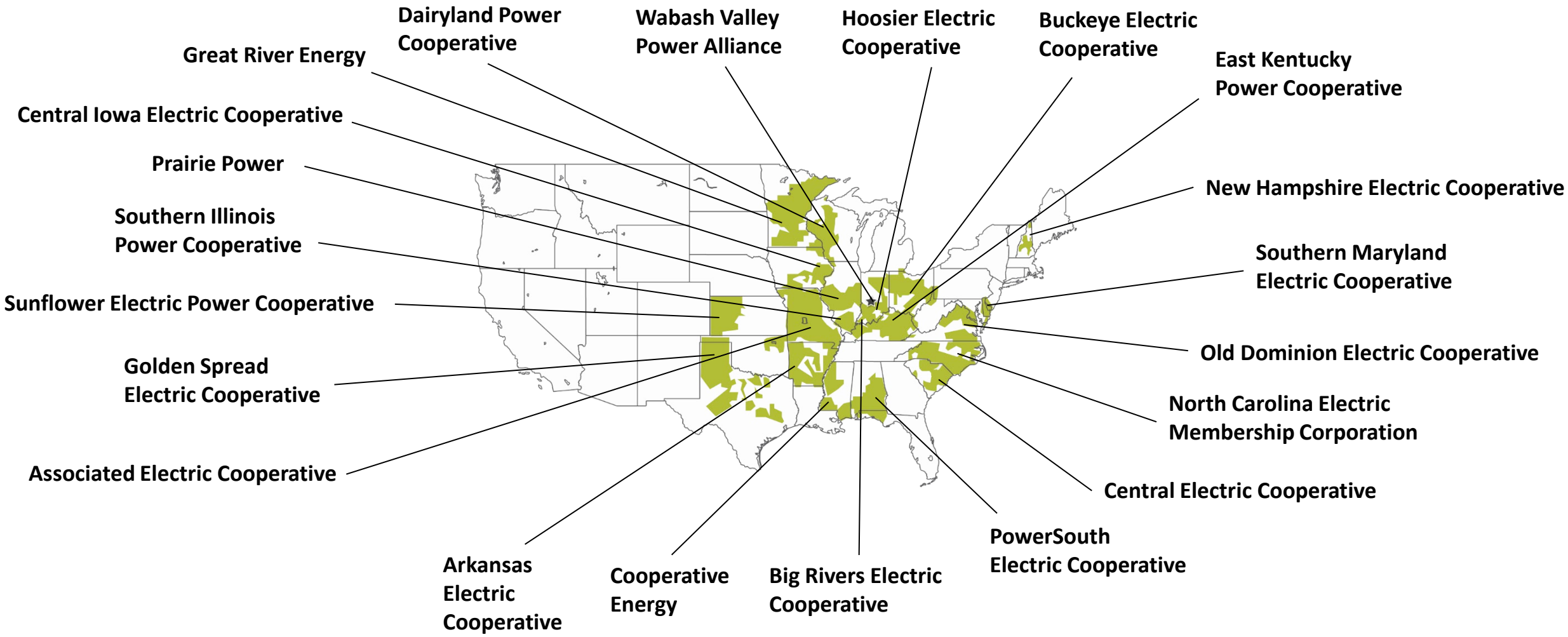
NATIONAL RENEWABLES COOPERATIVE ORGANIZATION

Market Opportunities & Challenges With Battery Storage And Other Emerging Technologies

Mike Keyser
Chief Executive Officer

February 14, 2022

Focused on Serving Our Members



Our Services

Market Intelligence Services

- NRCO Insider Newsletter
- Clean Energy Outlooks
- Information Hub
- Webinars
- Project Database
- Strategic Advice
- Member Sharing
- Presentations

Project Services

- Feasibility Studies
- Project Modeling
- Project Origination
- Project Management
- Program Development
- PPA Assistance

Recent NRCO Projects

NC Electric Cooperatives
Your Touchstone Energy® Cooperatives

- Member distribution system-connected solar + storage
- 16 projects
- 24 MW Solar
- 22 MW Lithium Ion Energy Storage
- Financed with CoBank lease program to capture ITC
- NRCO Role: led development, project management and financing

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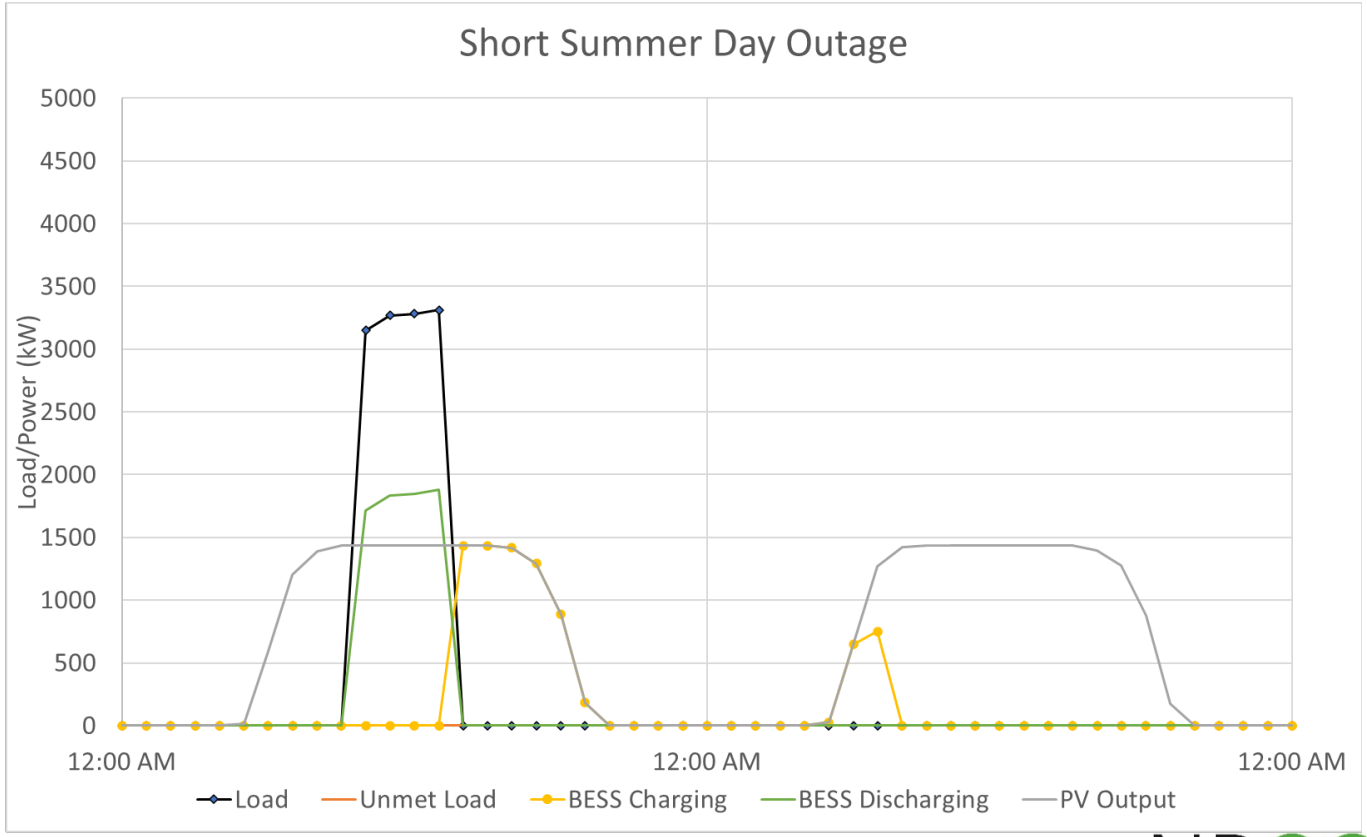
Feasibility Assessment

