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SEPTEMBER 8-9, 2021

NET-ZERO AMERICA

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POTENTIAL PATHWAYS, INFRASTRUCTURE, AND IMPACTS

E. Larson, C. Greig, J. Jenkins, E. Mayfield, A. Pascale, C. Zhang, J. Drossman, R. Williams, S. Pacala, R. Socolow, EJ Baik, R. Birdsey, R. Duke, R. Jones, B. Haley, E. Leslie, K. Paustian, and A. Swan, *Net-Zero America: Potential Pathways, Infrastructure, and Impacts*, interim report (345 pages), Princeton University, Princeton, NJ, December 15, 2020. Report, annexes, and data downloadable at

https://netzeroamerica.princeton.edu

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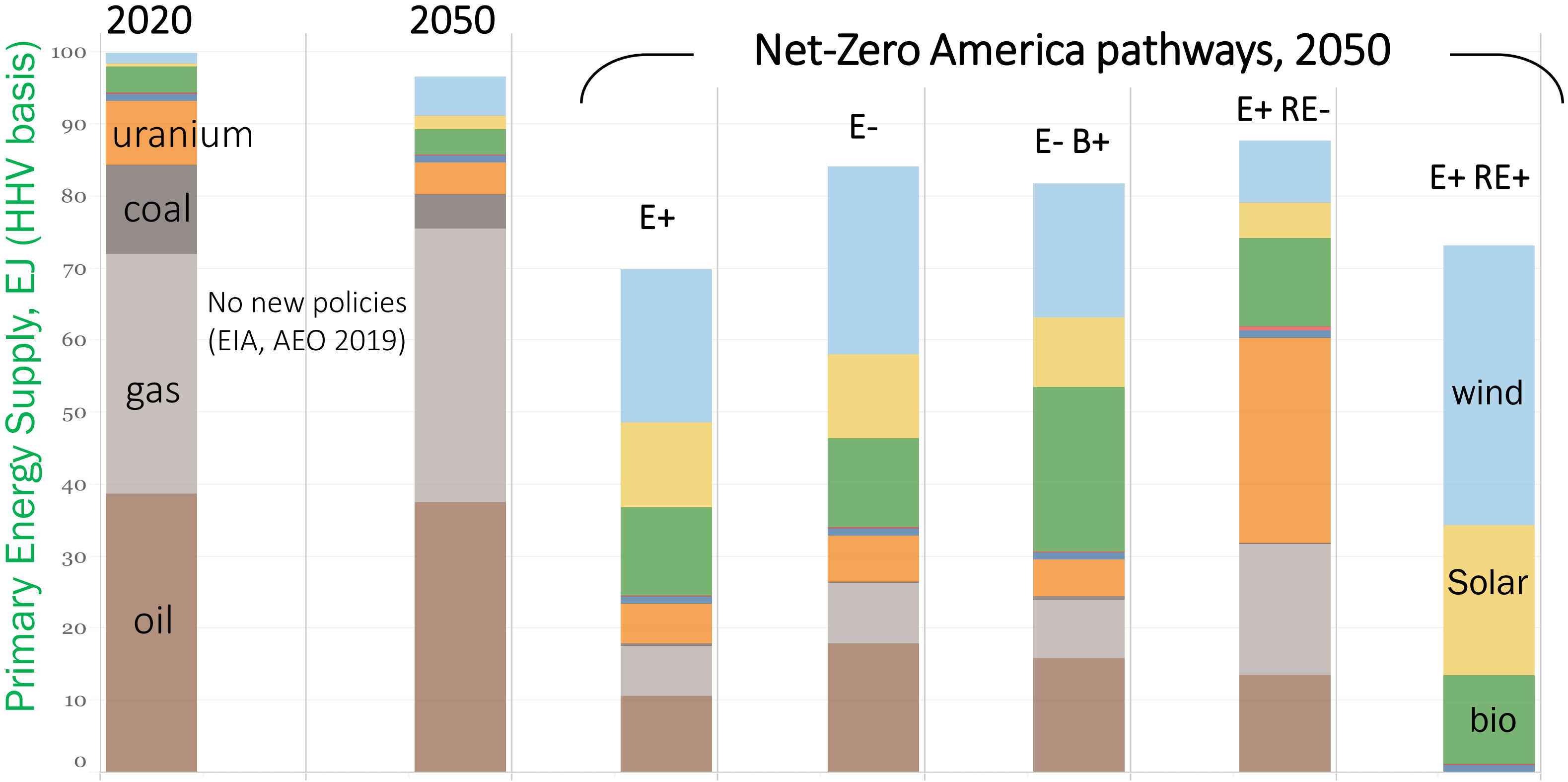
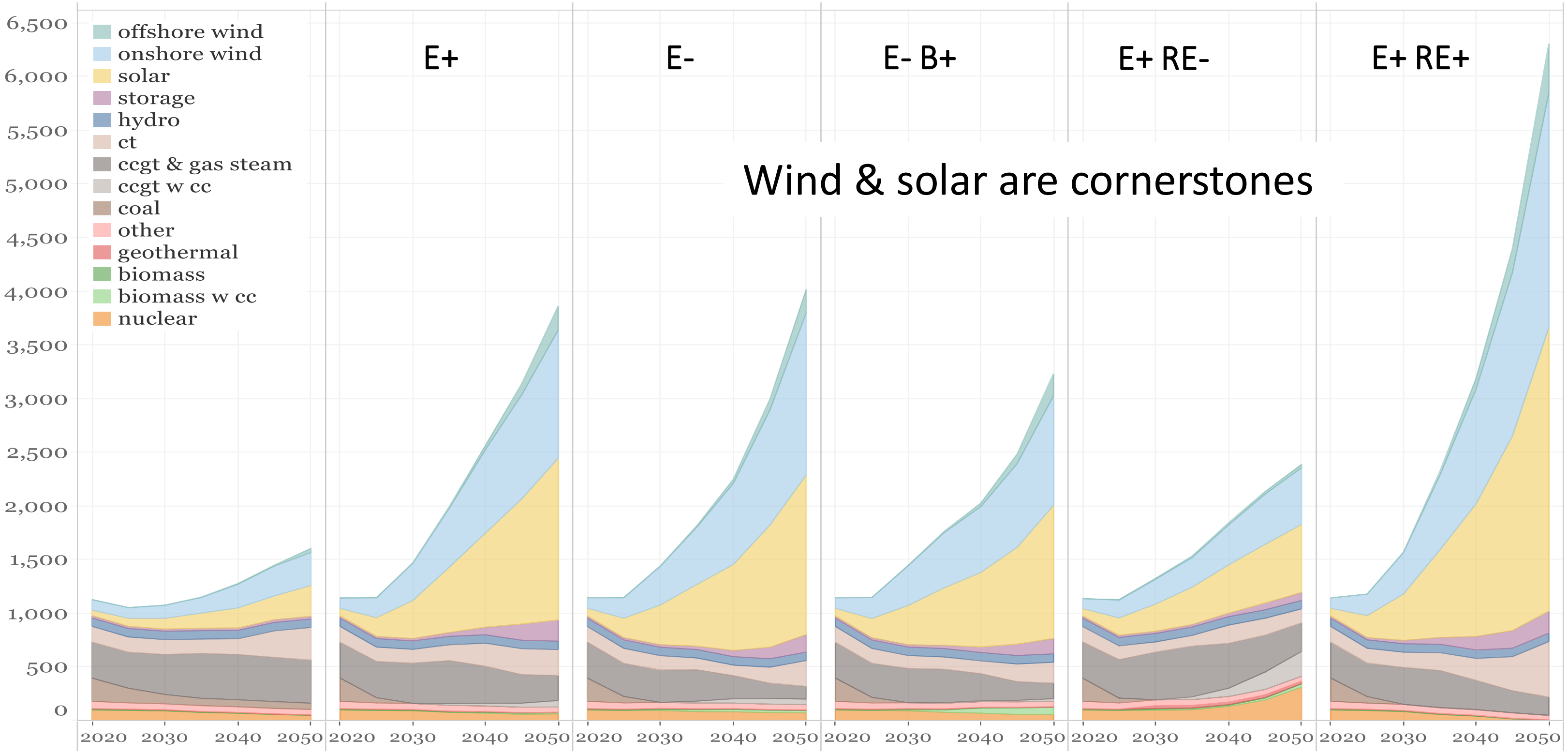
Carbon Mitigation Initiative

