WORLD RESOURCES INSTITUTE

ZERO-NET EMISSIONS BY 2050: CLIMATE REALITIES AND CHALLENGES

KARL HAUSKER, PH.D.
SENIOR FELLOW
KHAUSKER@WRI.ORG

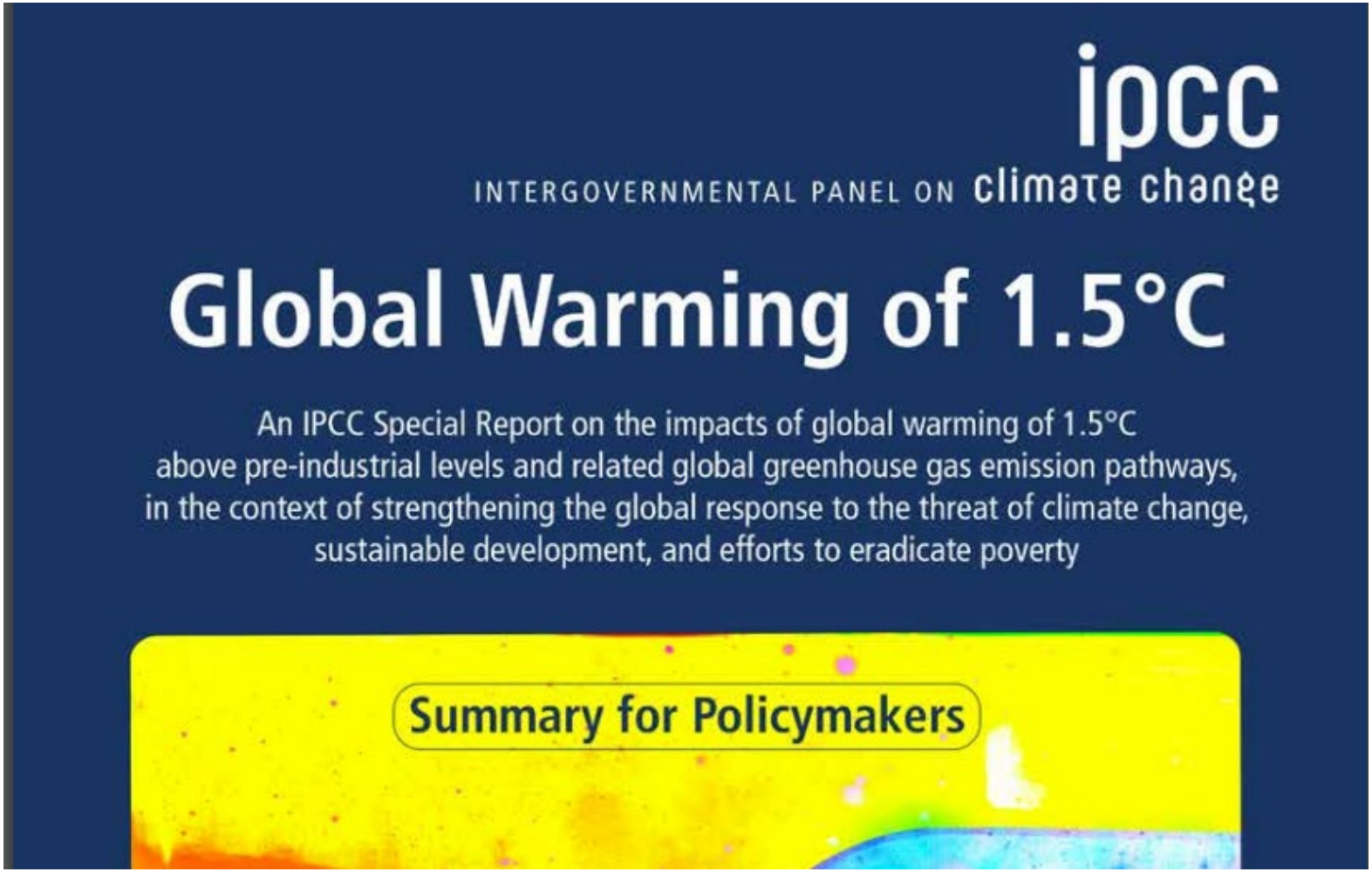
OCTOBER 2019

OUTLINE

- The mitigation challenge: the IPCC perspective
- Four strategies to reach zero net carbon
- The renewables revolution
  - how far can wind and solar take us?
- The need to “spread our chips”
  - roles for nuclear and CCS
- The imperative of carbon dioxide removal
- Key messages