Feasibility Assessment of Solar + Lithium-Ion Battery Energy Storage (BESS) at Distribution Substation

- Analyze capability of BESS to improve reliability of power supply to substation
- Evaluate opportunities for BESS to participate in ancillary resource markets or energy arbitrage
- Compare overall economics of Solar + BESS solution as non-wires alternative to transmission line upgrade or voltage controls on distribution circuit



Different Contract Models

- Direct Ownership → **Most risk / reward**
  Full control
- Tolling Agreement ($ per kW-month) → **Less risk / reward**
  Mostly full control
- Shared Revenue Agreement → **Least risk / reward**
  No control

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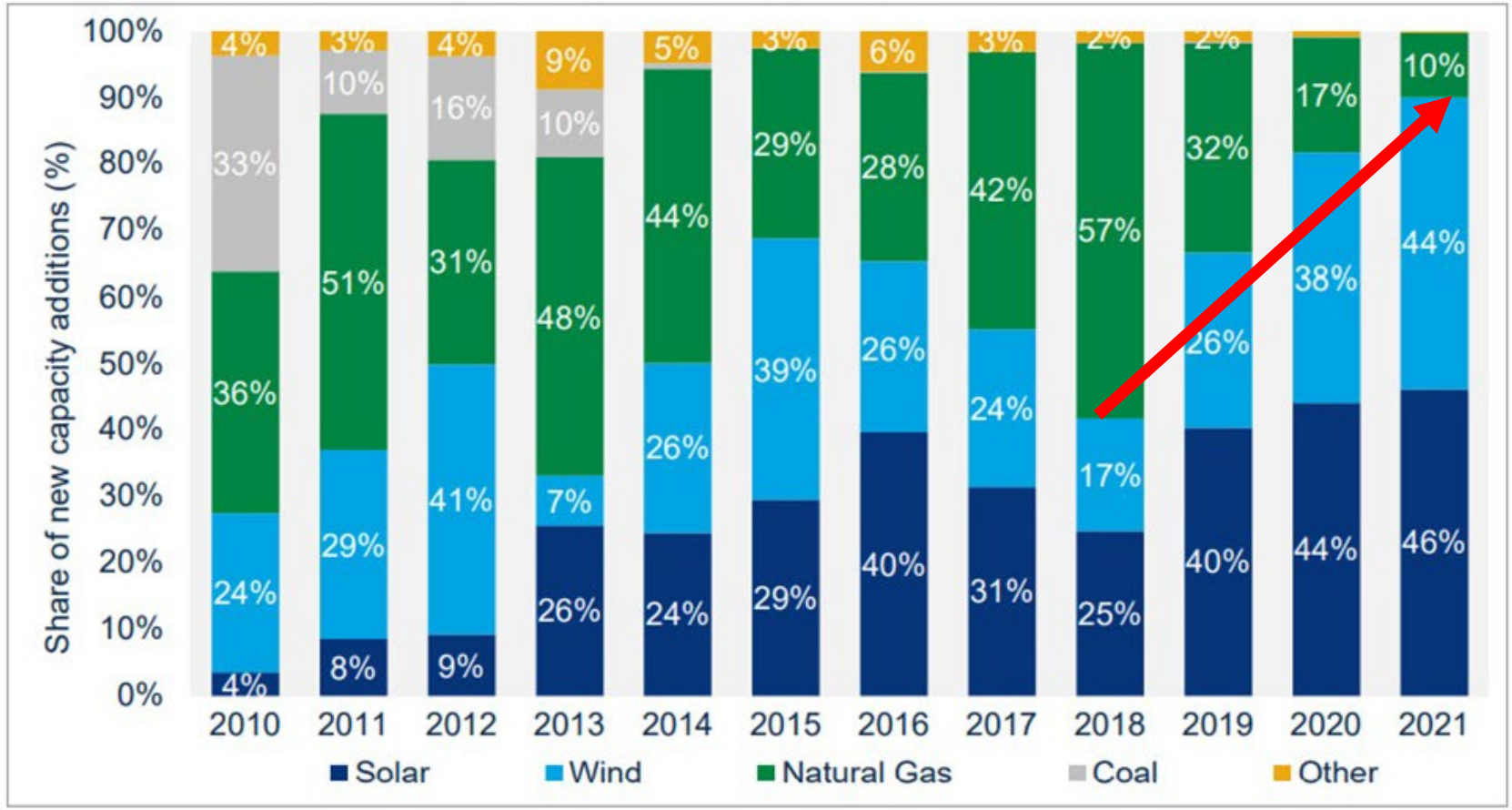
U.S. Electricity-Generating Capacity Additions (2010-2021)



Source: Wood Mackenzie, Federal Energy Regulatory Commission (for all other technologies); Note that some 2021 values were estimated based on Wood Mackenzie's North America Power Service data.

Source: WoodMac – "US Solar Market Insight: Executive Summary - 2021 Year in Review" (March 2022)

