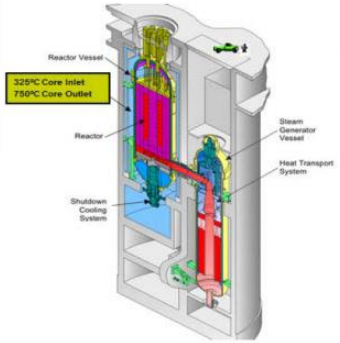
Molten Salt Reactors



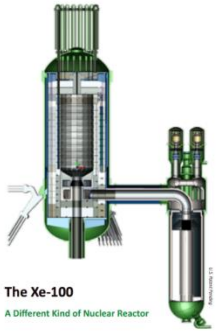
TerraPower

Terrestrial Energy

High Temperature Gas Reactors



Framatome

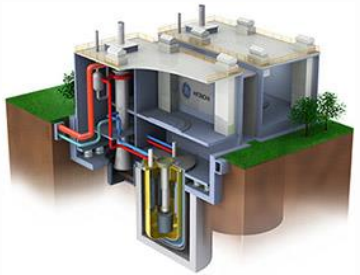


X-energy

Micro Reactors

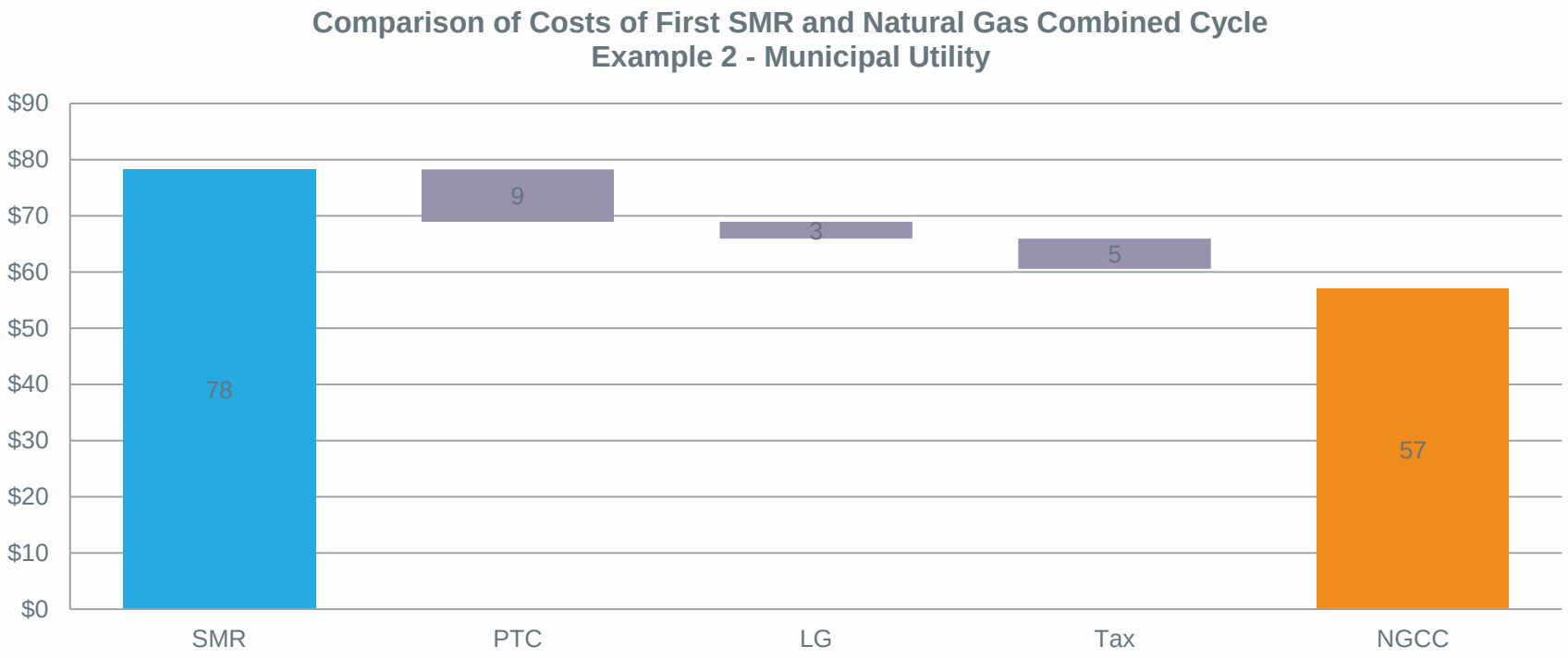
Westinghouse eVinci

Liquid Metal Reactors



GE PRISM

Need for Federal and State Policy Support



Micro-Reactors

Features
- 1 MWe to 10 MWe (typical)
- 10 year fuel life (typical)
- Operates independent of grid