5 Technologically Diverse Pathways to Net-Zero in 2050



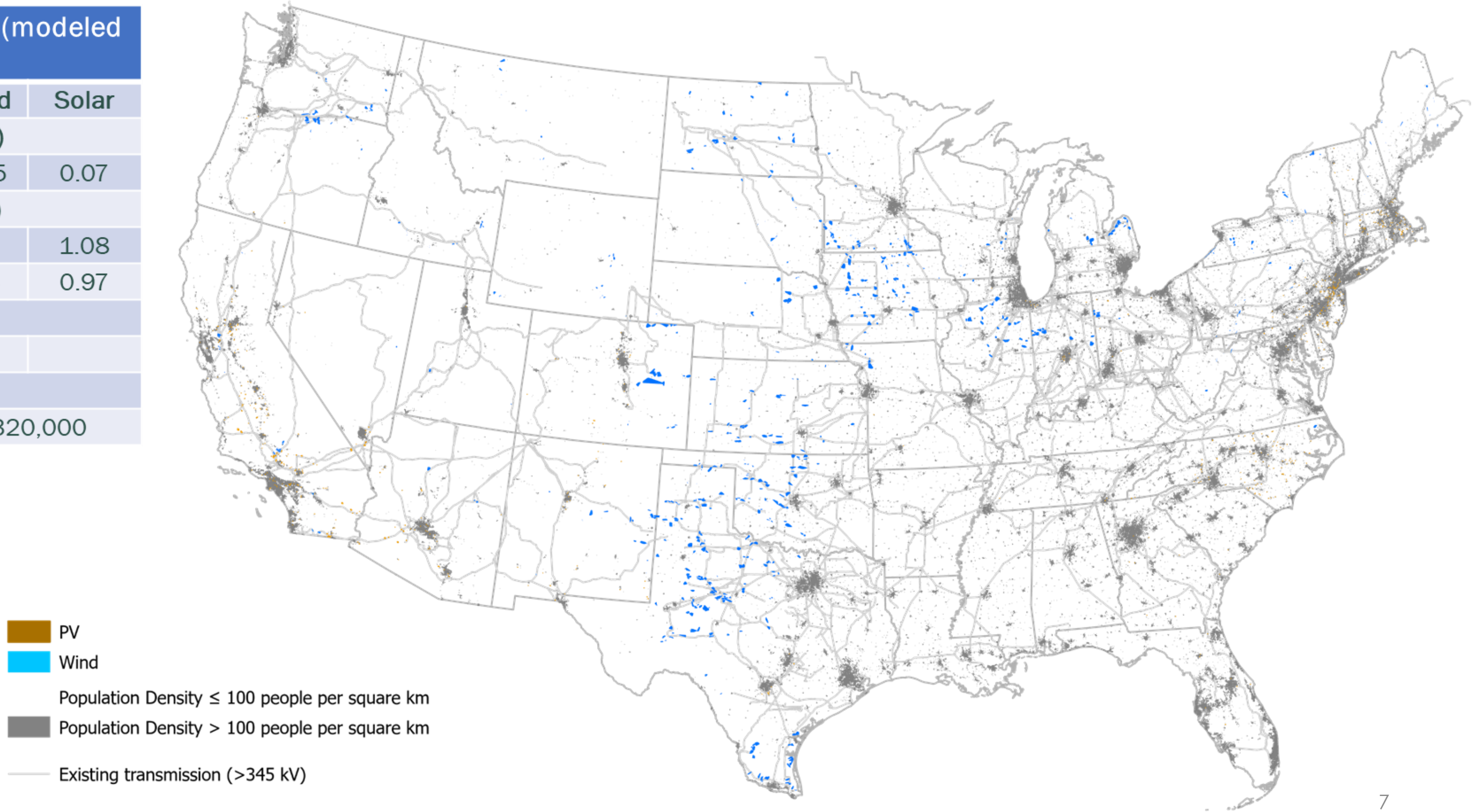
Unprecedented Infrastructure build over 3 decades
Supply – Demand - Transmission