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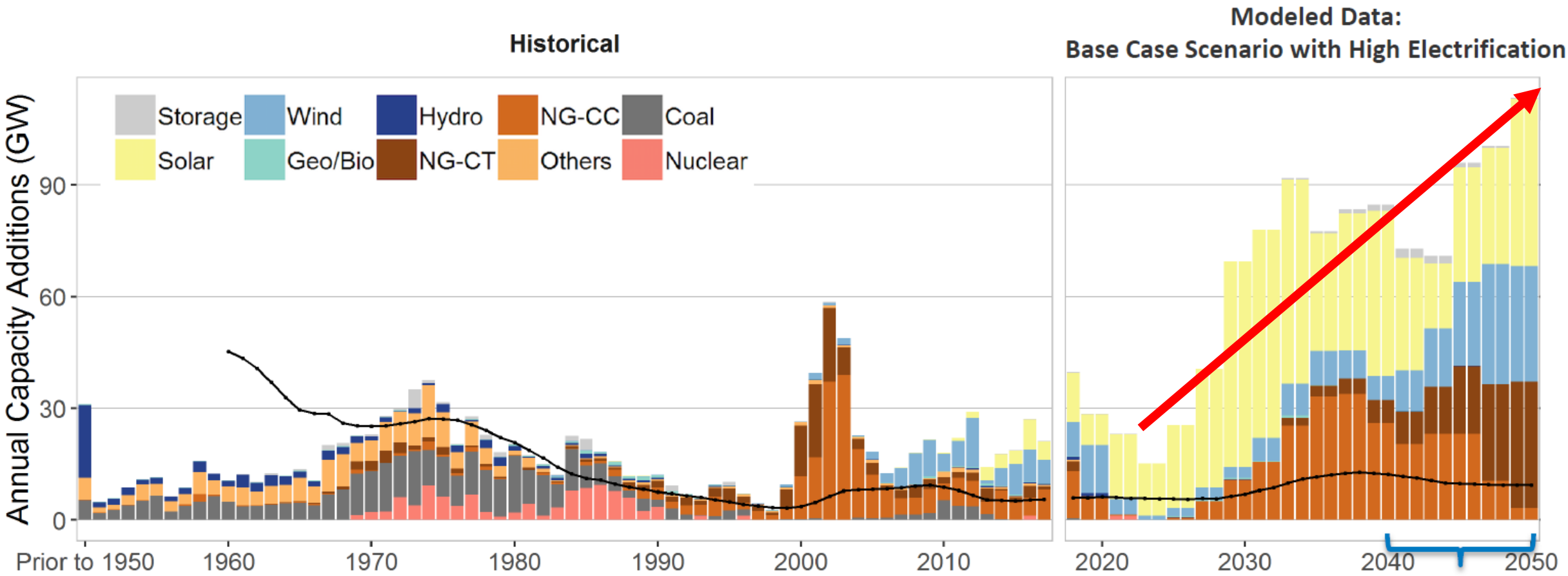
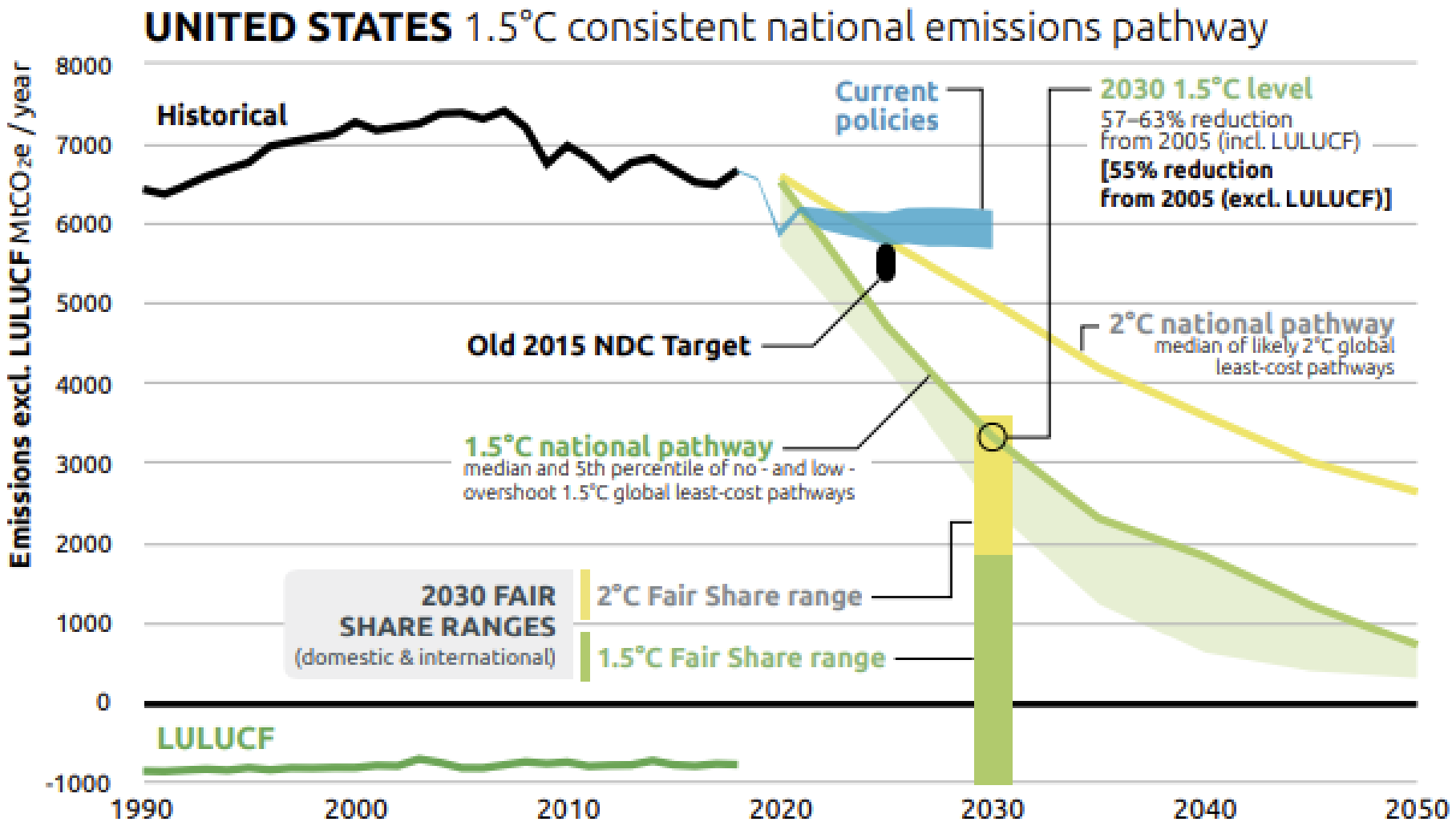
NREL: 50-65 GW RE/year



Solar: ~30-45 GW/yr
Natural Gas: ~35 GW/yr
Wind: ~20 GW/yr
even higher rates in some scenarios