HolosGen

OKLO
2 MWe

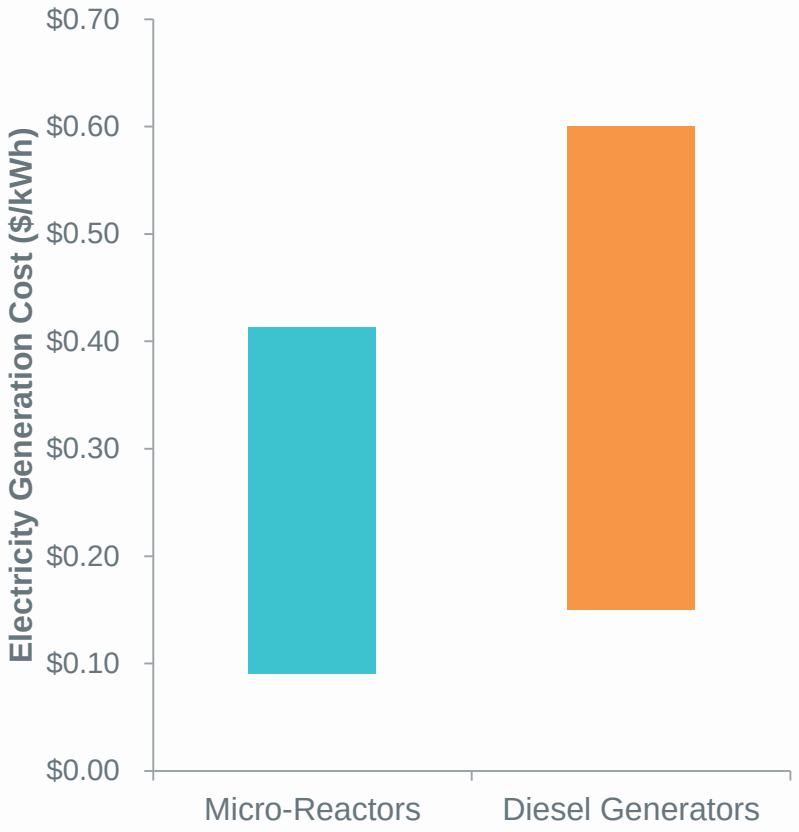
Westinghouse eVinci
200 kWe to 25 MWe

Others (not all inclusive)
- Elysium
- General Atomics
- Hydromine
- NuGen
- NuScale
- X-Energy

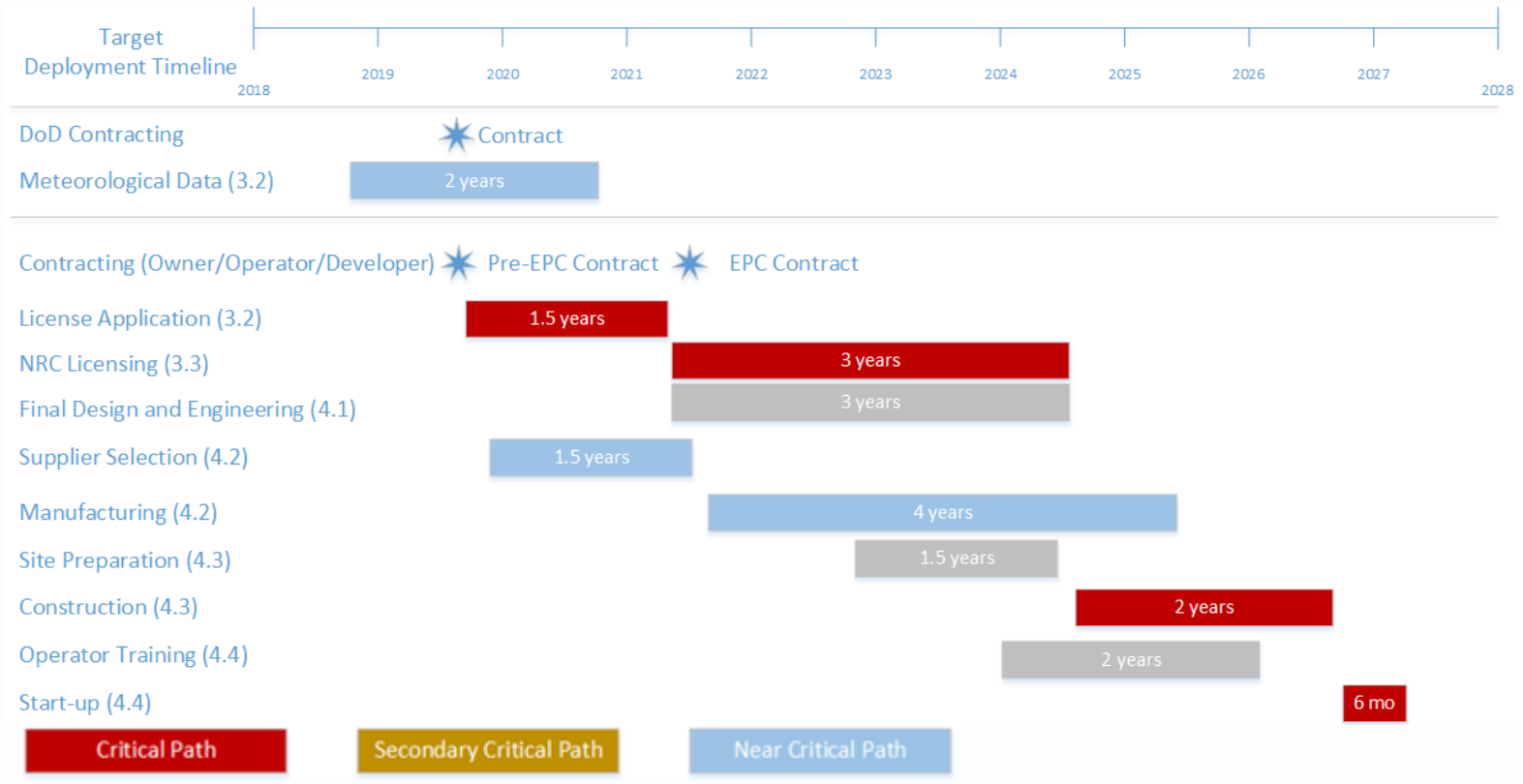
An Emerging Customer?