Electricity generation capacity increases 2-6 times



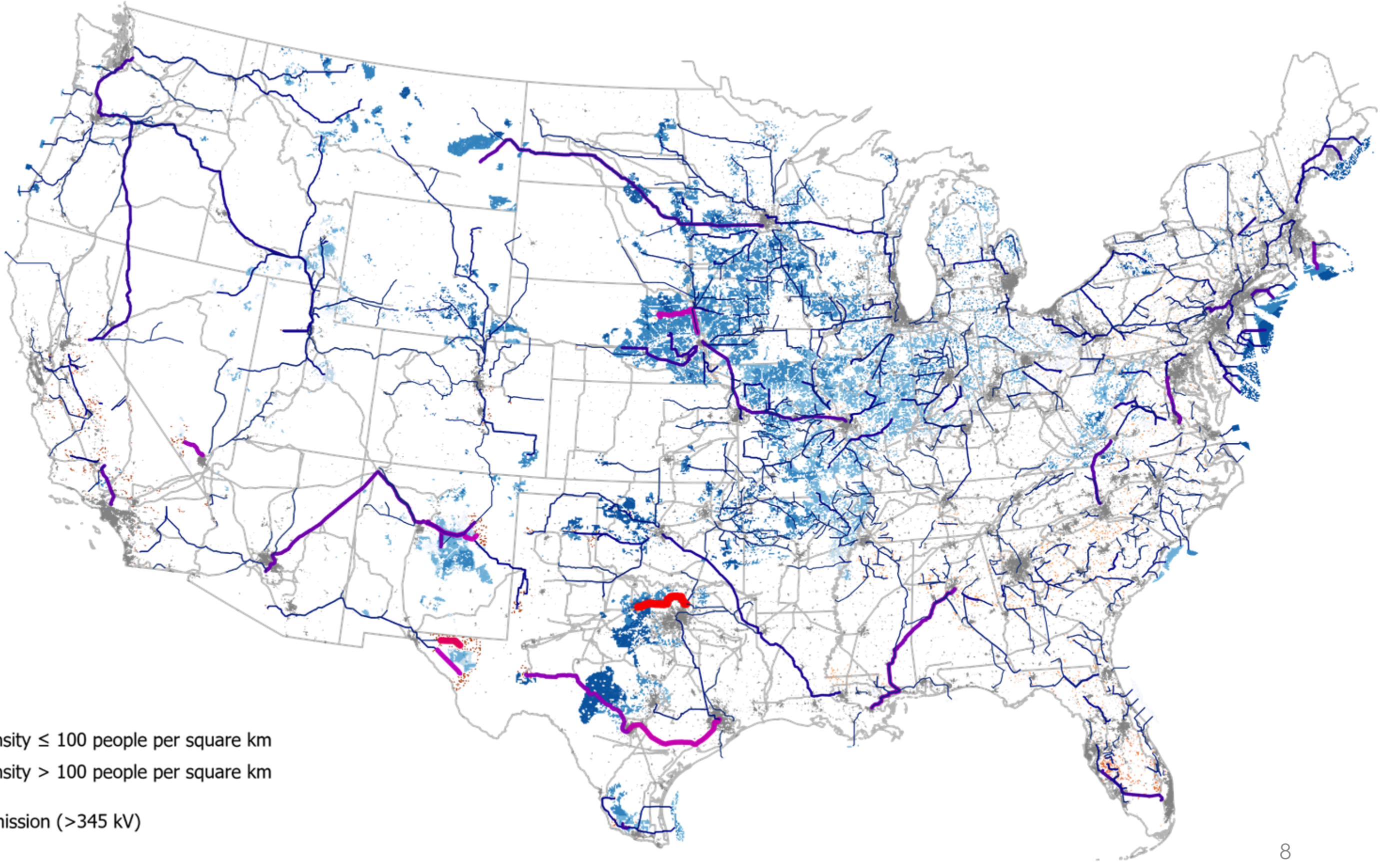
Wind, solar and HV transmission in 2020

As of end of 2020 (modeled year)		
	Wind	Solar
Capacity installed (TW)		
	0.15	0.07
Land used (1000 km^2)		
Total	58	1.08
Direct	0.6	0.97
Transmission capacity		
GW-km	320,000	



Wind, solar and HV transmission in 2050 – E+ pathway

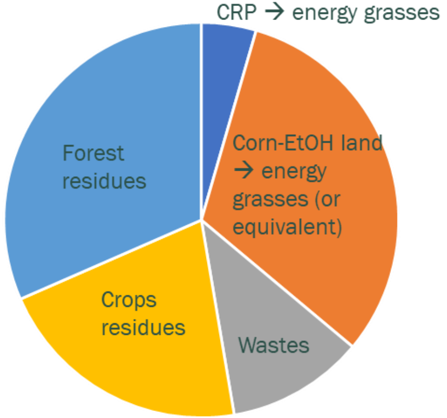
2020 - 2050 (cumulative)		
	Wind	Solar
Capacity installed (TW)		
	1.42	1.32
Land used (1000 km^2)		
Total	551	37.1
Direct	5.5	33.4
Capital invested (2018$)		
Trillion $	1.84	1.39
Transmission capacity		
GW-km	992,900 (3.1x 2020)	