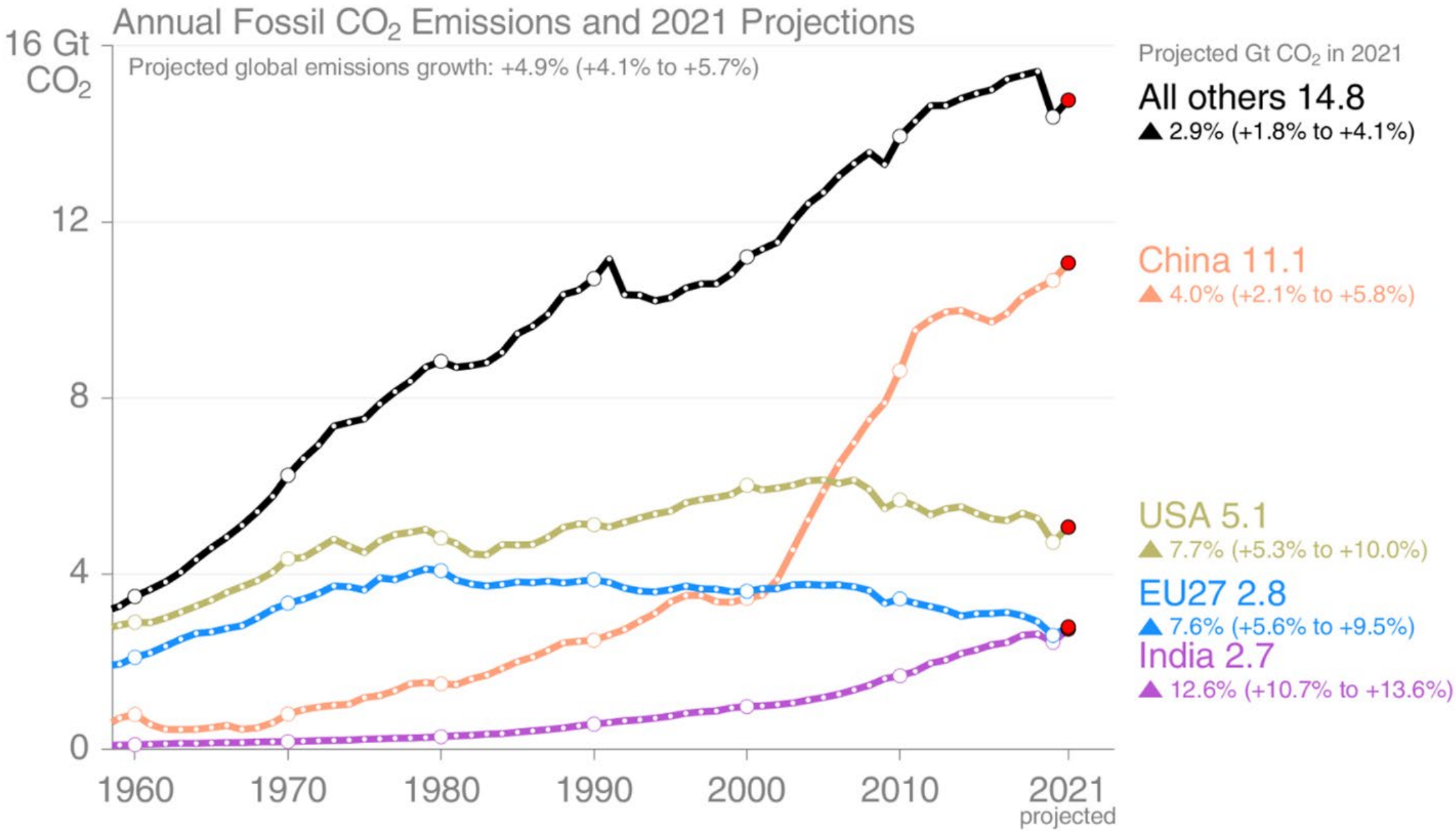
Murphy et al. (2021), https://www.nrel.gov/docs/fy21osti/72330.pdf

The Driving Force

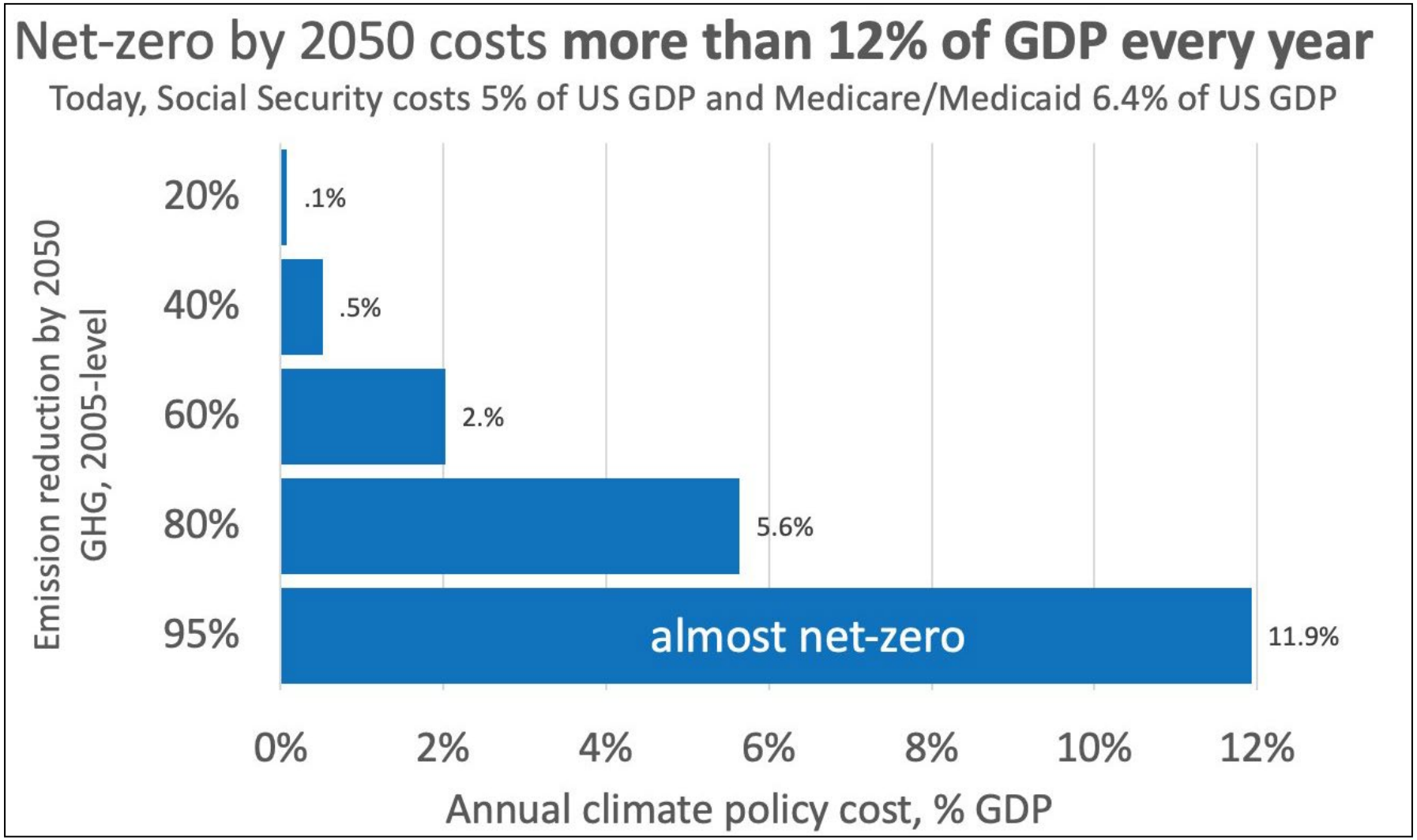


https://climateactiontracker.org/

LULUCF = Land Use Land Use Change Forestry aka natural syncs


Annual Fossil CO_2 Emissions and 2021 Projections
16 Gt CO_2
Projected global emissions growth: +4.9% (+4.1% to +5.7%)
12
8
4
0
1960
1970
1980
1990
2000
2010
2021
projected
Projected Gt CO_2 in 2021
All others 14.8
▲ 2.9% (+1.8% to +4.1%)
China 11.1
▲ 4.0% (+2.1% to +5.8%)
USA 5.1
▲ 7.7% (+5.3% to +10.0%)
EU27 2.8
▲ 7.6% (+5.6% to +9.5%)
India 2.7
▲ 12.6% (+10.7% to +13.6%)