Estimated Costs

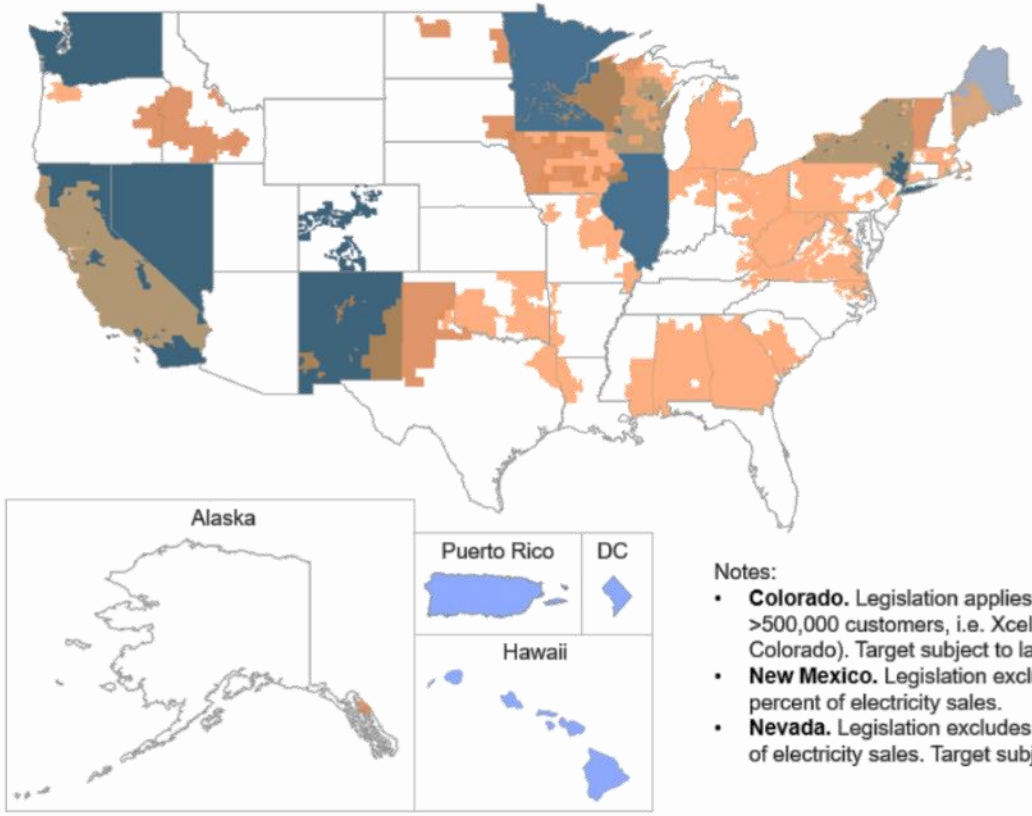
- Diesel generator costs
  - Primarily fuel costs
  - Fuel from $2.86/gallon to $4.89/gallon
- Micro-reactor costs
  - Include used fuel disposal and decommissioning
  - 10 year fuel life
  - 40 year plant life
  - 95% capacity factor



Deployment Timeline



State Emissions Reduction Targets



States with 100% Clean Energy Standards, in Law

States with 100% Clean Energy Standards, Introduced

States with 100% Renewable Energy Portfolios, in Law

States with 100% Renewable Energy Portfolios, Introduced

Utilities with 100% Clean Energy / Zero-Carbon Pledges

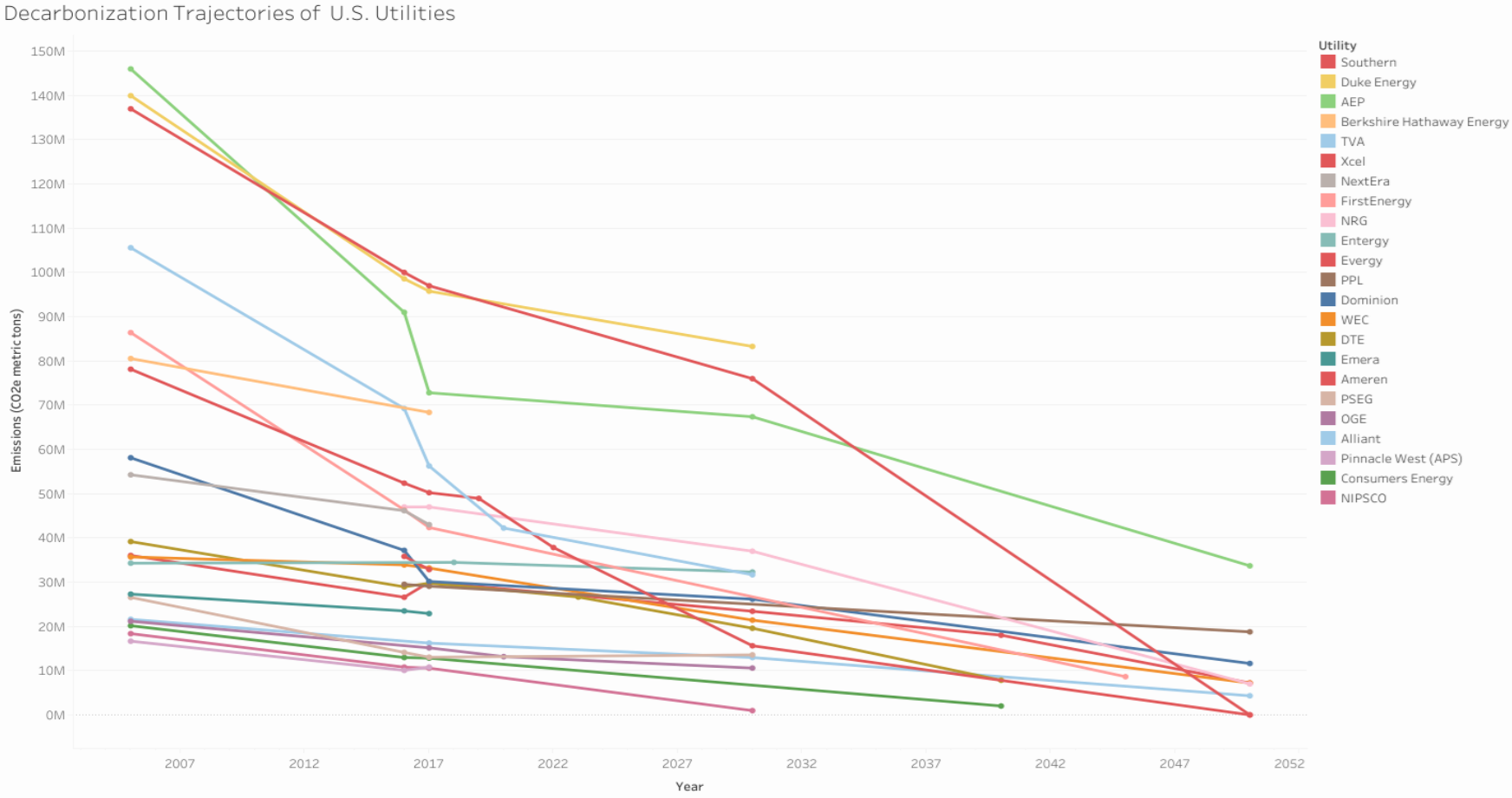
Utilities with 80-90% GHG Emission Reduction Pledges