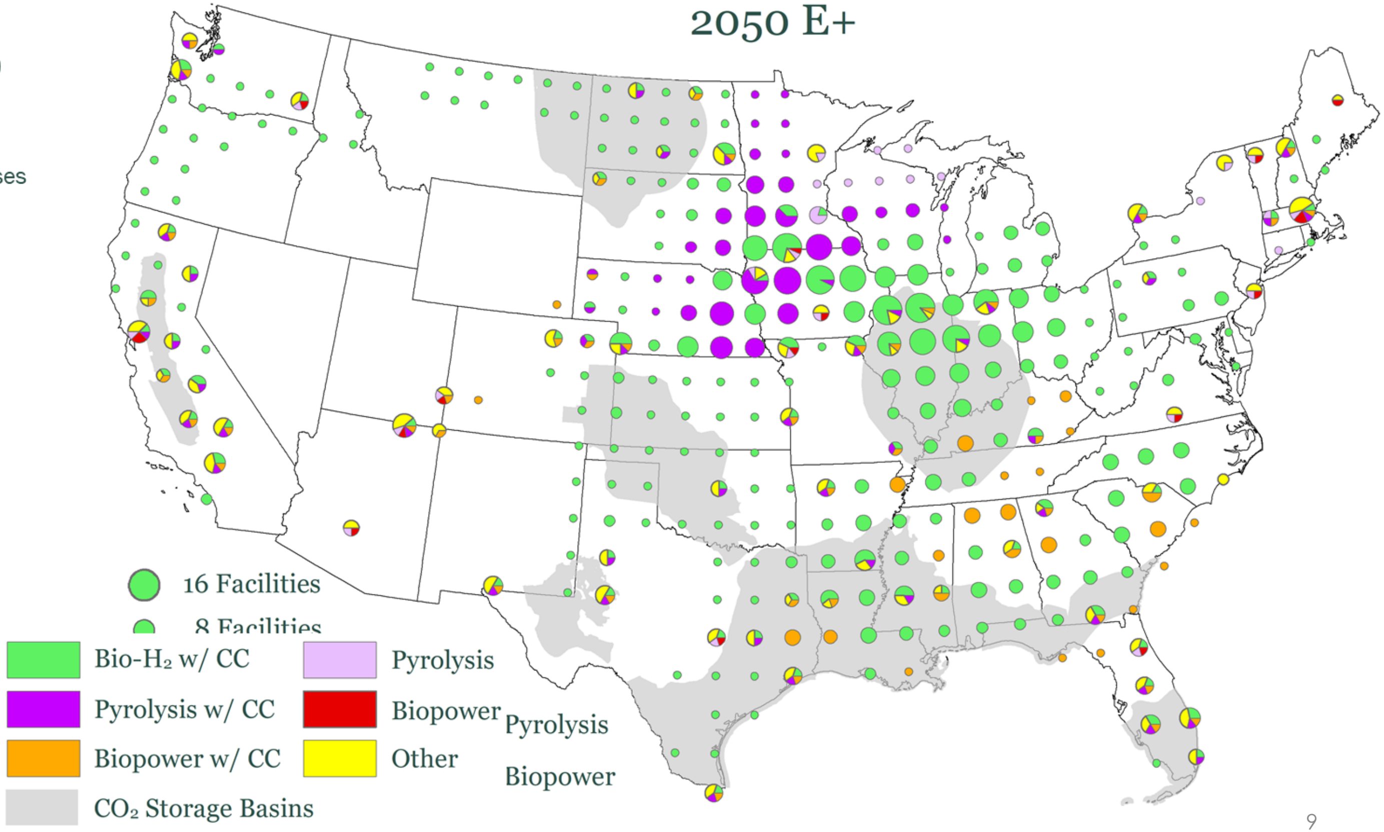


Almost $1 trillion invested in a major new bioenergy in industry

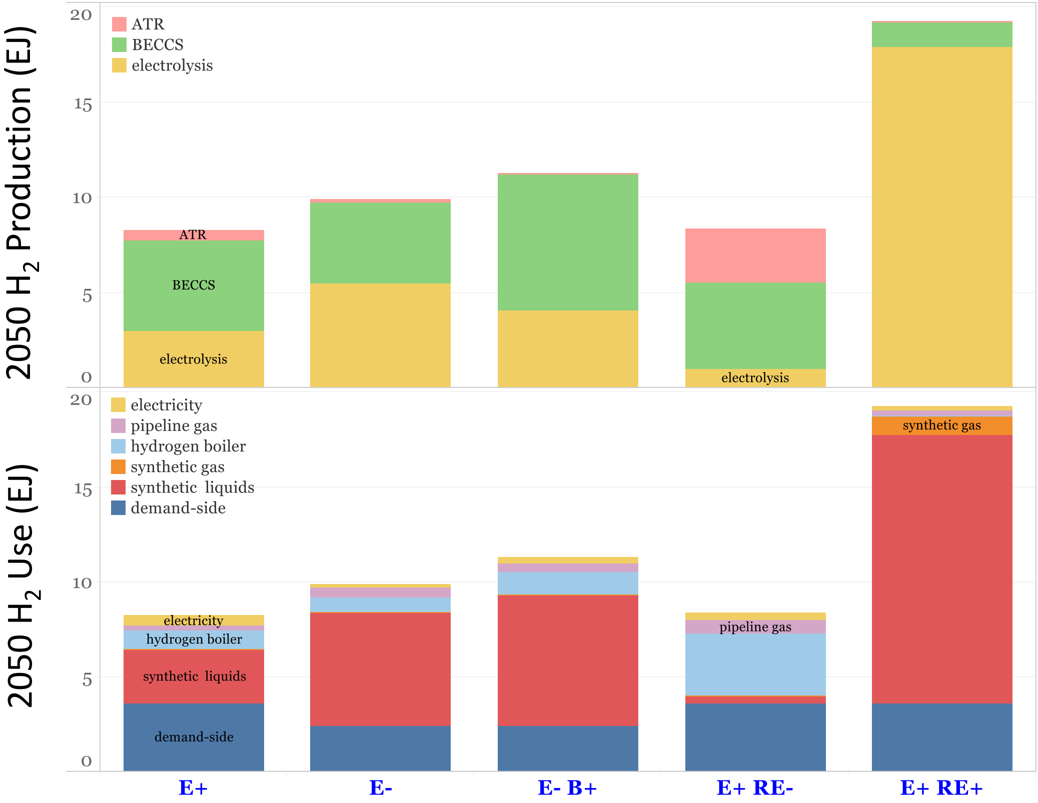
2050 non-food biomass use:

- 618 million dry t (12.2 EJ)
- 17% of primary energy
- Sources:





60 – 130 million tonnes/year of hydrogen produced in 2050



H_2 sources

ATR = natural gas reforming with CO_2 capture.

BECCS = biomass gasification with CO_2 capture (negative net emissions).

Electrolysis = water splitting using electricity.

H_2 uses

Electricity = H_2 burned in gas turbines

Pipeline gas = "hythane" blend in NG pipelines

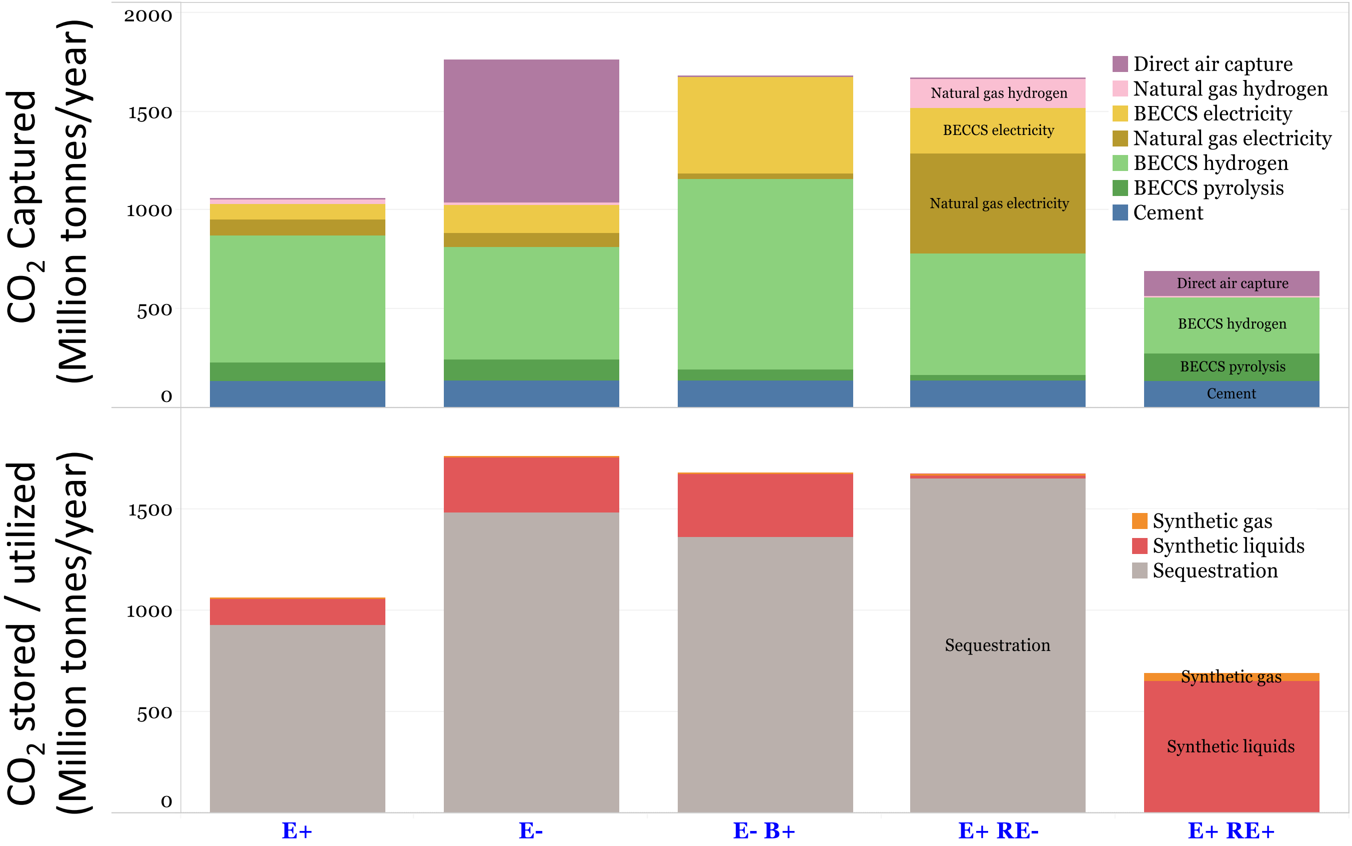
H_2 boiler = industrial steam generation.