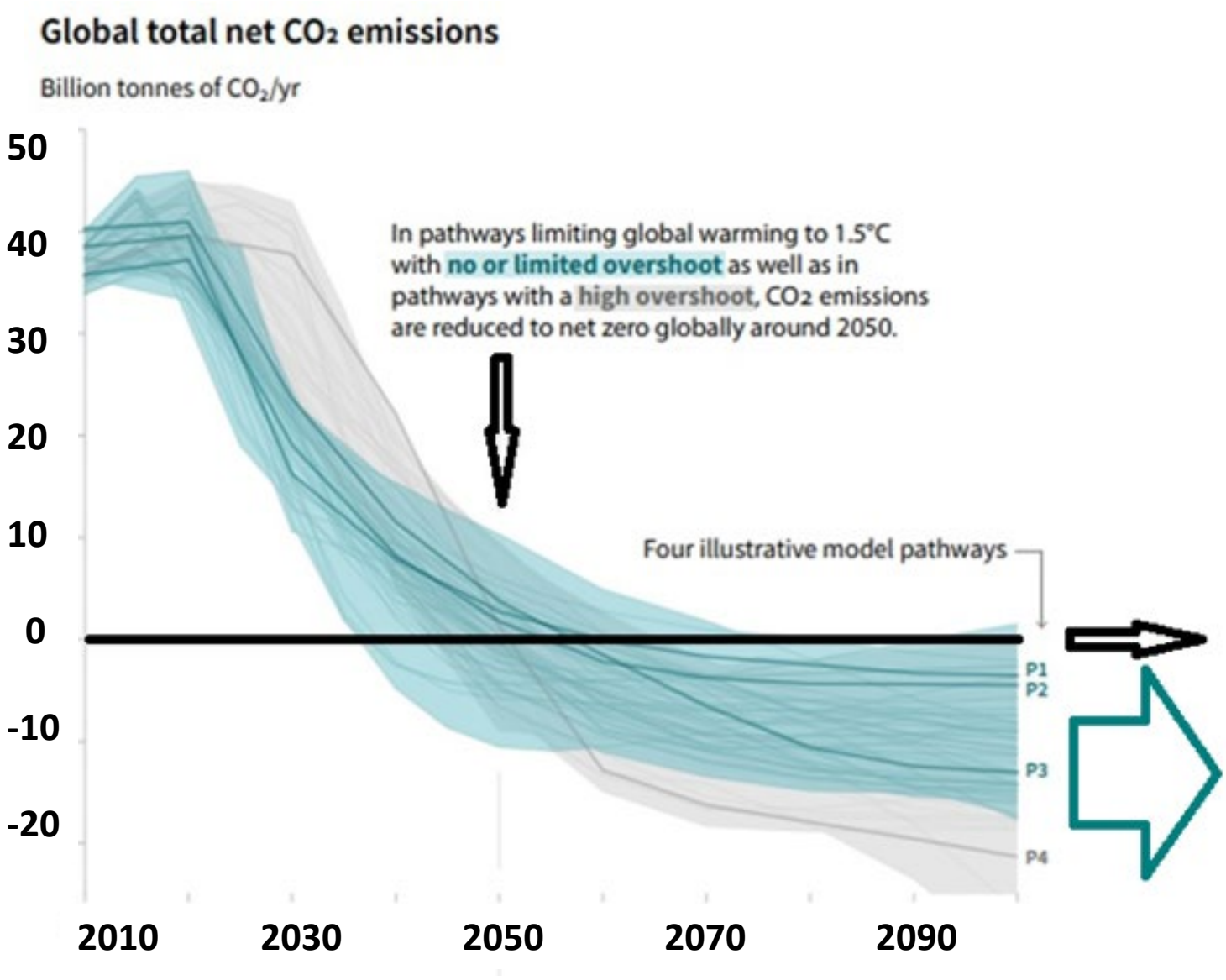
- *Speed limit, weblinks, Q&A*

IPCC REPORT RELEASED IN OCT. 2018 LAYS OUT GLOBAL PATHWAYS TO A SAFE CLIMATE



https://www.ipcc.ch/sr15/chapter/summary-for-policy-makers/

1.5ºC PATHWAYS REQUIRE NET-ZERO BY MID-CENTURY

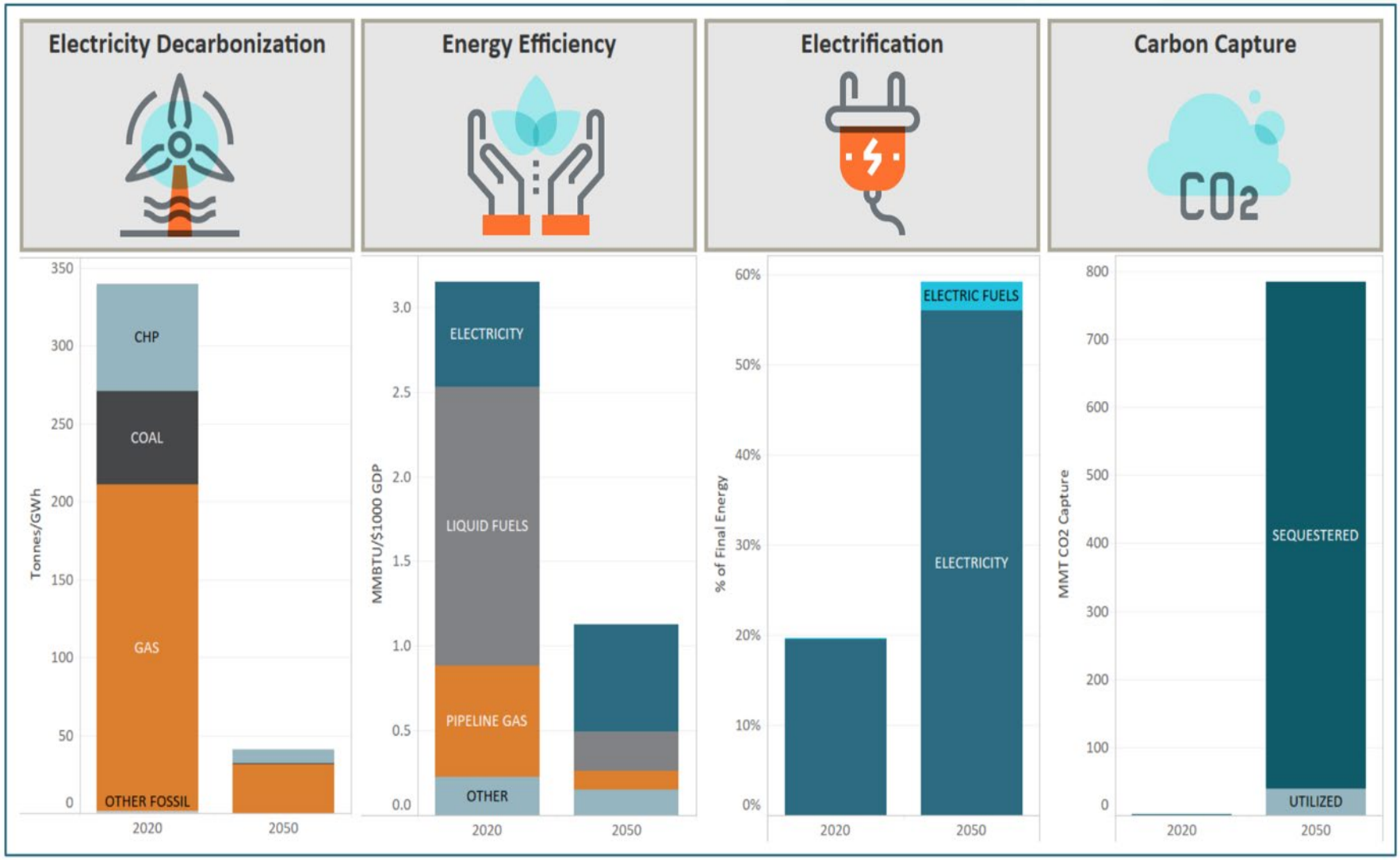


Net Zero Emissions

Illustrative pathways: P1, P2, P3, P4

https://www.ipcc.ch/sr15/chapter/summary-for-policy-makers/