Notes:

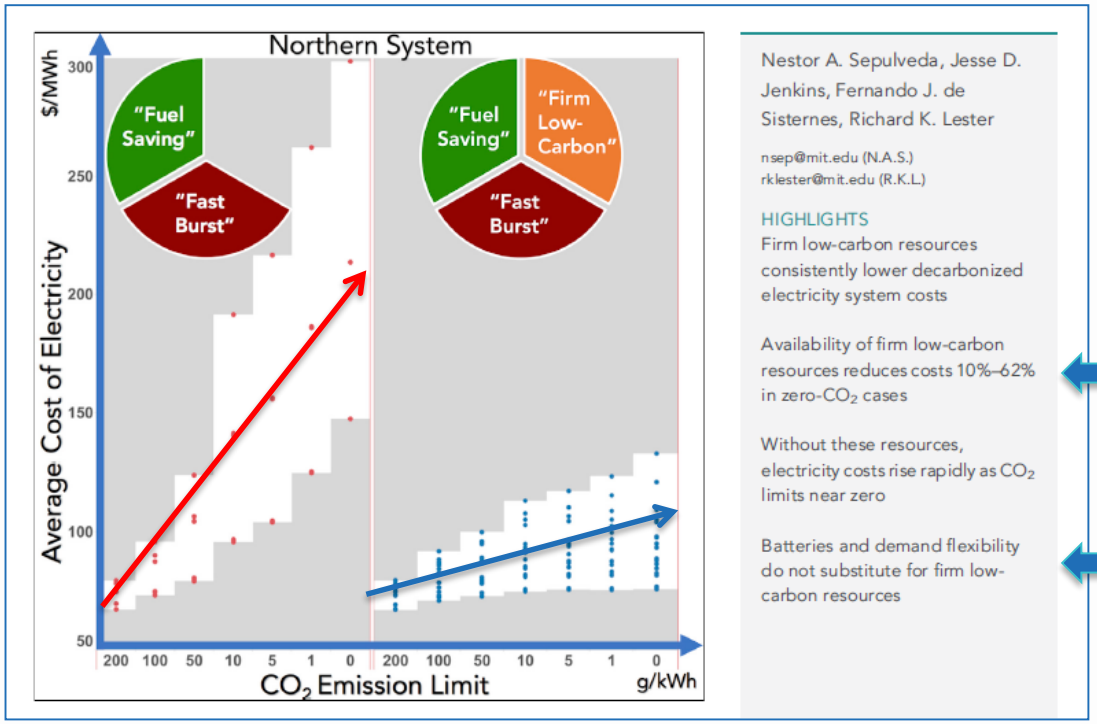
- **Colorado.** Legislation applies only to non-municipal utilities that serve >500,000 customers, i.e. Xcel Energy (Public Service Company of Colorado). Target subject to later study or action.
- **New Mexico.** Legislation excludes co-ops, which account for about 20 percent of electricity sales.
- **Nevada.** Legislation excludes co-ops, which account for about 6 percent of electricity sales. Target subject to later study or action.

Source: Clean Air Task force, June 2019

Utility Decarbonization Commitments



Firm, Low-carbon Generation Enables Affordable Decarbonization



Nestor A. Sepulveda, Jesse D. Jenkins, Fernando J. de Sisternes, Richard K. Lester

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rklester@mit.edu (R.K.L.)

HIGHLIGHTS

Firm low-carbon resources consistently lower decarbonized electricity system costs