Synthetic gas

Synthetic liquids

Demand side = transport, chemicals, steel

700 to 1.700 million tonnes/year CO_2 capture, utilization & storage (CCUS)



CO_2 sources

Direct air capture

Natural gas BECCS electricity

Natural gas electricity

BECCS hydrogen

BECCS pyrolysis

Cement

CO_2 Destination

Synthetic liquid fuels

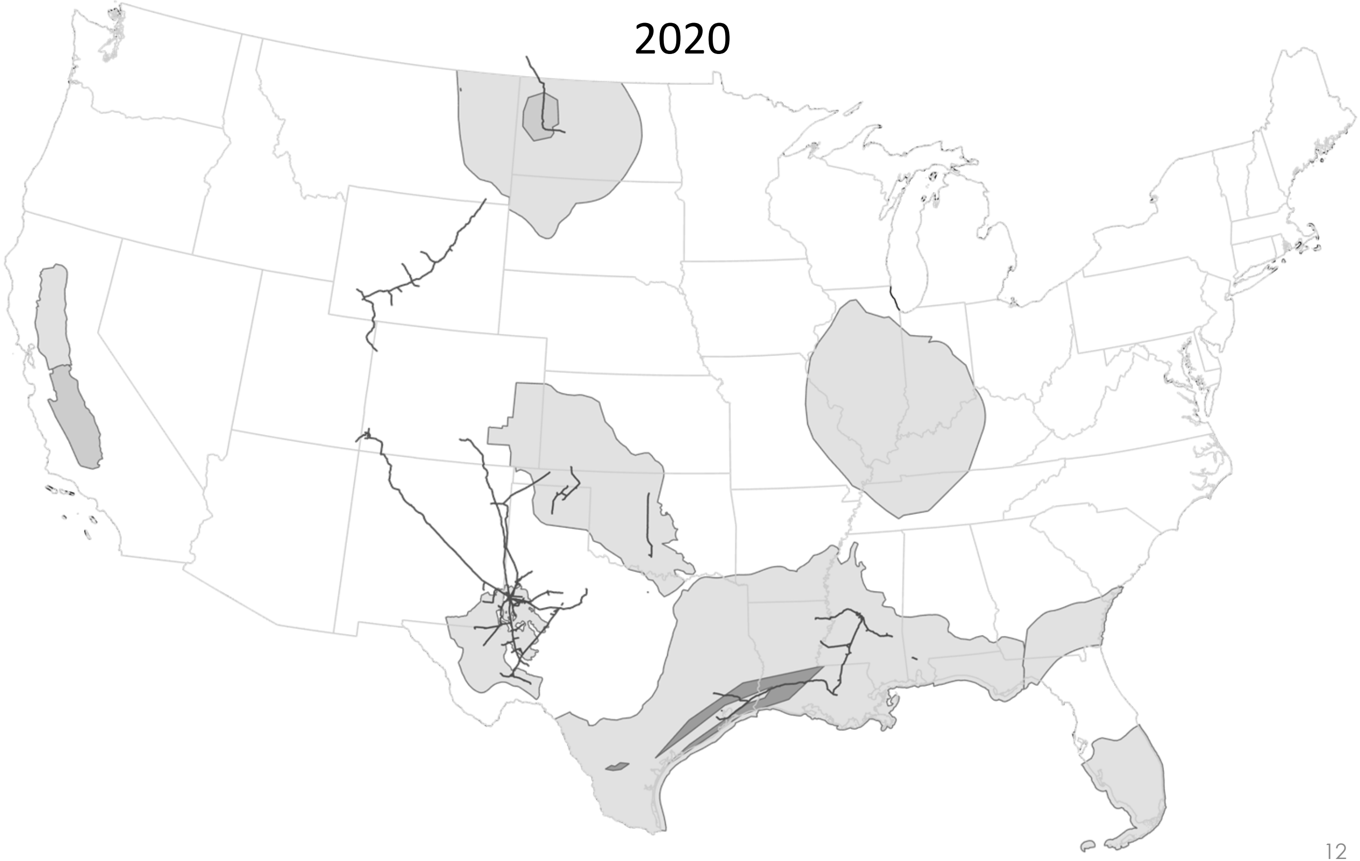
Synthetic gas

Geologic storage

A new national CO_2 transport & storage network

The 2020 U.S. CO_2 transport network

- 80 million tCO_2/yr transported
- 8,500 km of pipelines



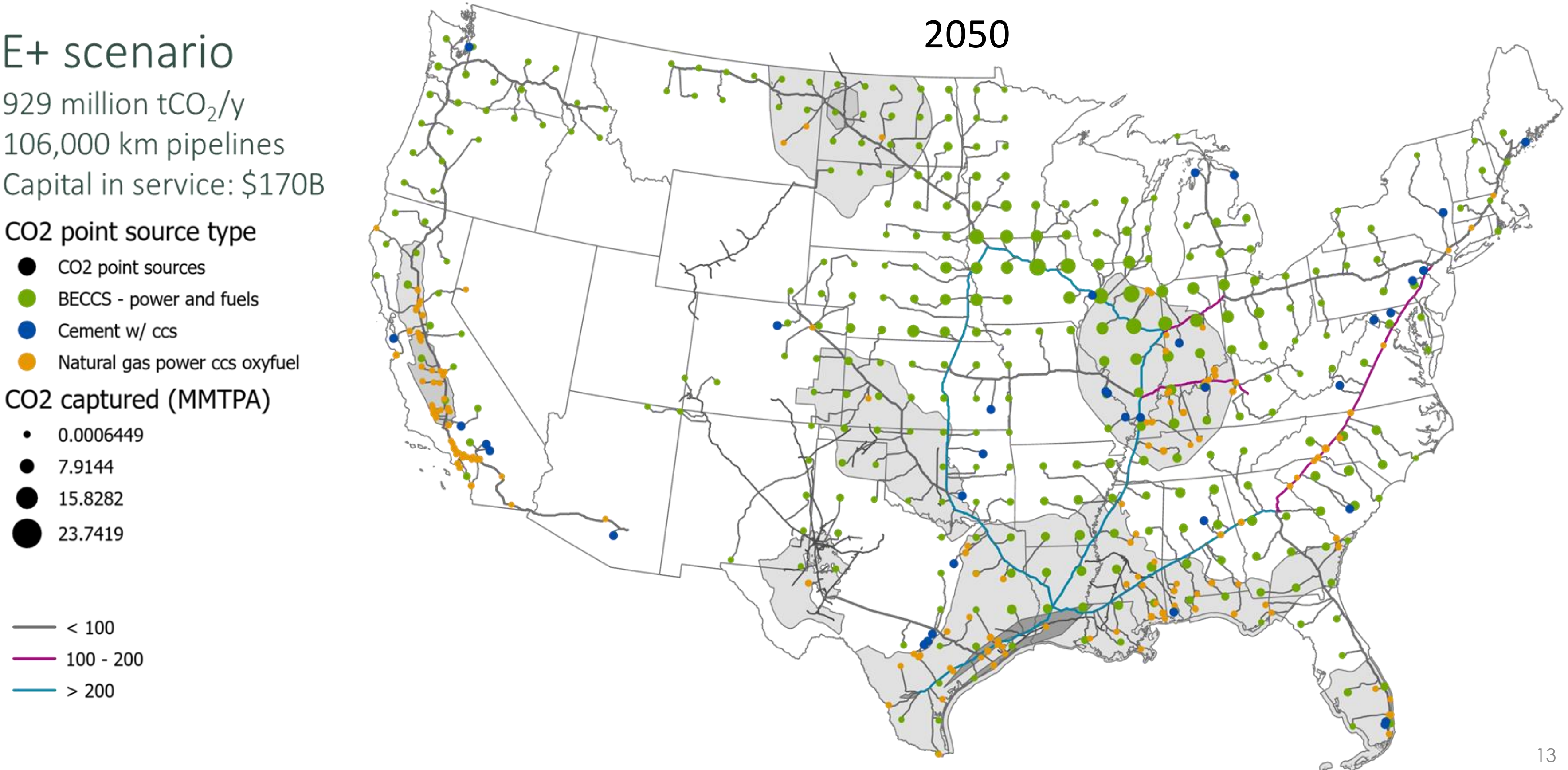
A new national CO_2 transport & storage network