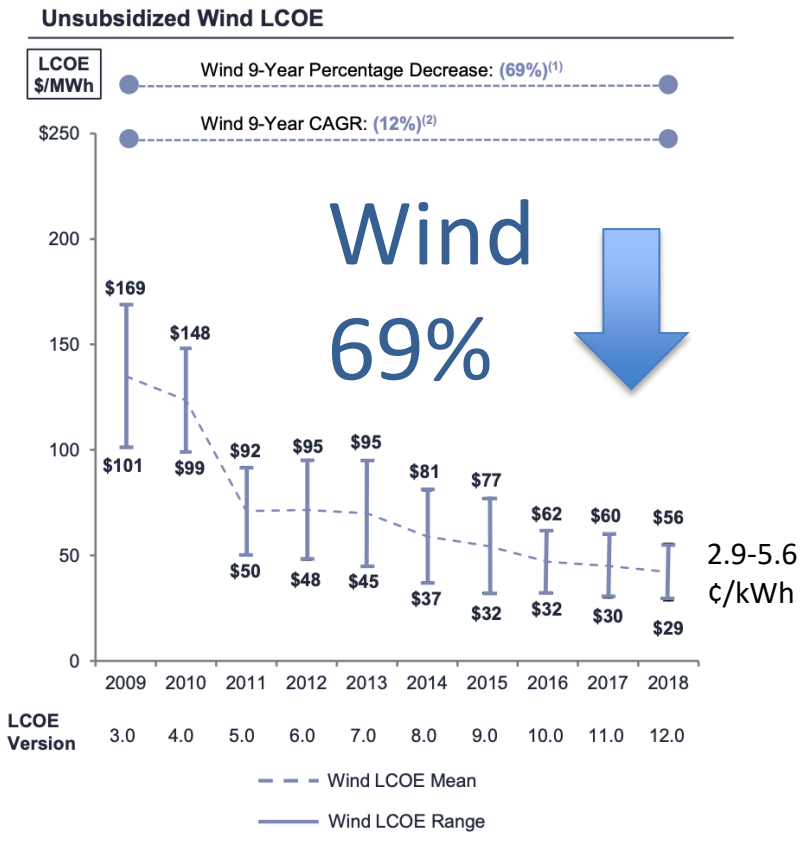
FOUR STRATEGIES TO TRANSFORM THE ENERGY SYSTEM TO ZERO-CARBON

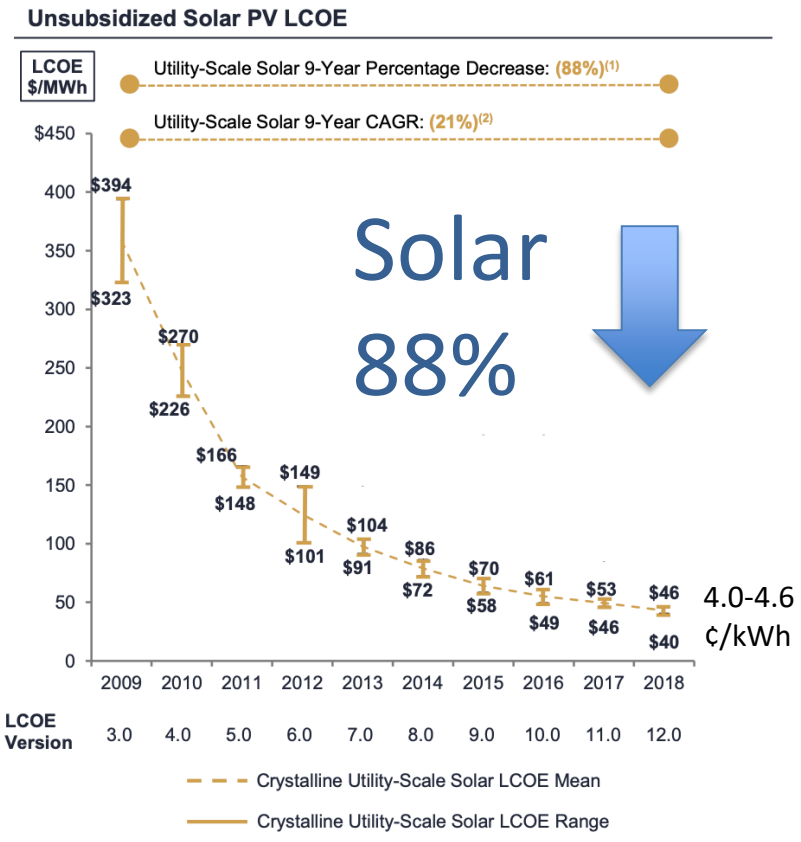


https://www.evolved.energy/single-post/2019/05/08/350-ppm-Pathways-for-the-United-States

THE RENEWABLES REVOLUTION

Dramatic cost decreases in wind and solar PV over the past 10 years
LCOE: Wind: 3 – 6 cents/kWh. Solar PV: 4 – 5 cents/kWh (Utility-Scale).