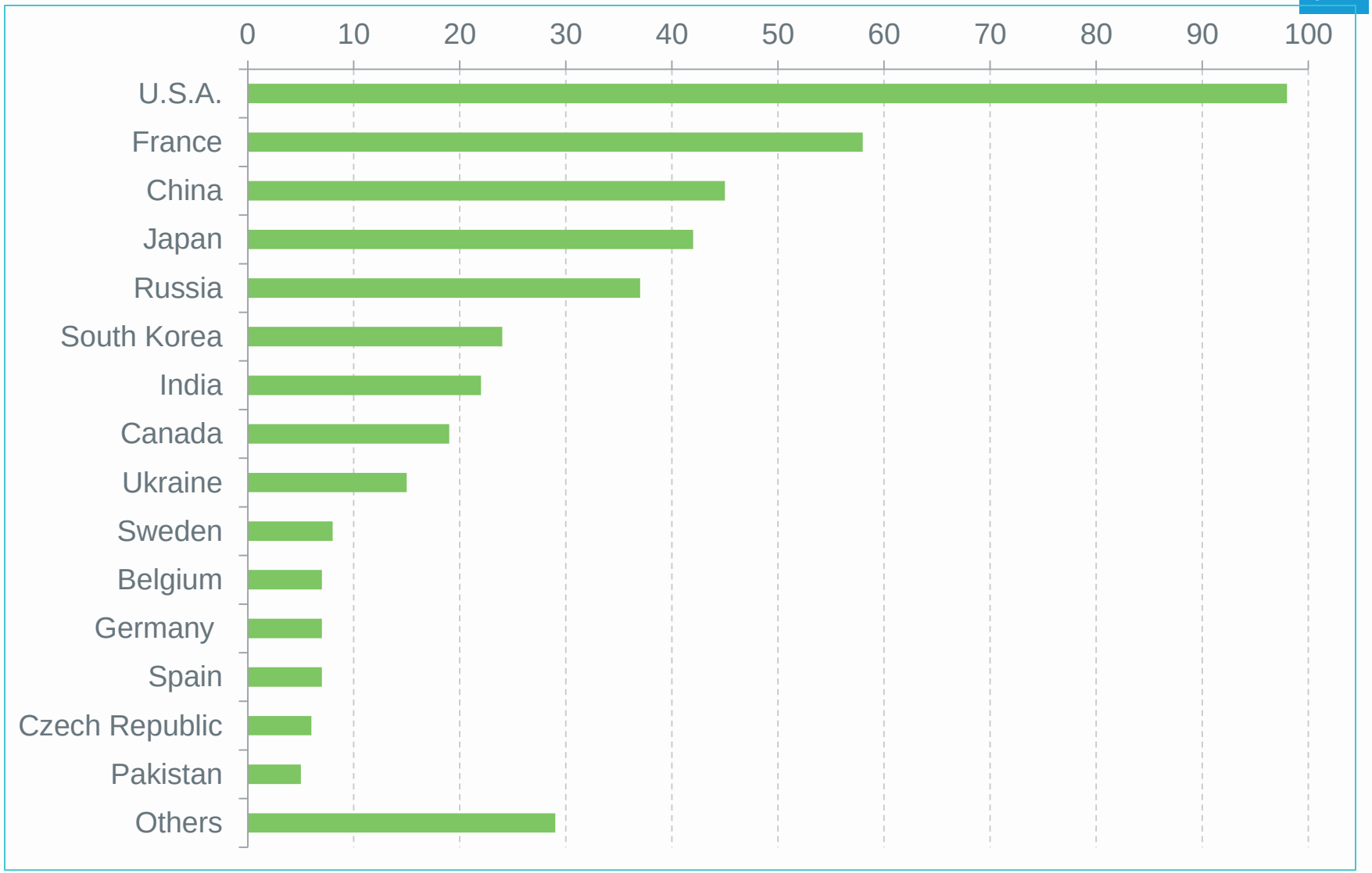
Availability of firm low-carbon resources reduces costs 10%–62% in zero-CO_2 cases