Cost of Net Zero (Current Technology)



Source: Nature Climate Change – "The surprisingly inexpensive cost of state-driven emission control strategies" (August 23, 2021).

Inflation Reduction Act

- Long-term tax credit runway
  - Revamped ITC/PTC landscape in place thru 2032+
- Direct pay
  - Coops finally can access renewable credits and self-development
  - Provides an alternate route to working through developers and Wall Street
- Standalone BESS credit
  - Liberates energy storage from the solar/wind co-development shackles

Monitoring Emerging Technologies

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BESS Market Opportunities

In Front of the Meter

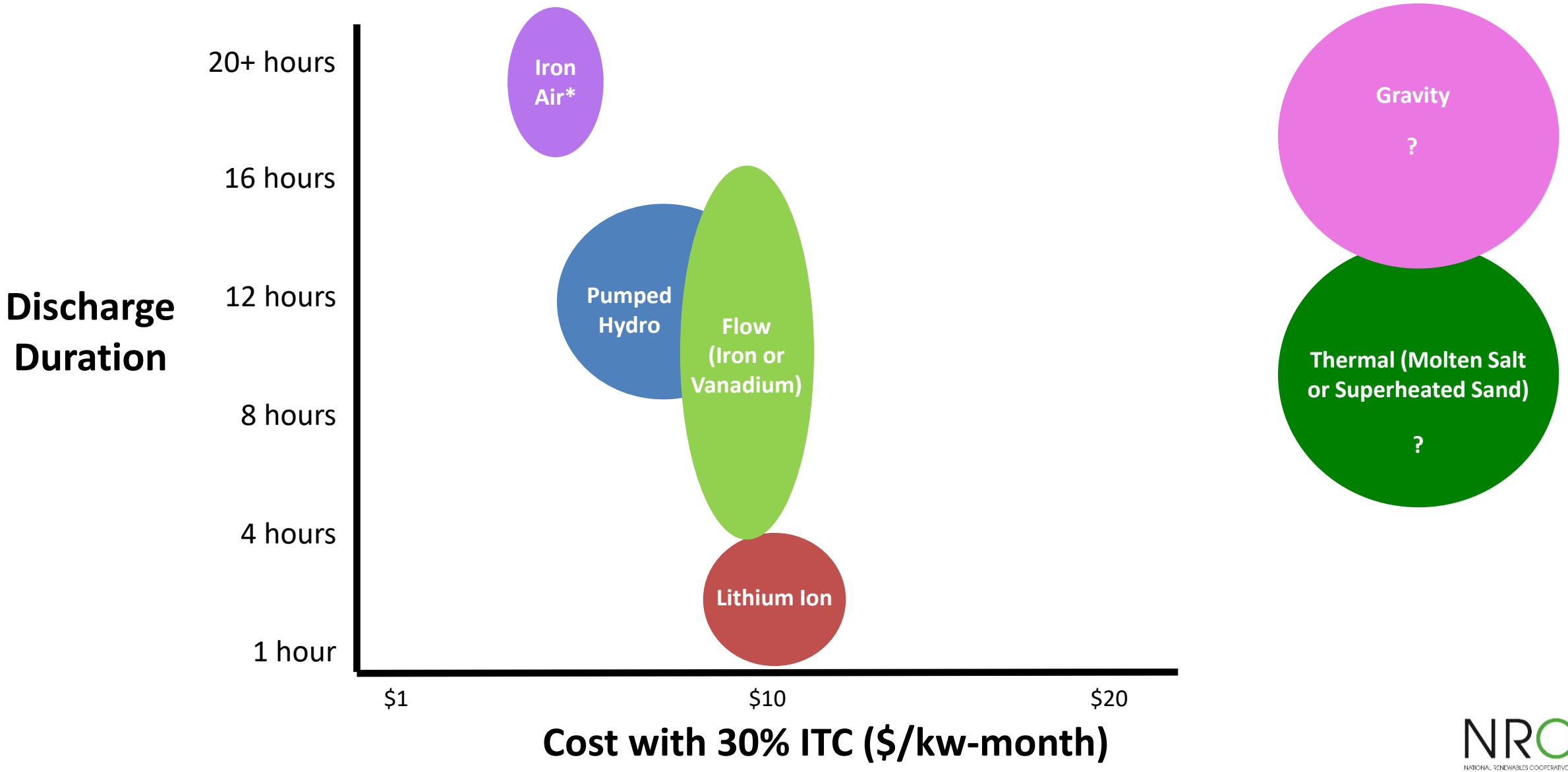
- Energy arbitrage
- Capacity accreditation
- Ancillary services
- Transmission congestion relief
- Transmission upgrade deferral
- Resource adequacy
- Renewables smoothing (if paired)

Behind the Meter

- Energy arbitrage
- Demand / transmission charge avoidance
- Ancillary services
- Distribution upgrade deferral
- Reliability improvement/backup power
- Renewables smoothing (if paired)

“Stack” the Value Streams to Make a Business Case

Battery Technologies



Key Battery Terms

Key Terms	
Capital Cost	$24,000,000
Power Rating	10 MW
Energy Rating	40 MWh
Cycles Per Year	365
Operating Cost	$750,000 / year

Power Rating / Energy Rating

10 MW / 40 MWh

$$\frac{\$24{,}000{,}000}{40{,}000\ \text{kWh}} = \$600/\text{kWh}$$

(Just a number!)