LAZARD

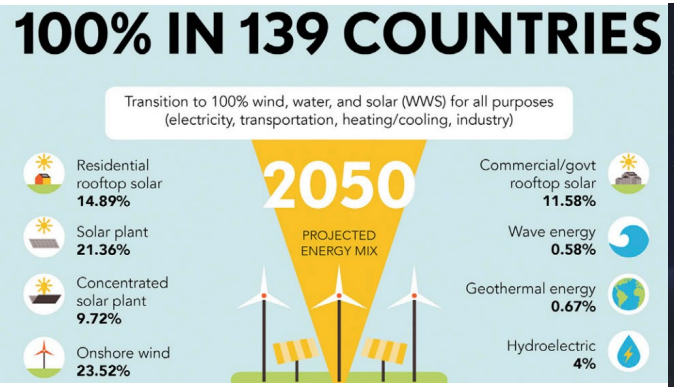
Source: Lazard estimates.
(1) Represents the average percentage decrease of the high end and low end of the LCOE range.
(2) Represents the average compounded annual rate of decline of the high end and low end of the LCOE range.

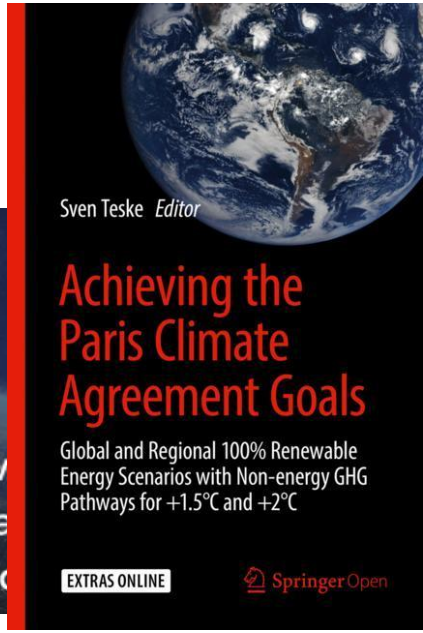
8

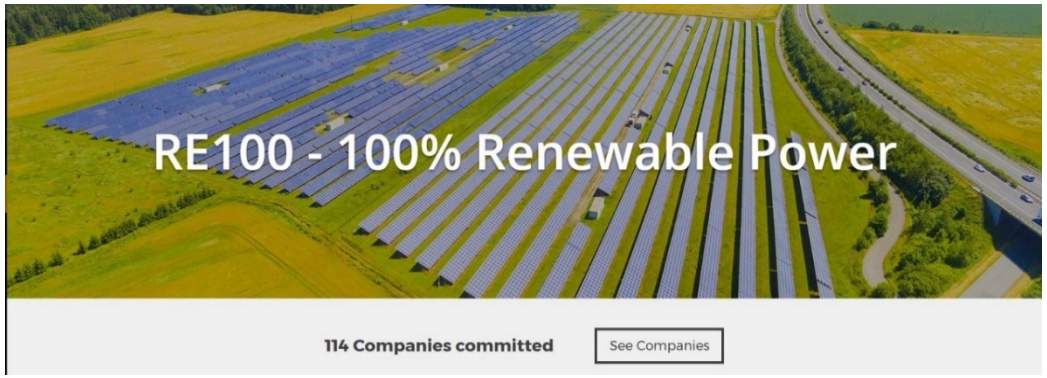
Lazard's LCOE Analysis, v.12.0, Nov. 2018,
https://www.lazard.com/perspective/levelized-cost-of-energy-and-levelized-cost-of-storage-2018/