Without these resources, electricity costs rise rapidly as CO_2 limits near zero

Batteries and demand flexibility do not substitute for firm low-carbon resources

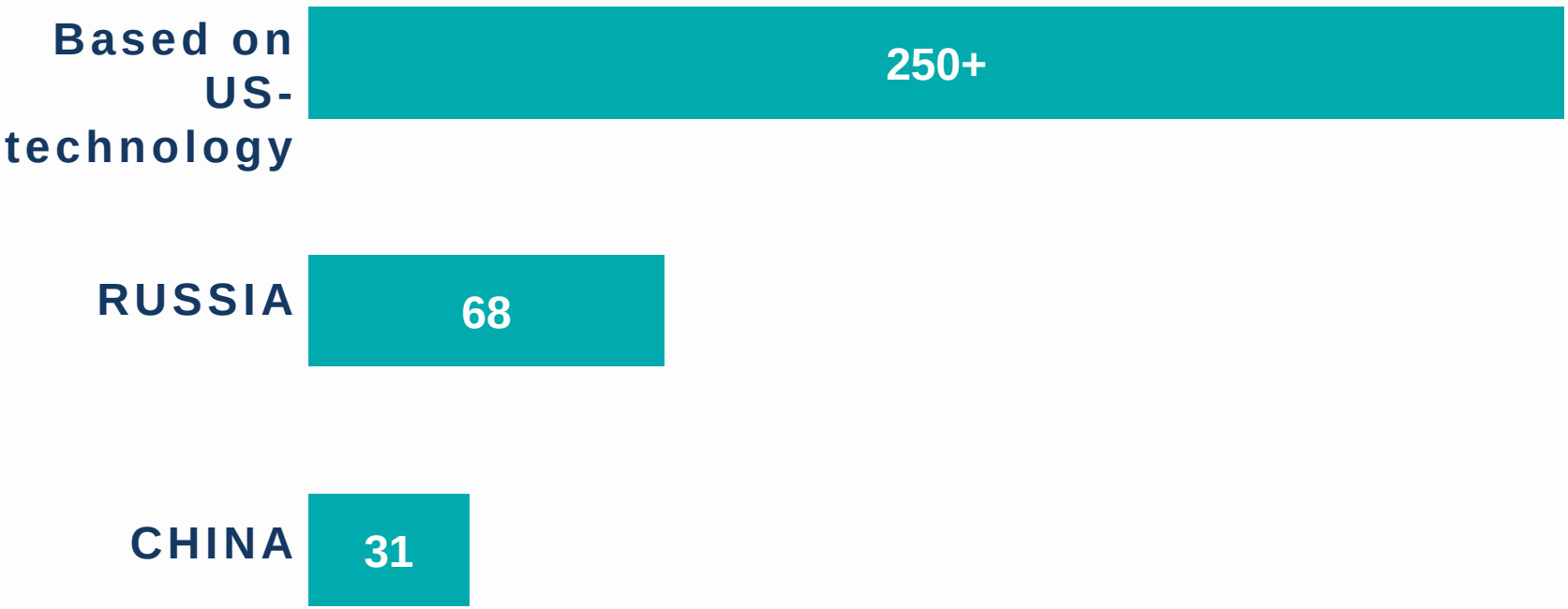
THRIVE

453 OPERATIONAL REACTORS AROUND THE WORLD



US NUCLEAR ENERGY TECHNOLOGY ONCE LED…

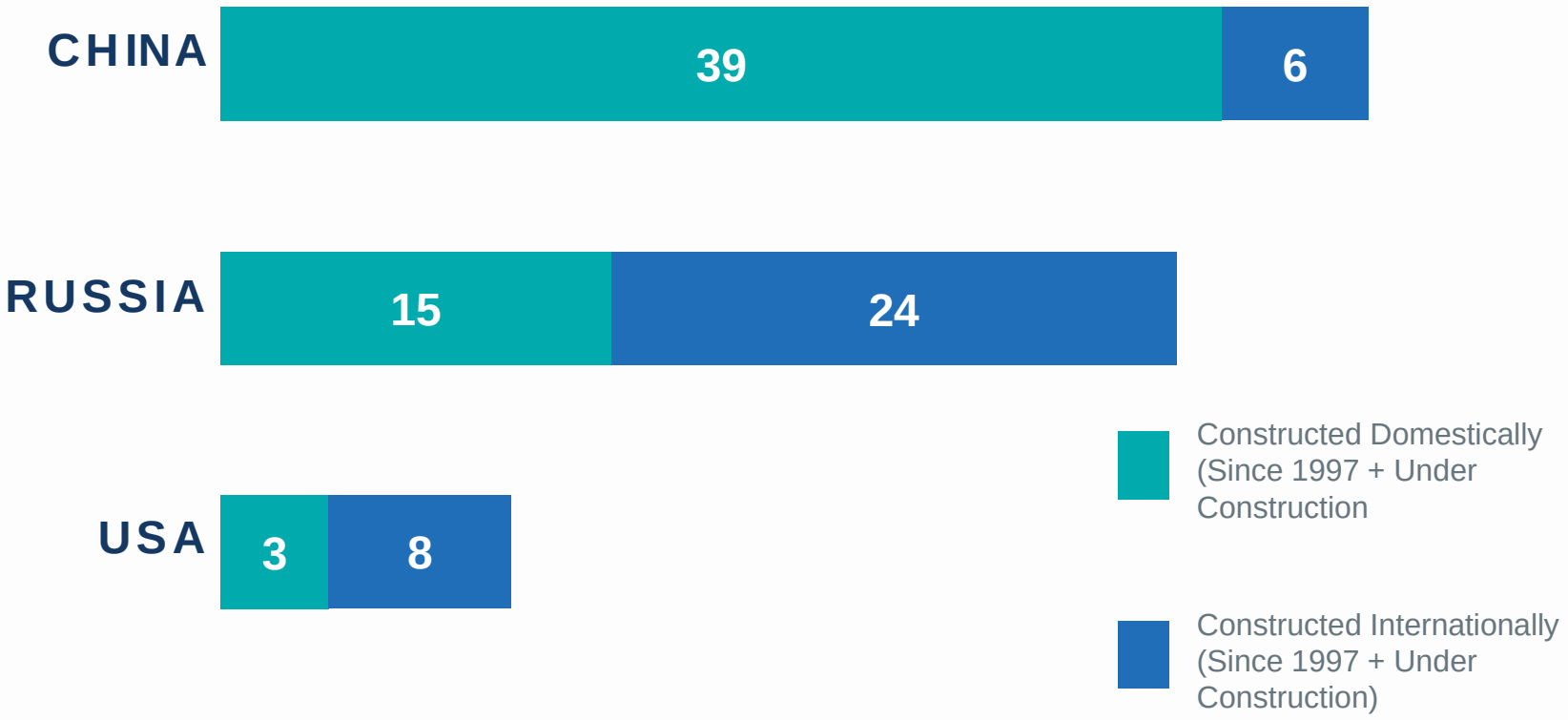
U.S. technology is the basis for most of the world's operating nuclear reactors



Source: International Atomic Energy Agency: PRIS Database
Updated: September 2018

…TODAY, RUSSIA AND CHINA ARE WINNING

China and Russia are leading in constructing their domestic designs



Source: International Atomic Energy Agency: PRIS Database
Updated: September 2018

A CENTURY-LONG RELATIONSHIP

Licensing & Construction

Cooperation on:

- Reactor system procurement
- Operator training
- Regulatory capacity
- Construction quality & safety
- Environmental protection

5-10 YEARS

Operations

Cooperation on:

- Physical security
- Cyber security
- Nuclear material protection & accountability
- Nuclear nonproliferation
- Supply of fuel & services
- Research & development
- Workforce development
- Nuclear materials transportation
- Operational safety & performance
- Safety regulation

60-80+ YEARS

Decommissioning

Cooperation on:

- Decommissioning services
- Decontamination technologies
- Nuclear waste management
- Environmental protection