Not to be confused with…

$$\frac{(\$24{,}000{,}000 + (\$750{,}000 * 20\ \text{years})}{(365 * 20\ \text{years} * 40{,}000\ \text{kWhs})} = \$0.13/\text{kWh}$$

Levelized Cost of Storage (LCOS)

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Lithium-Ion

Pros

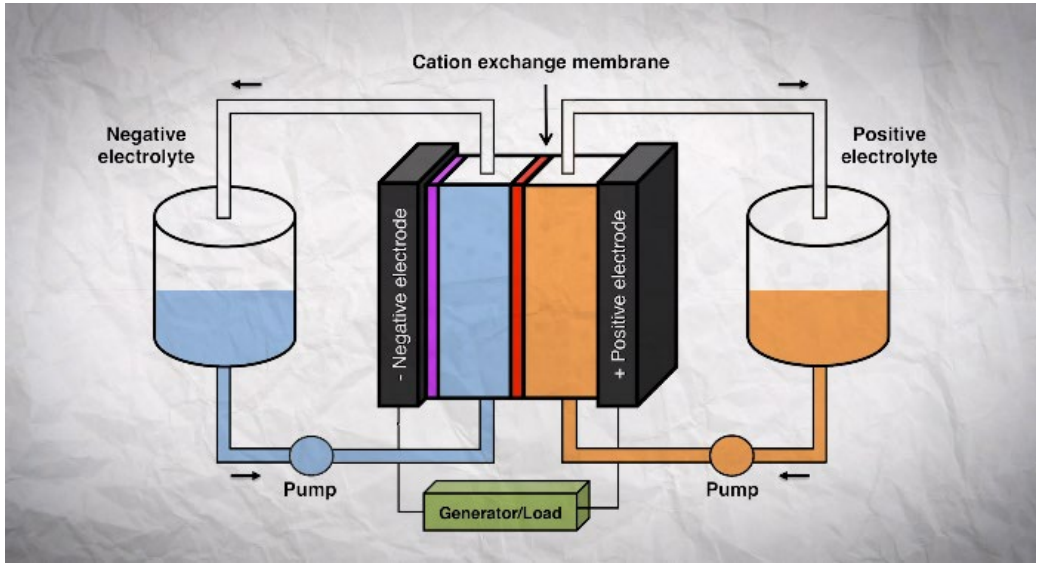
- Rapid-response shock absorbers
- Great for peak reductions
- Can produce multiple value streams
- Power sector benefiting from Li-ion R&D from transportation sector

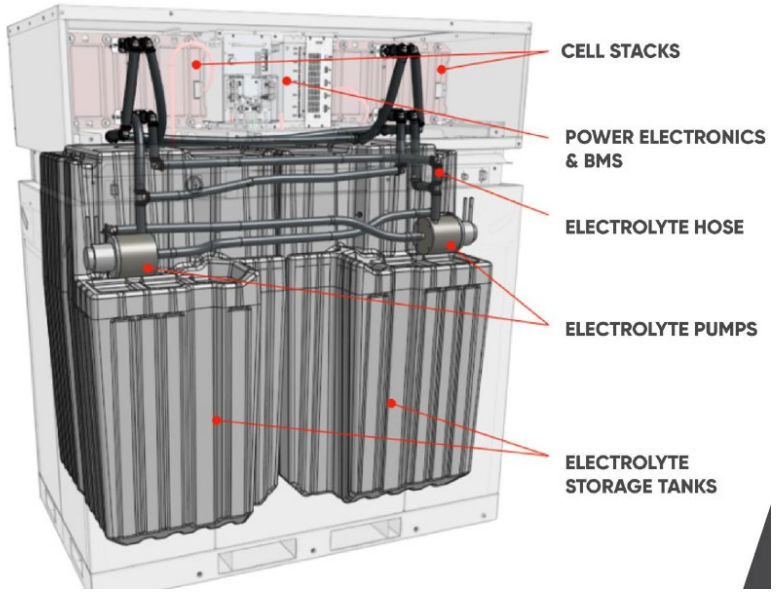
Cons

- Maximum 4 hour duration
- Battery degradation
- Supply/demand constraints
- Location of minerals
- Cost
- Frequent O&M
- Power competing with transportation sector for minerals

Flow Batteries

- Energy discharge: 4 – 18 hours
- 10,000-plus battery cycles with little or no loss of storage capacity
- 20-30 years with little or no fire hazard
- Power/energy decoupling
- Commercialization by ESS, Invinity and Lockheed Martin
- Reaching cost-parity with Li-ion today





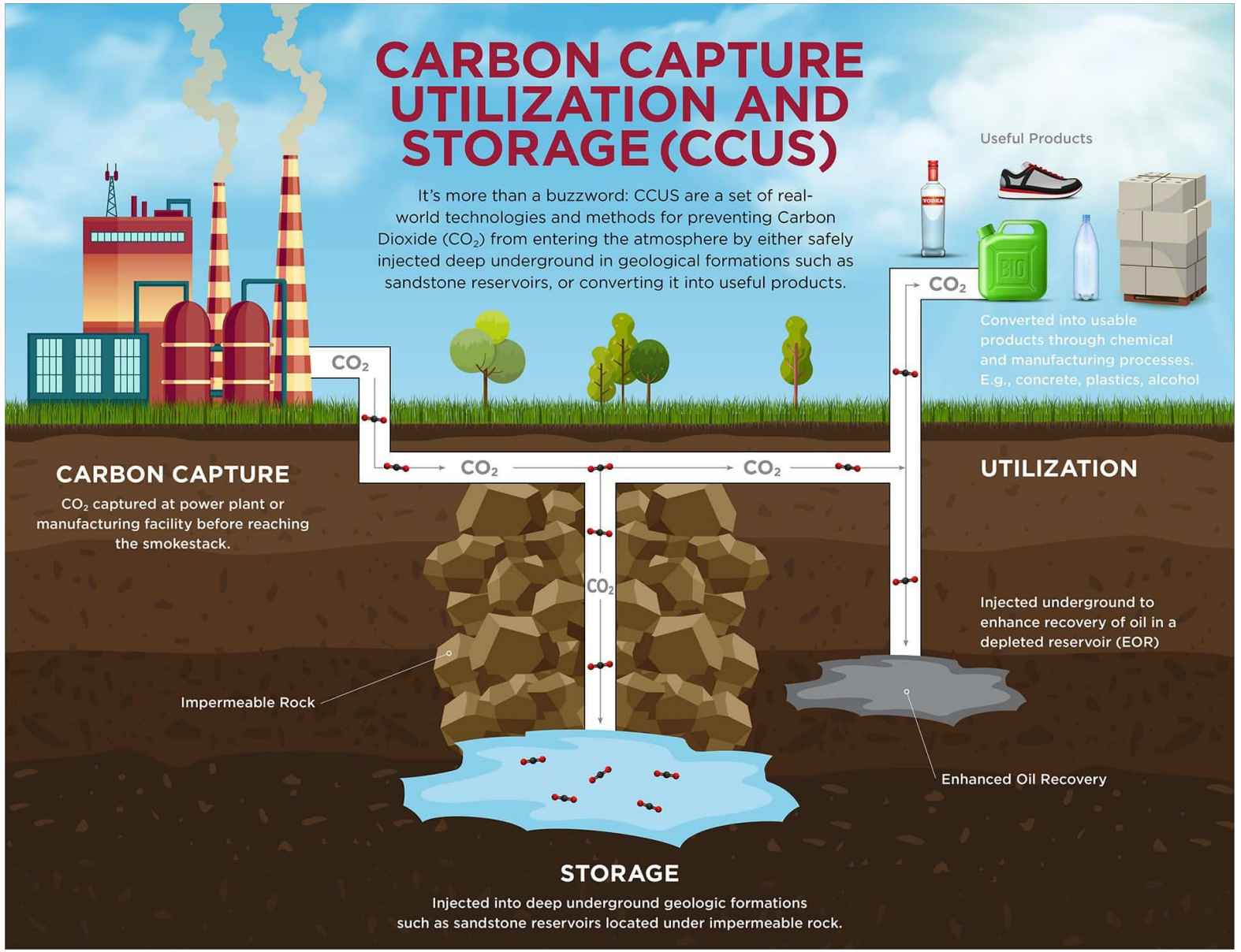
Source: PowerMag.com: "Flow Batteries: Energy Storage Option for a Variety of Uses" (March 2, 2020)