WORLD RESOURCES INSTITUTE

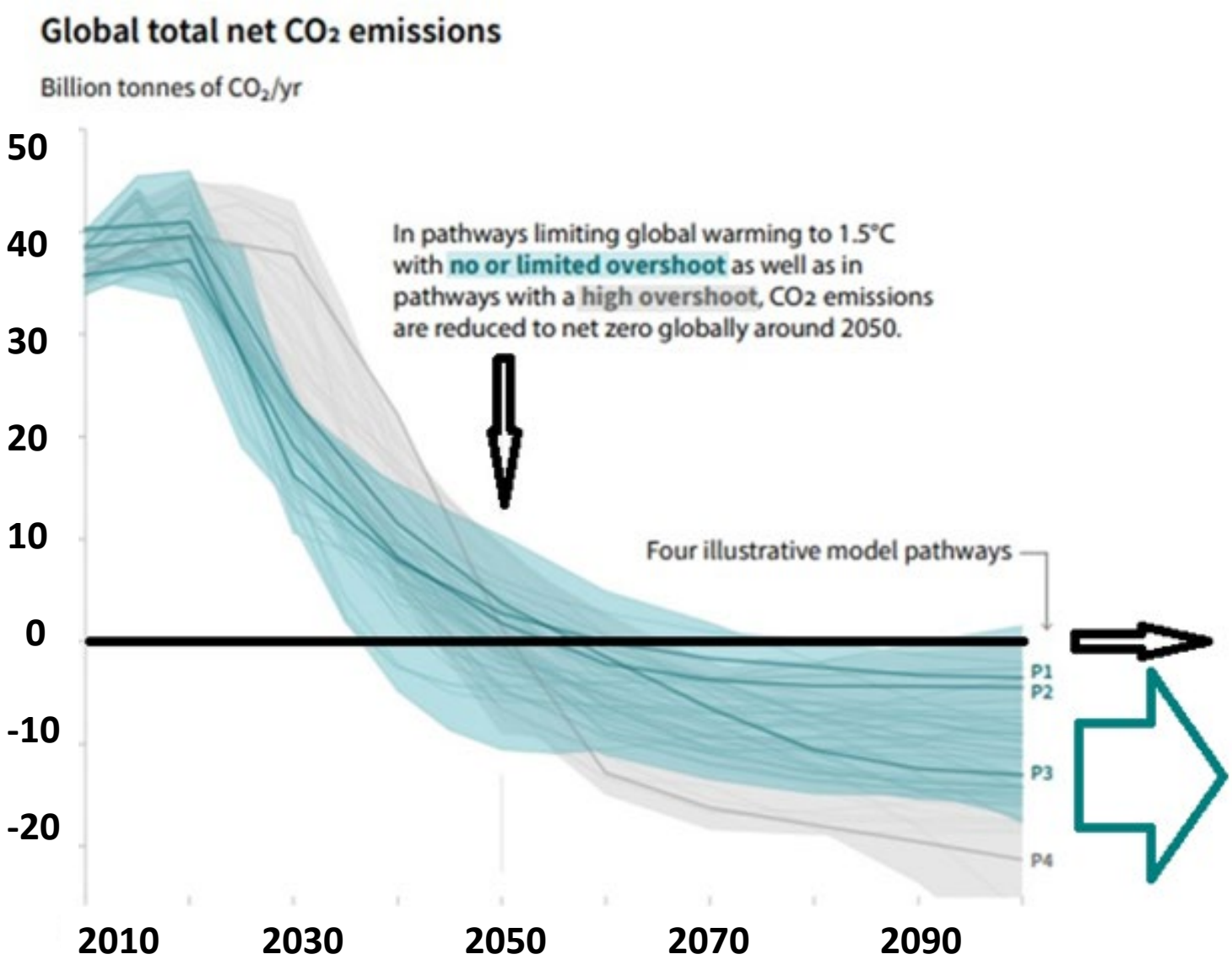
EMBRACING 100% RENEWABLES







1.5ºC PATHWAYS INDICATE RENEWABLE SHARE OF ELECTRICITY GENERATION OF 63-81 PERCENT



Net Zero Emissions

%Renewable of elec. gen.:

P1 – 77%

P2 – 81%

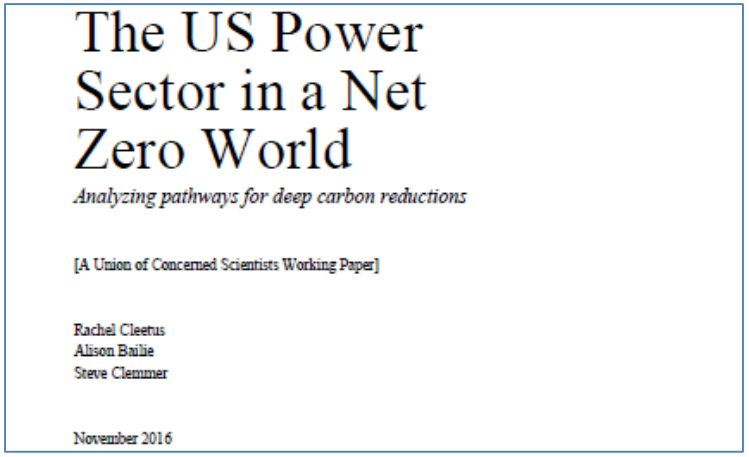
P3 – 63%

P4 – 70%

https://www.ipcc.ch/sr15/chapter/summary-for-policy-makers/

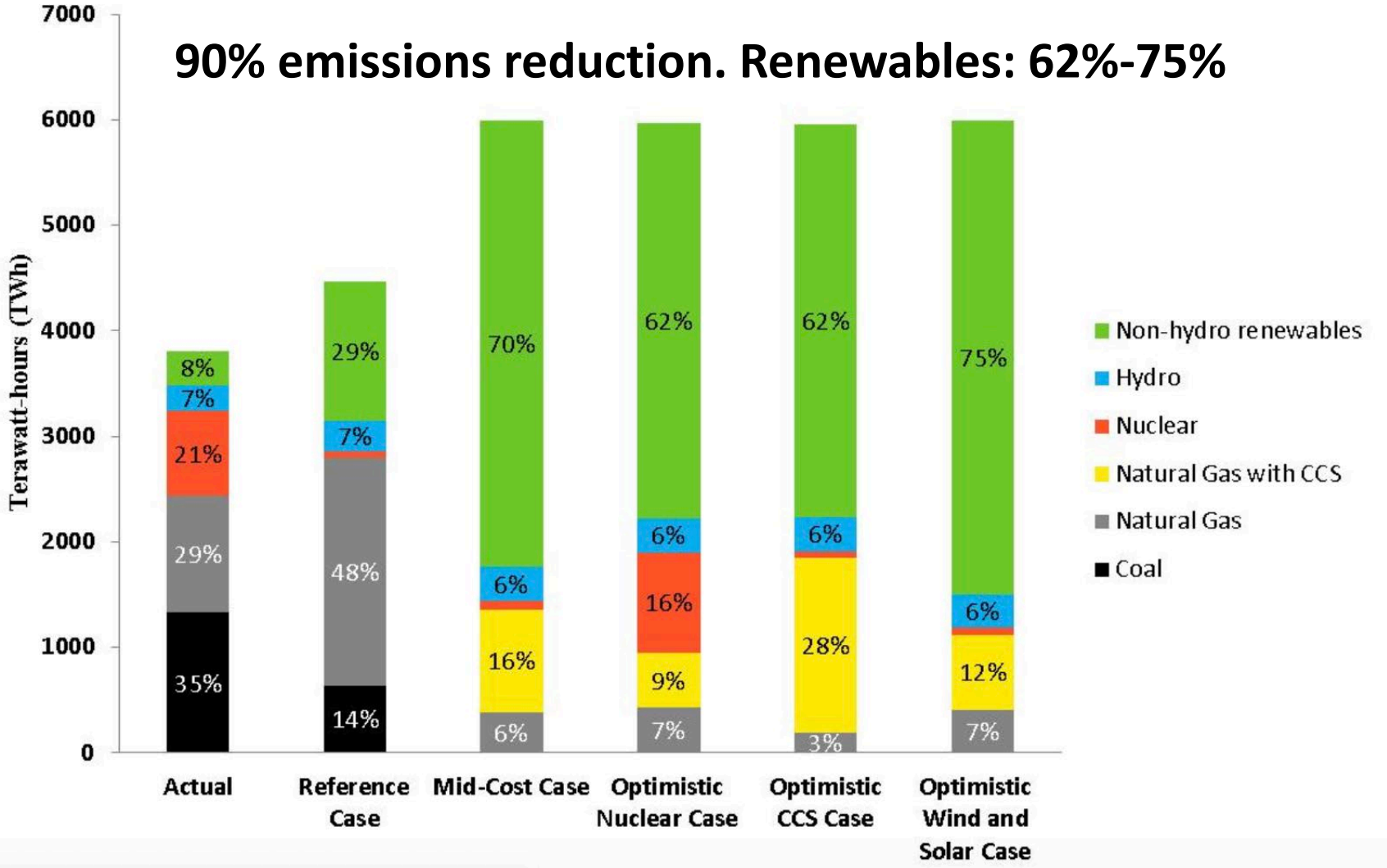
MODELING OF U.S. IN 2050: RENEWABLES BECOME LARGEST ELECTRICITY SOURCE (50-80%)