5-10 YEARS

UNITED STATES

REUTERS

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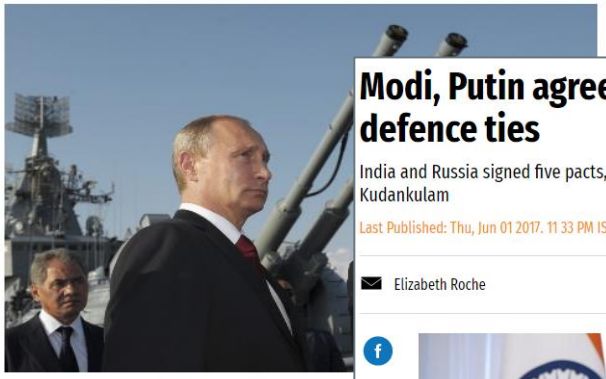
The Great Debate

Russia building nuclear reactors – and influence – around the globe

By Hannah Thoburn | April 29, 2015



Russian President Vladimir Putin (2nd L), his Egyptia
R) and Russia's Defense Minister Sergei Shoigu (L)
at the port of Sochi, August 12, 2014. REUTERS/Ale

Russia has been notoriously brazen in usi
national power. President Vladimir Putin's
headlines and sometimes left substantial p
in other energy-related areas have been le

Pakistan PM Nawaz Sharif Inaugurates Chinese-Assisted Nuclear Power Plant

World | Press Trust of India | Updated: December 28, 2016 16:25 IST

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if thanked China for extending cooperation in nuclear field. (File)

-starved Pakistan today received a major boost as a China-backed 340
lant, Chasma-III, in its Punjab province was inaugurated by Prime
rif who termed it as a milestone in the government's efforts to end the
dding. The Chashma-III plant is located at Chashma in Mianwali district

Modi, Putin agree to expand nuclear power plant, push defence ties

India and Russia signed five pacts, including a crucial agreement on setting up two more atomic power plants at Kudankulam

Last Published: Thu, Jun 01 2017. 11 33 PM IST

Elizabeth Roche

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The pact is seen as a major outcome of the talks between Prime Minister Narendra Modi and Russian President Vladimir Putin. Photo: Grigory Dukor/Reuters

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Chernobyl memories faded? Kiev turns blind eye to disaster risk in nuclear deal with US

Published time: 19 May, 2014 15:35
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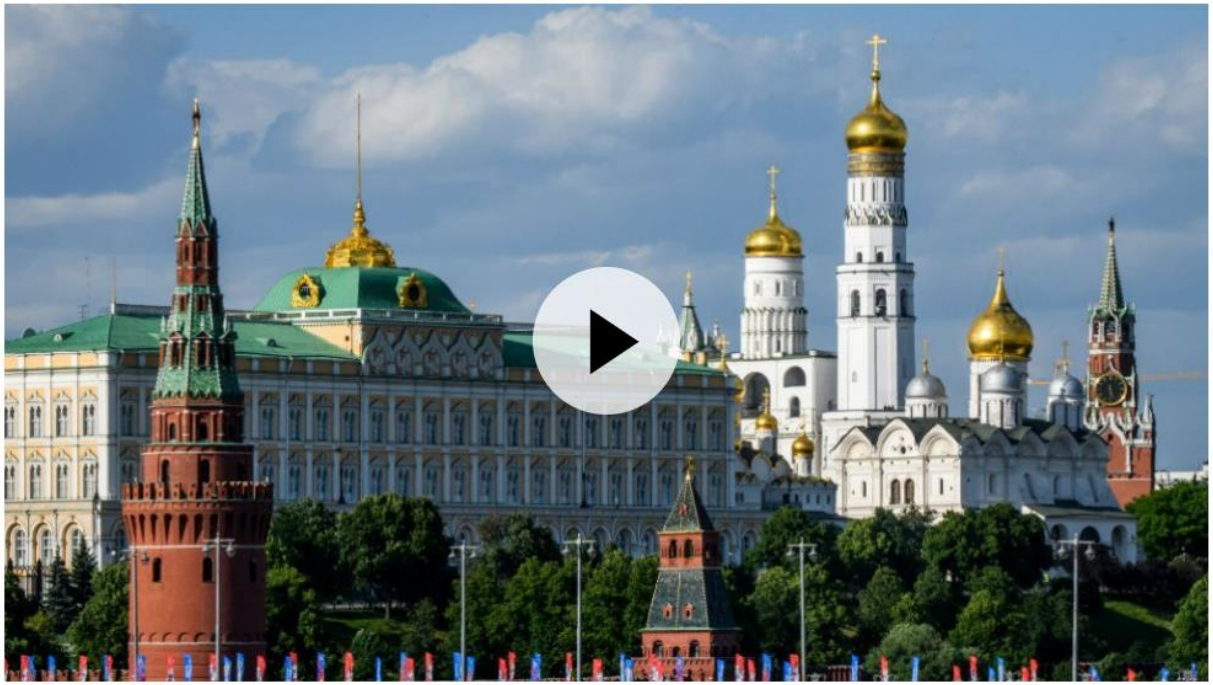
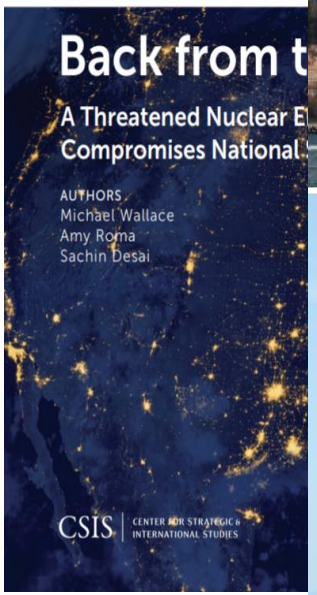
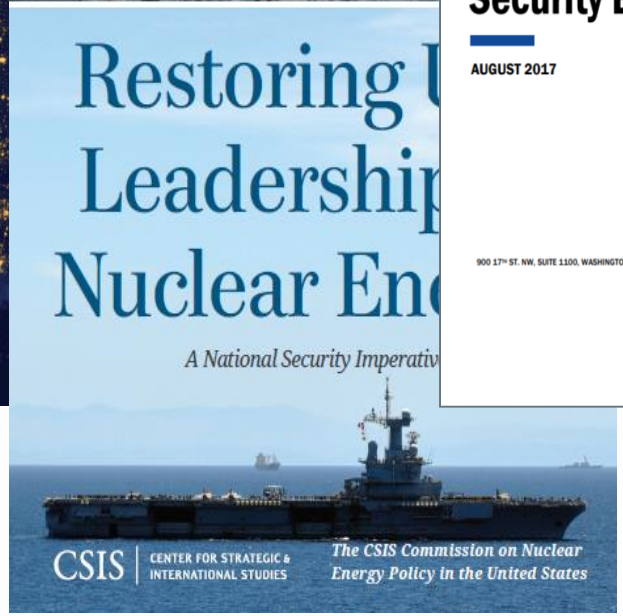