Other Emerging Technologies

Carbon Capture, Utilization & Storage (CCUS)

Green Hydrogen

Carbon Capture, Utilization & Storage



CCUS

Pros

- World is still deeply dependent on hydrocarbons
- Many nations have sizable young coal-fired generation fleets
- U.S. 45Q tax credits available
  - **$85/mt sequestered**
  - **Direct pay eligible**

Cons

	CAPEX	Efficiency
CCGT*	+ 150%	-10%
Coal*	+40-50%	-30%

- Not capturing 100%
- Transportation and storage challenges
- Parasitic loss
- High risk vis a vis other technology choices

** Cost and Performance Baseline for Fossil Energy Plants – Vol I" - DOE/NETL - September 24, 2019, https://climate.mit.edu/, and IPCC Special Report on Carbon Dioxide Capture and Storage*

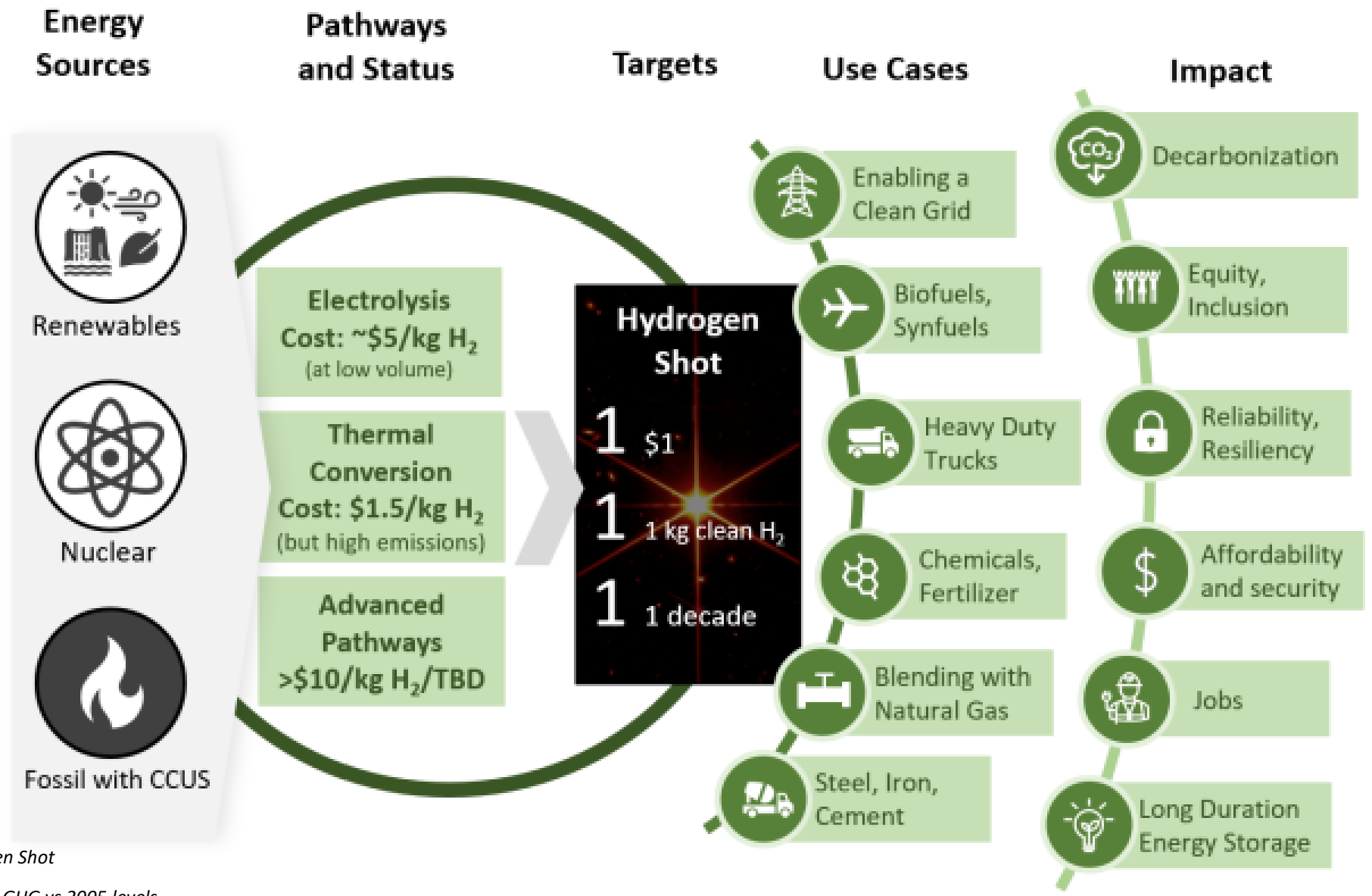
CCUS By The Numbers

$ 4,663,703,166	total tax benefits
	(direct pay)
$ 2,460,000,000	CCS retrofit cost
$ 2,592,000,000	12 year parasitic loss
$ 738,000,000	12 year O&M
$ 720,000,000	12 year transport & storage
$ 5,790,000,000	all-in 12 year cost
$ (1,126,296,834)	Simple payback

$ 99,936,496	total tax benefits
	(direct pay)
$ 1,420,000,000	CCS retrofit cost
$ 72,000,000	12 year parasitic loss
$ 426,000,000	12 year O&M
$ 24,000,000	12 year transport & storage
$ 1,918,000,000	all-in 12 year cost
$ (1,818,063,504)	Simple payback