CAVEAT "BEYOND XX% RENEWABLES, SYSTEM COSTS INCREASE SHARPLY"



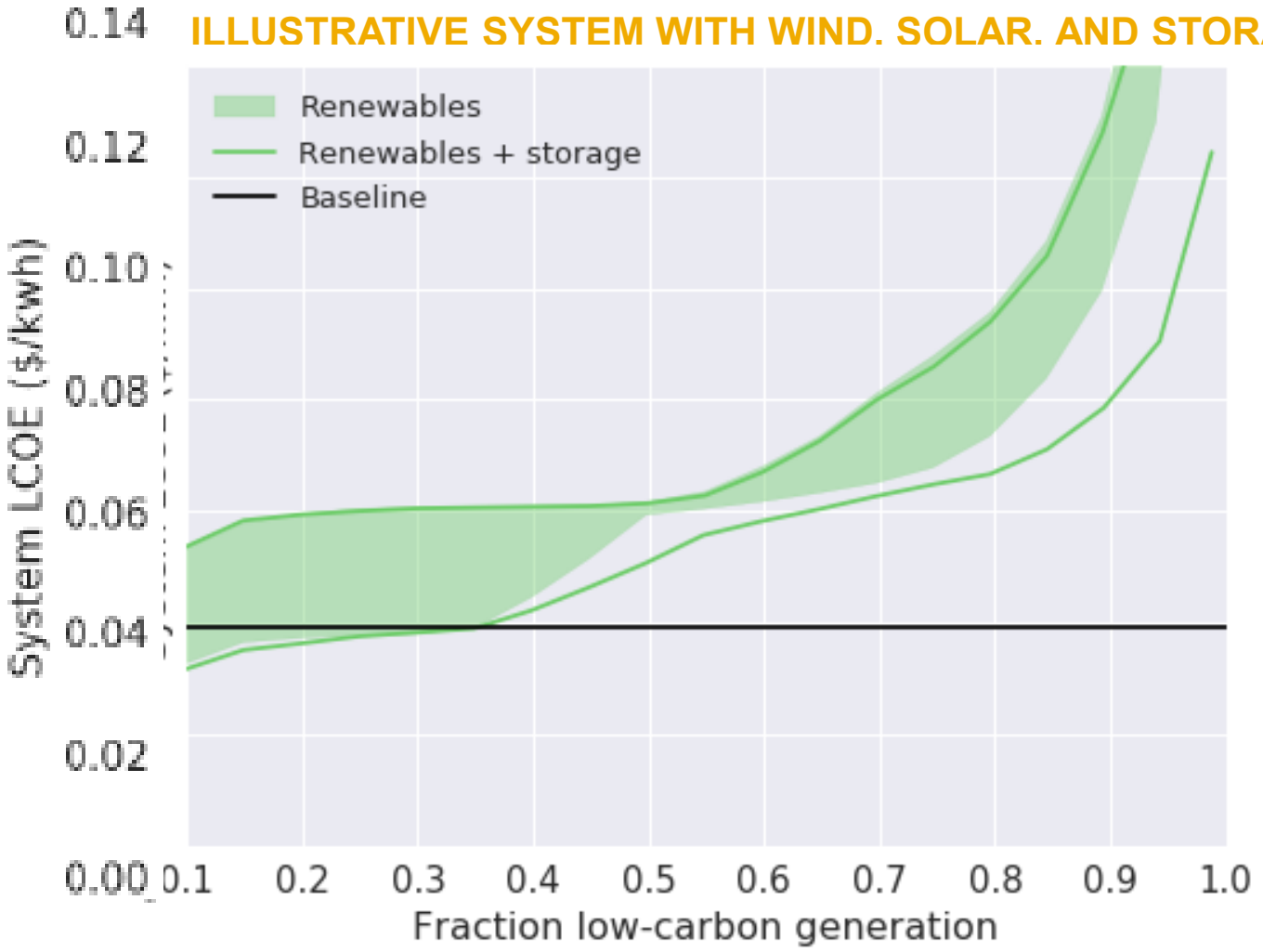
https://unfccc.int/files/focus/long-term_strategies/application/pdf/mid_century_strategy_report-final_red.pdf
www.riskybusiness.org/fromrisktoreturn/
https://www.nrdc.org/resources/americas-clean-energy-frontier-pathway-safer-climate-future
https://www.ucsusa.org/sites/default/files/attach/2016/11/UCS-Deep-Decarbonization-working-paper.pdf?_ga=2.263568588.1974402731.1534852232-1981528426.1534852232

EXAMPLE OF A 2050 ELECTRICITY GENERATION MIX: FOUR SCENARIOS, UNION OF CONCERNED SCIENTISTS



Cleetus et al., US Power Sector in a Net Zero World, 2016

"SYSTEM LCOE" INCREASES SHARPLY WITH HIGH RENEWABLE PENETRATION



"Integration" costs drive up system LCOE:

- **Transmission**
- **Load shifting**
- **Storage**
  - **Daily**
  - **Seasonal**
  - **Weather flux**

See also: Hausker (2019), https://kleinmanenergy.upenn.edu/paper/betting-climate-solutions
Frew et al (2016) , https://web.stanford.edu/group/efmh/jacobson/Articles/Others/16-Frew-Energy.pdf
Sepulveda, N., Jenkins, J.D., et al. (2018), "The role of firm low-carbon resources in deep decarbonization of electric power systems," *Joule*

https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3015424

"SPREAD YOUR CHIPS"

UCS REPORT CITES VALUE OF EXISTING NUCLEAR PLANTS

- **Without policies to replace retired nuclear power generation with low-carbon energy technologies, utilities could turn to natural gas and coal to fill the gap**
  - could result in a *4 to 6 percent* increase ir US power sector emissions.