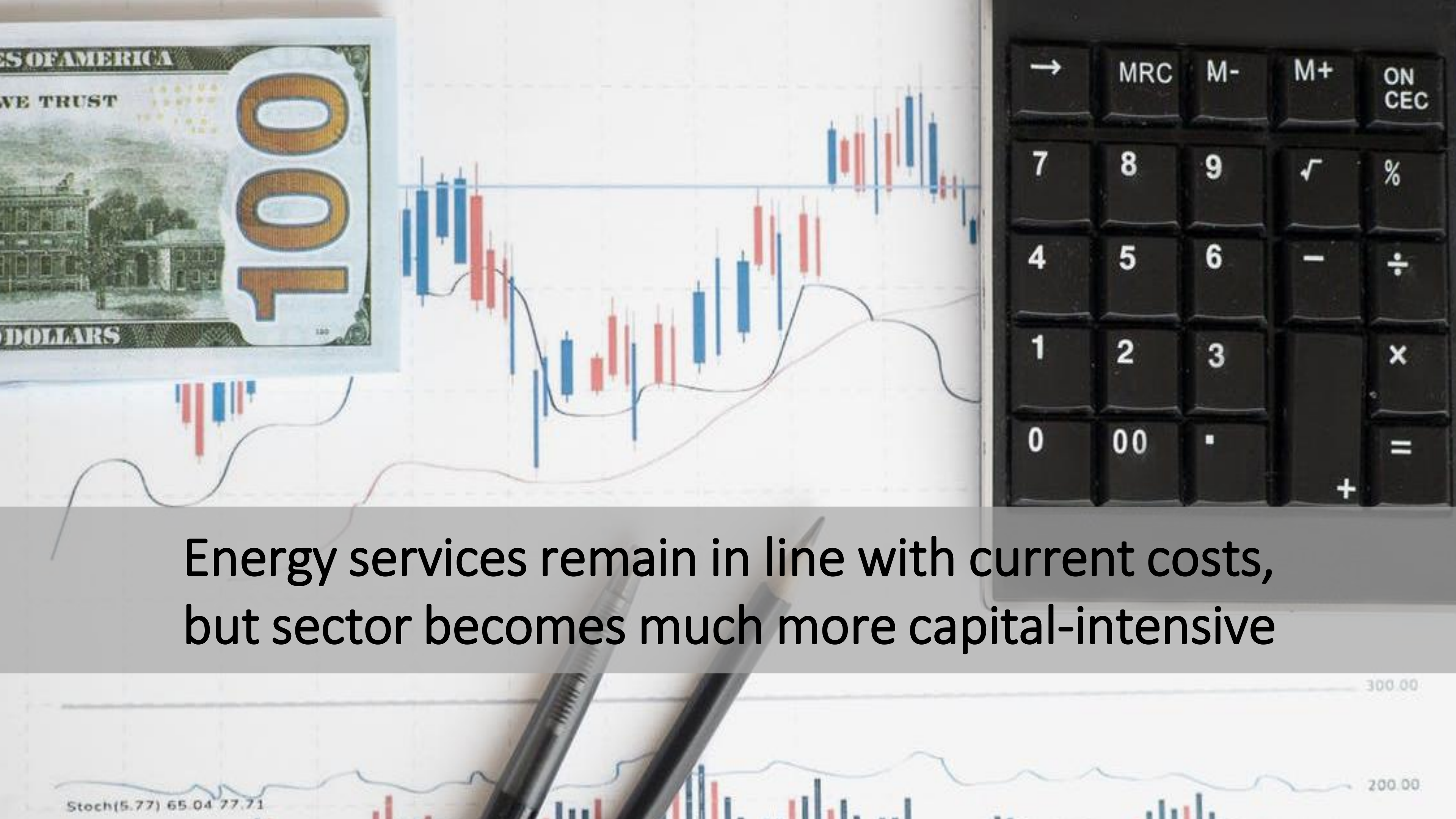
E+ scenario

929 million tCO_2/y

106,000 km pipelines

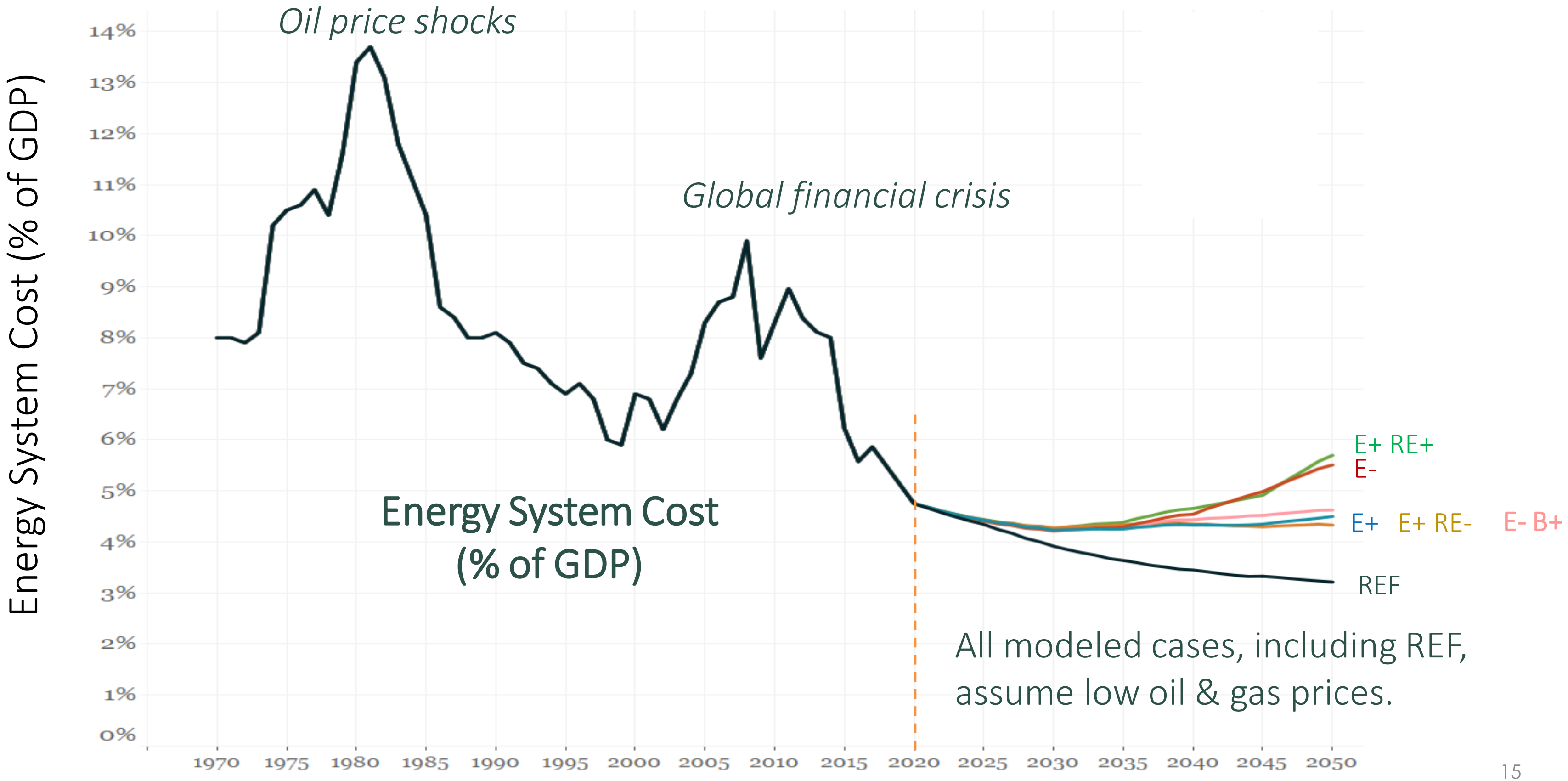
Capital in service: $170B