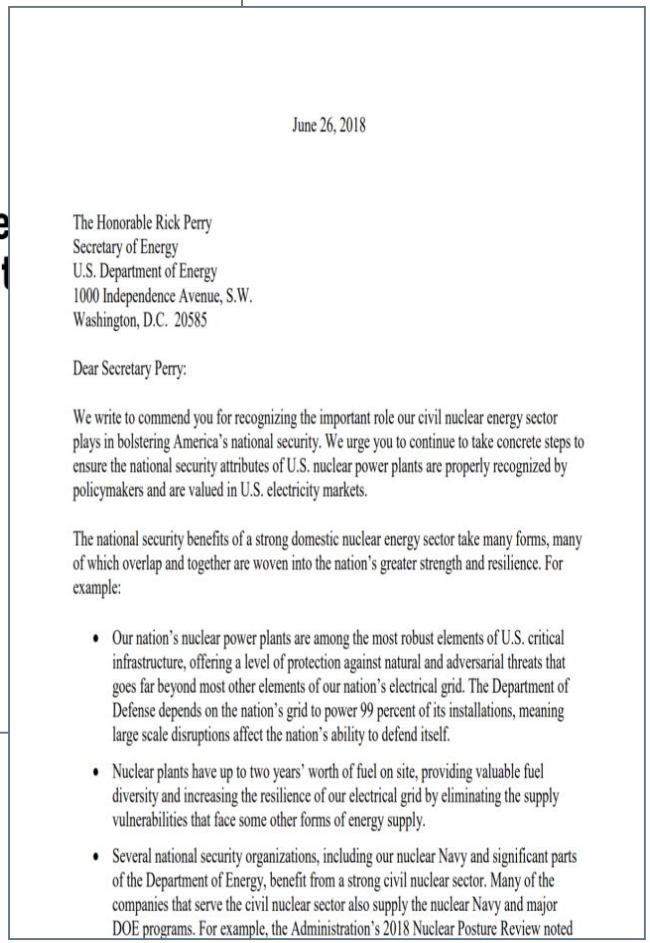
AFP (file photo) | The Kremlin in Moscow, Russia.

Text by: NEWS WIRES | Video by: Alison SARGENT

THE NATIONAL SECURITY IMPERATIVE







June 26, 2018

The Honorable Rick Perry
Secretary of Energy
U.S. Department of Energy
1000 Independence Avenue, S.W.
Washington, D.C. 20585

Dear Secretary Perry:

We write to commend you for recognizing the important role our civil nuclear energy sector plays in bolstering America's national security. We urge you to continue to take concrete steps to ensure the national security attributes of U.S. nuclear power plants are properly recognized by policymakers and are valued in U.S. electricity markets.

The national security benefits of a strong domestic nuclear energy sector take many forms, many of which overlap and together are woven into the nation's greater strength and resilience. For example:

- Our nation's nuclear power plants are among the most robust elements of U.S. critical infrastructure, offering a level of protection against natural and adversarial threats that goes far beyond most other elements of our nation's electrical grid. The Department of Defense depends on the nation's grid to power 99 percent of its installations, meaning large scale disruptions affect the nation's ability to defend itself.
- Nuclear plants have up to two years' worth of fuel on site, providing valuable fuel diversity and increasing the resilience of our electrical grid by eliminating the supply vulnerabilities that face some other forms of energy supply.
- Several national security organizations, including our nuclear Navy and significant parts of the Department of Energy, benefit from a strong civil nuclear sector. Many of the companies that serve the civil nuclear sector also supply the nuclear Navy and major DOE programs. For example, the Administration's 2018 Nuclear Posture Review noted

Creating A Brighter Nuclear Energy Future: The Essentials

- Markets and policies (e.g. CES) that fully value what nuclear delivers and stimulate new build
  - Current plants - ITC
  - New reactors – ITC or PTC
- Sustained successful operating of existing plants
  - Safe operations
  - Continually increasing operational efficiency
- Continued movement toward more risk-informed regulation

Creating A Brighter Nuclear Energy Future: The Essentials

- Investment in RDD&D that preserves U.S. status as leading innovator
  - Cost-effective, flexible new designs
  - Advanced fuels, I&C, materials, construction/fab techniques, etc.
  - Preserve existing & add new capabilities
- Success in export markets
  - Ex-Im Bank
  - Administration advocacy
- Increased public acceptance/social license
  - Resolve back-end of the fuel cycle
  - New approaches to siting, public engagement