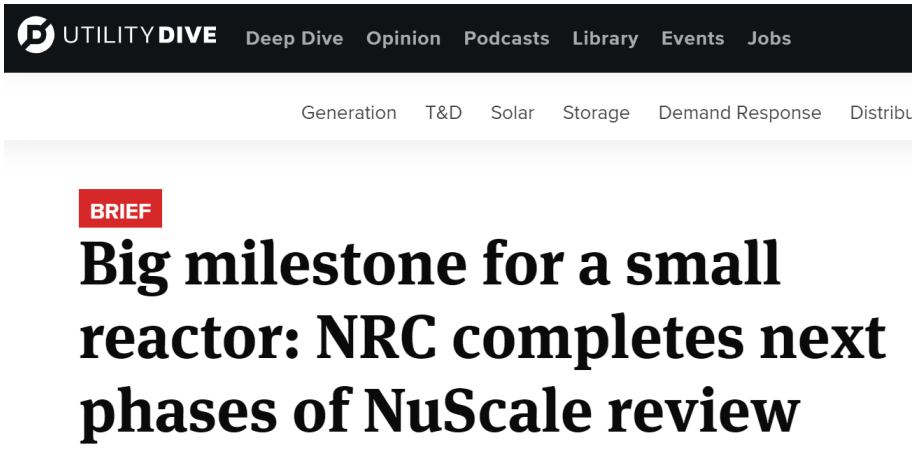

Union of Concerned Scientists

EXECUTIVE SUMMARY

The Nuclear Power Dilemma

Declining Profits, Plant Closures, and the Threat of Rising Carbon Emissions

SMALL MODULAR REACTORS HOLD PROMISE


UTILITY DIVE Deep Dive Opinion Podcasts Library Events Jobs

Generation T&D Solar Storage Demand Response Distribu

BRIEF

Big milestone for a small reactor: NRC completes next phases of NuScale review

https://www.ucsusa.org/sites/default/files/attach/2018/11/Nuclear-Power-Dilemma-executive-summary.pdf

CARBON CAPTURE AND STORAGE WORKS
COSTS WILL DECREASE WITH INNOVATION AND SCALE

Vox

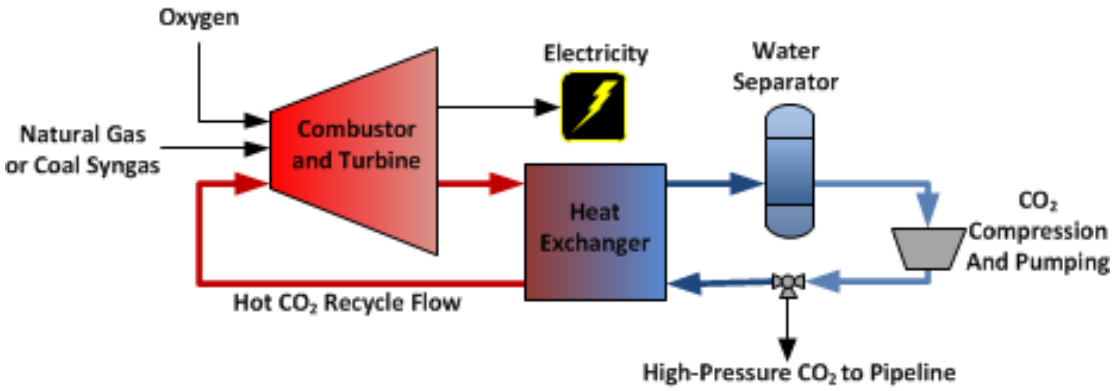
RECODE EXPLAINERS THE HIGHLIGHT FUTURE PERFECT THE GOODS POLITICS & POLICY MORE

That natural gas power plant with no carbon emissions or air pollution? It works.

The carbon-capture game is about to change.