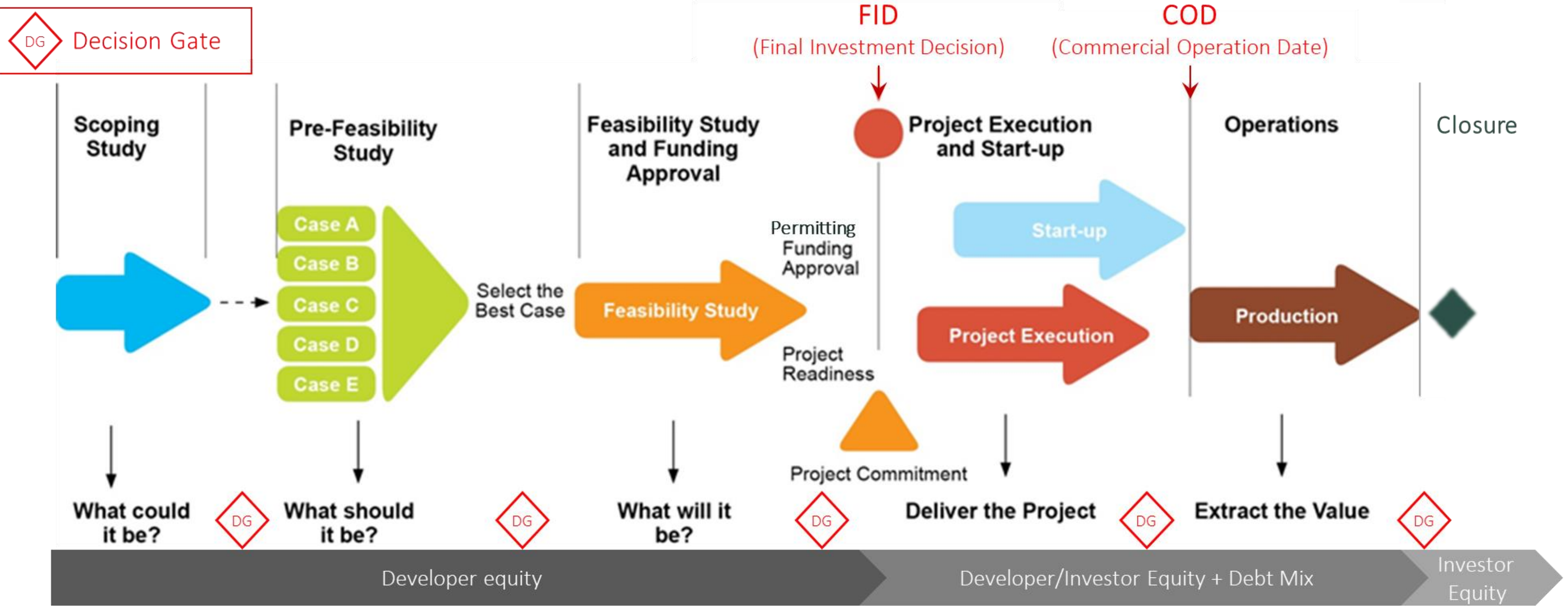
Energy services remain in line with current costs, but sector becomes much more capital-intensive