Green Hydrogen

Hydrogen Decarbonization Hopes



Source: DOE Hydrogen Shot

- *10% Reduction in GHG vs 2005 levels*

Hydrogen

Pros

- Emissions = Water
- GE HA turbines can presently handle a 50/50 H_2 and natural gas blend:*
  - 25% CO_2 reduction vs. natural gas-only
  - 2030 is GE's goal for 100% H_2 capability
- IRA Hydrogen Incentives
  - Inputs
    - 30% ITC + for Solar/Wind/Energy Storage
    - 45Q – Carbon Capture Credits
  - Output
    - 45V – Hydrogen Production Tax Credit
    - Up to $3.00/kg

Cons

- Production – Not a fuel; it must be made
  - From Fossil Fuels: 95% comes from NG
  - Electrolysis Split Water into Hydrogen and Oxygen
    - Powered by Nuclear or Renewables (A Lot of MW Needed)
- Distribution
  - Can embrittle steel and other metals, weakening them to the point of fracture
- Storage
  - At room temp holds less than 1/300th the energy of gas
  - Liquification – Cooling process that requires energy
  - Compression – strong tanks = low volume
  - Solid State – metal hydrides
- Costs**
  - Today $4-$6/kg = $32-$48/MMBtu
  - 2050 - $0.80-$1.60/kg = $6.4-$12.80/MMBtu

** Source: GE – www.ge.com/power/future-of-energy*

** BNEF

1 Turbine Example

- GE 9F.04 288MW Plant 12-hour run
  - 22,400 kg/hr of Hydrogen needed
  - 49.3kWh* of energy to produce 1kg/H2
    - 13,252 MWh for a 12-hour run
  - Cost of input fuel (wind & solar)
    - 13,252MWh *$40/MWh = $530,080
    - $530,080/ 22,400kg = $1.97/kg = $15.76/MMBtu
  - Capacity Needed for 1 Turbine
    - 50% Wind 50% Solar
    - Blended Capacity Factor = 40%
    - Capacity Needed = 1,380MW

To replace all NG used for Electricity Generation you would need ~ 1,232,500 MW of Wind & Solar

Seeking Alpha

** Assumes 80% Efficiency*

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Final Thoughts

50 Years of Climate Warnings

1972: UN "environment protection boss" warns:

"We have ten years to stop the catastrophe"


DAGENS NYHETER Tisdagen den 25 januari 1972

FN:s "miljövårdschef" varnar:

"Vi har tio år på oss att hejda katastrofen"

Arbetsgivarna vill förlänga HTF-avtalet

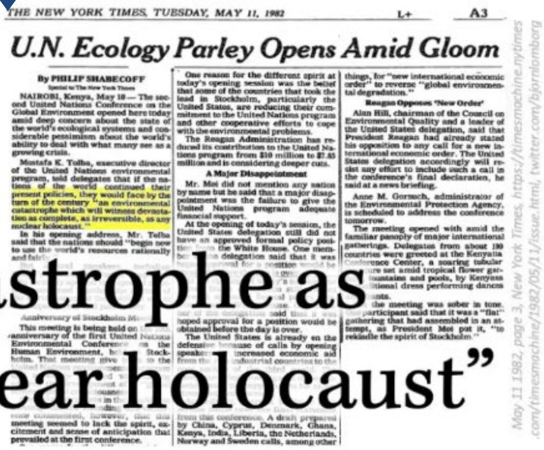
1972

1982

1982: *Tolba, head of UN Environment Programme in The New York Times:*

If the nations of the world continue their current policies they will face **by the year 2000:**

"an environmental catastrophe as irreversible as any nuclear holocaust"


THE NEW YORK TIMES, TUESDAY, MAY 11, 1982

U.N. Ecology Parley Opens Amid Gloom

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50 Years of Climate Warnings

***1989**: Senior UN environmental official tells Associated Press, published around the world*

We have to fix climate change **by 1999** or **climate change goes beyond human control** :

"Global disaster, nations wiped off the face of the earth, crop failures"

U.N. Predicts Disaster if Global Warming Not Checked

PETER JAMES SPIELMANN June 30, 1989

Associated Press

UNITED NATIONS (AP) _ A senior U.N. environmental official says entire nations could be wiped off the face of the Earth by rising sea levels if the global warming trend is not reversed by the year 2000.

Coastal flooding and crop failures would create an exodus of "eco- refugees,' ' threatening political chaos, said Noel Brown, director of the New York office of the U.N. Environment Program, or UNEP.

He said governments have a 10-year window of opportunity to solve the greenhouse effect before it goes beyond human co

Coastal regions will be inundated; one-sixth of Bangladesh could be flooded, displacing a fourth ... in the Nile Delta would be flooded, cutting ... and U.S. Environmental Protection Agency study.

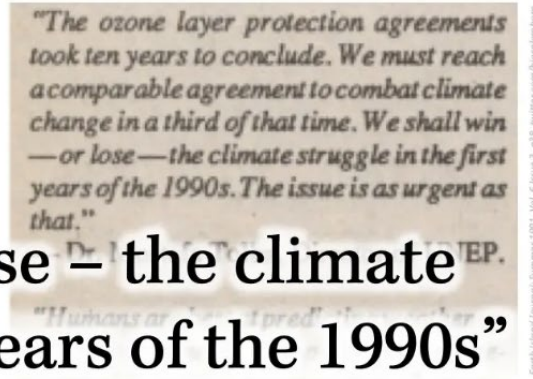
1989

1990

***1990**: Mostafa Tolba, head of UN Environment Programme:*

We must to fix climate change before 1995:

"We shall win – or lose – the climate struggle in the first years of the 1990s"



"The ozone layer protection agreements took ten years to conclude. We must reach a comparable agreement to combat climate change in a third of that time. We shall win —or lose—the climate struggle in the first years of the 1990s. The issue is as urgent as that."

EP.

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50 Years of Climate Warnings

***2007**: Rajendra Pachauri, head of the UN Climate Panel:*

"What we do in the next two to three years will determine our future"

"If there is no action before 2012, that's too late"

U.N. Chief Seeks More Leadership on Climate Change

Rosenthal, Elisabeth; Andrew C. Revkin contributed reporting from New York.
New York Times, Late Edition (East Coast); New York, N.Y. [New York, N.Y]. 18 Nov 2007: 1.3.

Abstract

The New York Times

Translate

...an] said of the ...on Climate ...

"If there's no action before 2012, that's too late," said Rajendra Pachauri, a scientist and economist who heads the IPCC. "What we do in the next two to three years will determine our future. This is the defining moment."

2007

2019

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MEETINGS COVERAGE

GENERAL ASSEMBLY — GA/12131
SEVENTY-THIRD SESSION, HIGH-LEVEL MEETING ON CLIMATE AND SUSTAINABLE DEVELOPMENT (AM & PM) — 28 MARCH 2019

Only 11 Years Left to Prevent Irreversible Damage from Climate Change, Speakers Warn during General Assembly High-Level Meeting

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Thank you

Mike Keyser

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