Energy services remain in line with current costs as a % of GDP



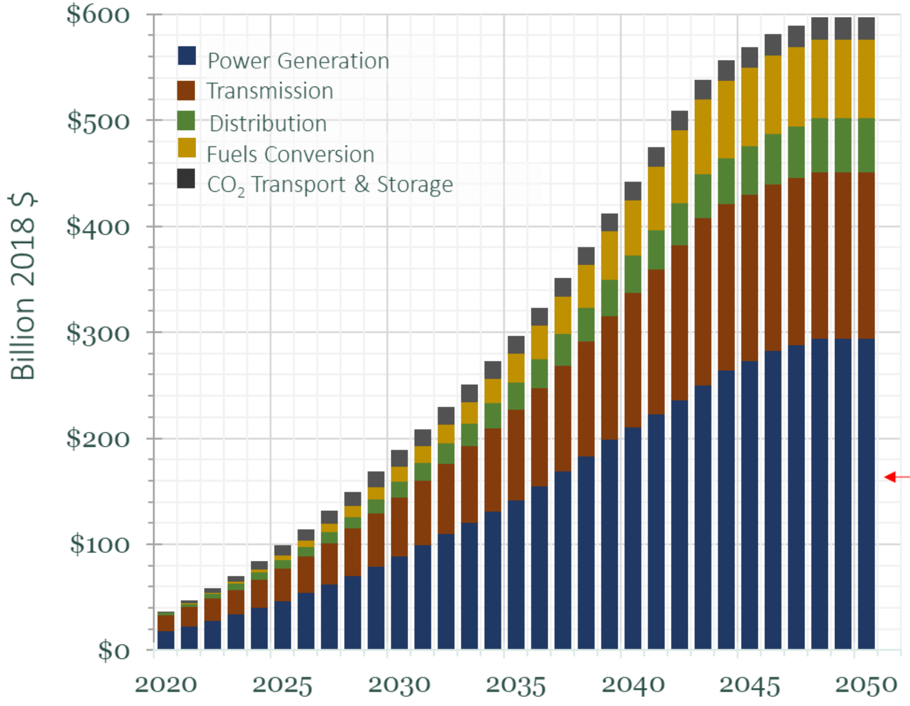
Capital Mobilization Challenge

Lead-times, risk capital to fund decision sequence

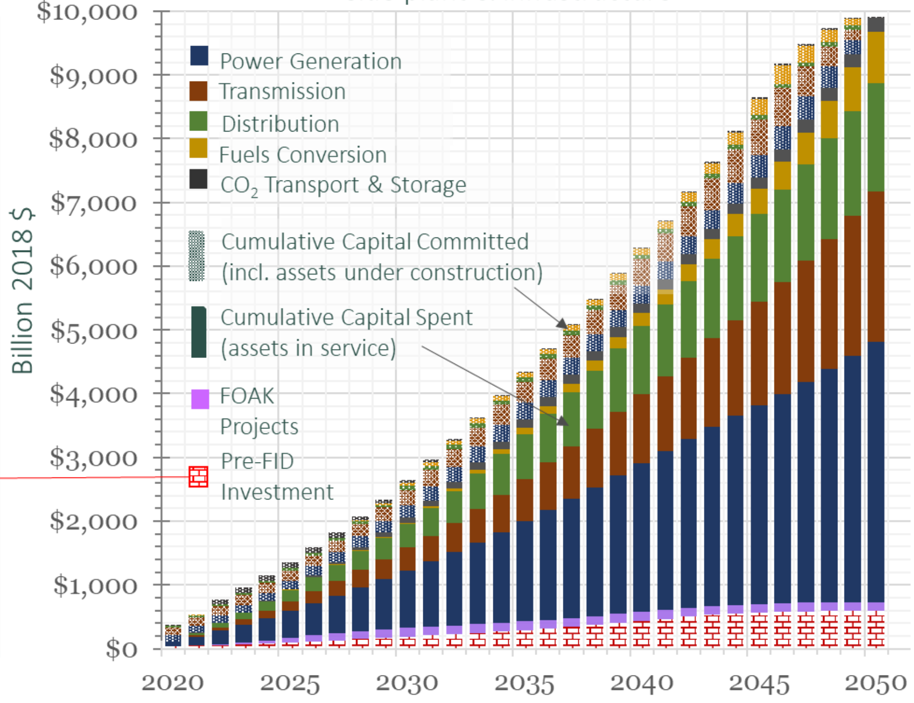


E+ Pathway involves more that $10 trillion supply side capital (2.5 X BAU)

$600 billion at-risk Pre-FID development costs to support >$9 trillion in capital investment decisions



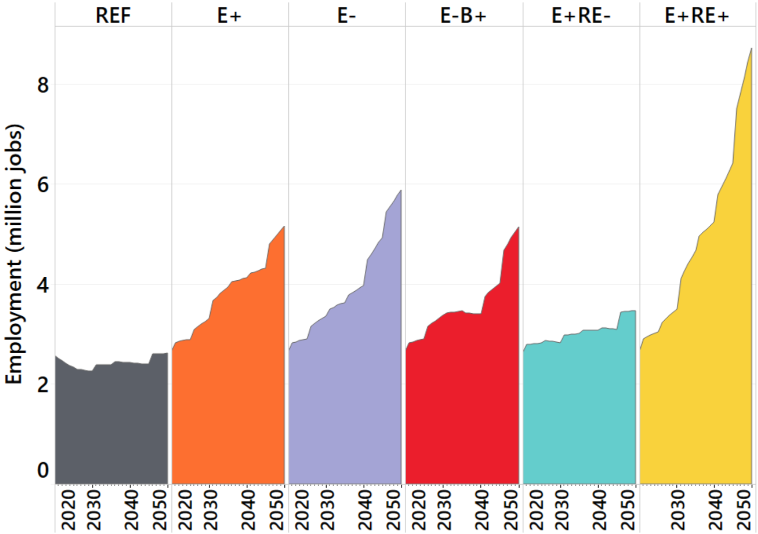
>$10 trillion cumulative capital investment in supply-side plant & infrastructure



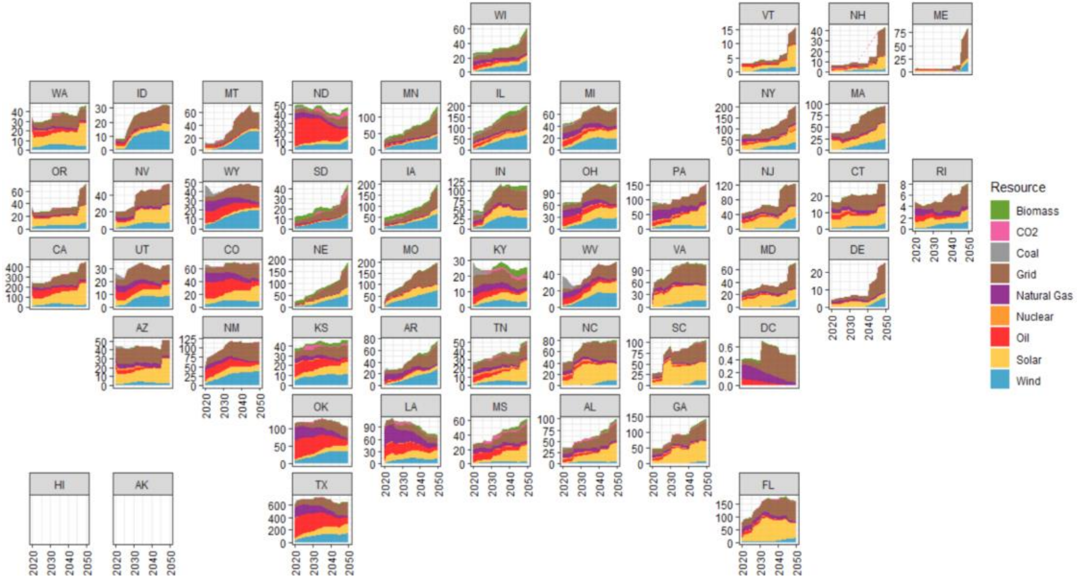
Note: Excludes investments in demand-side transport, buildings and industry; biomass crop establishment; and land sink enhancements.

Energy work force – huge boost in jobs but mobilization challenge?

Energy sector (supply-side) jobs increase by 1.5 to 4 times to 2050



But benefits (and challenges) are not homogeneous



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