By David Roberts | @drvox | david@vox.com | Jun 1, 2018, 9:40am EDT

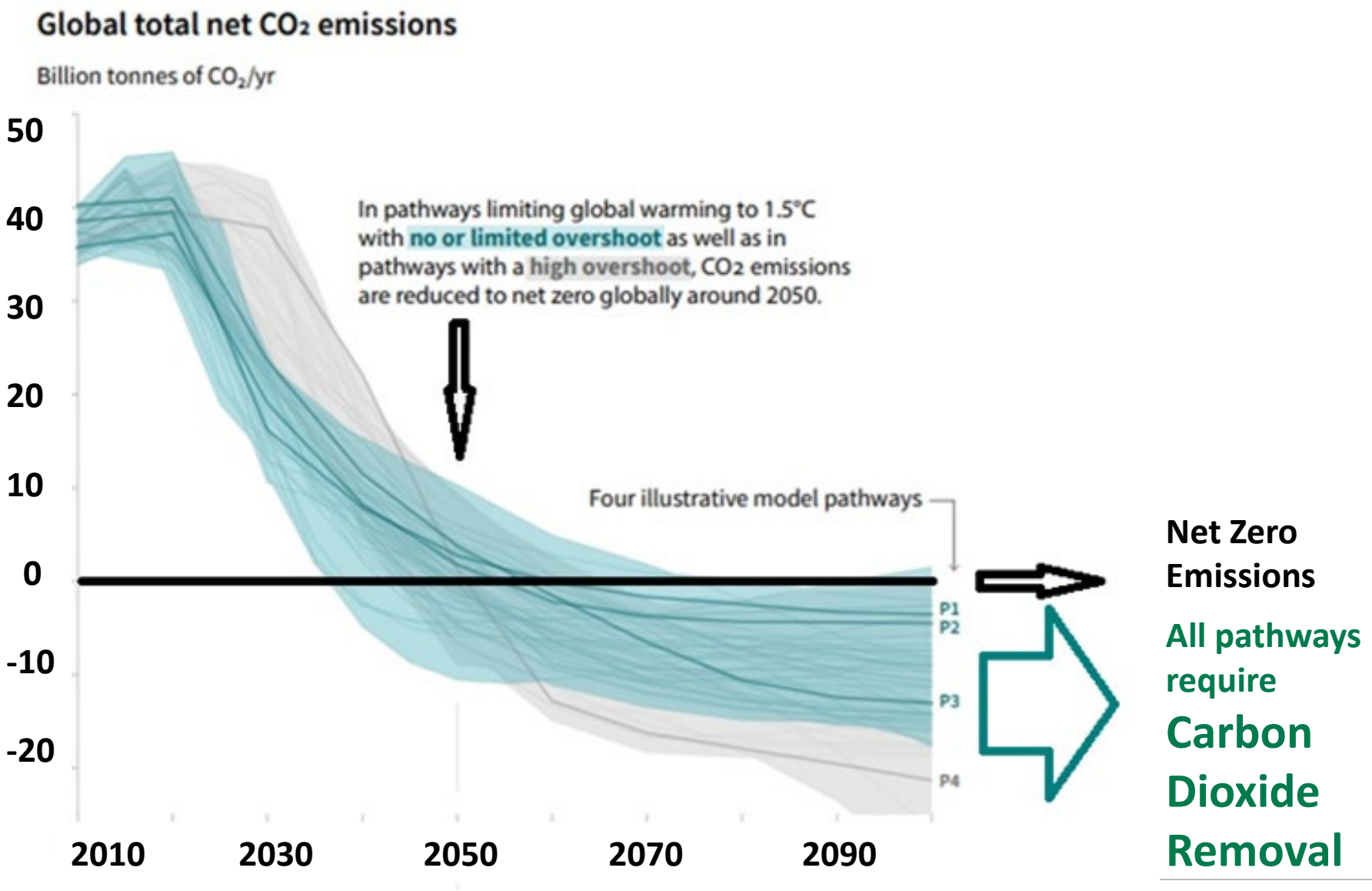
NETPOWER



NETPOWER

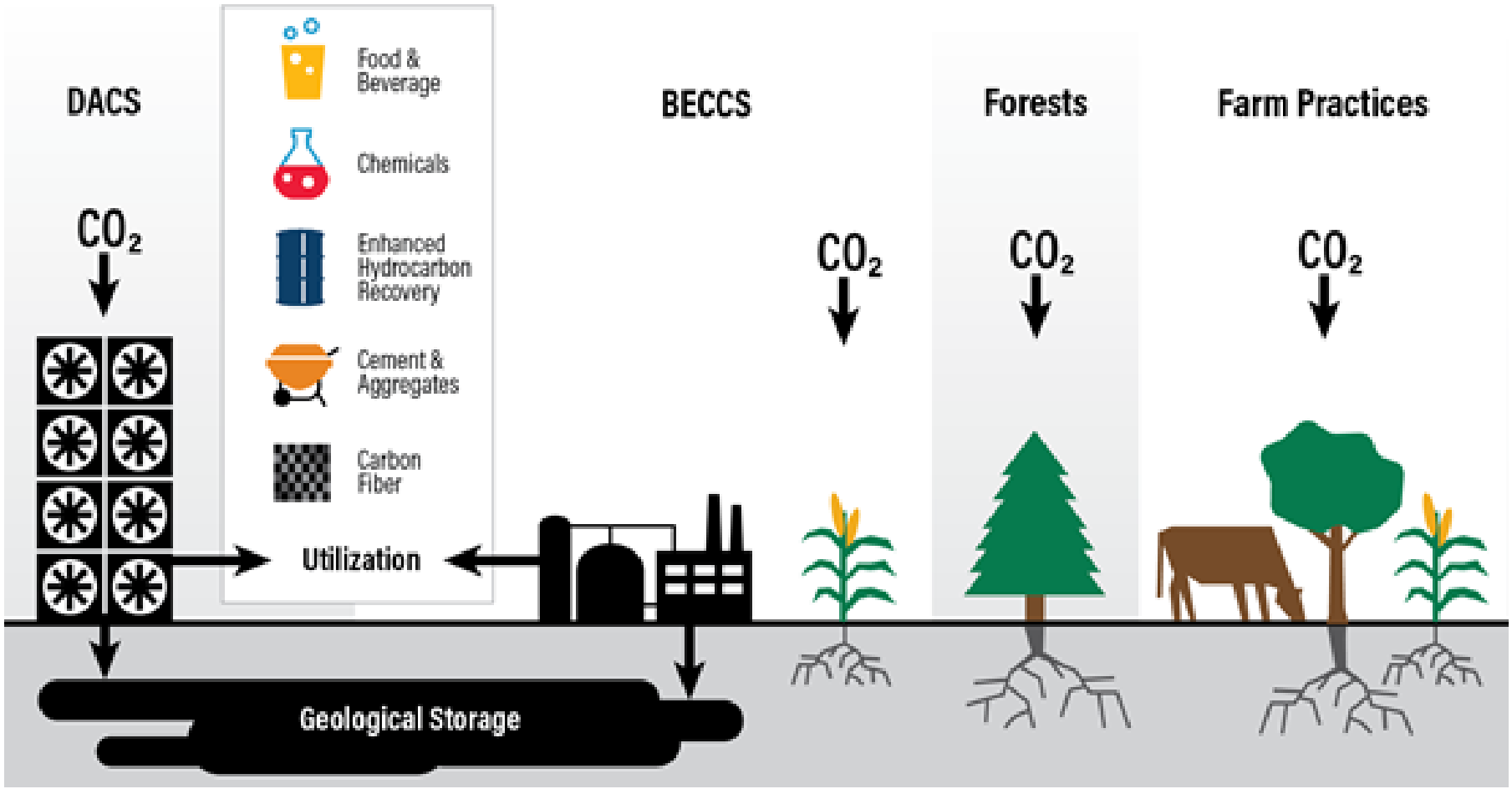
CARBON CAPTURE MUST BE FULLY COMMERCIALIZED

CRITICAL FOR INDUSTRY AND FOR CARBON DIOXIDE REMOVAL



https://www.ipcc.ch/sr15/chapter/summary-for-policy-makers/

CARBON DIOXIDE REMOVAL TECHNIQUES



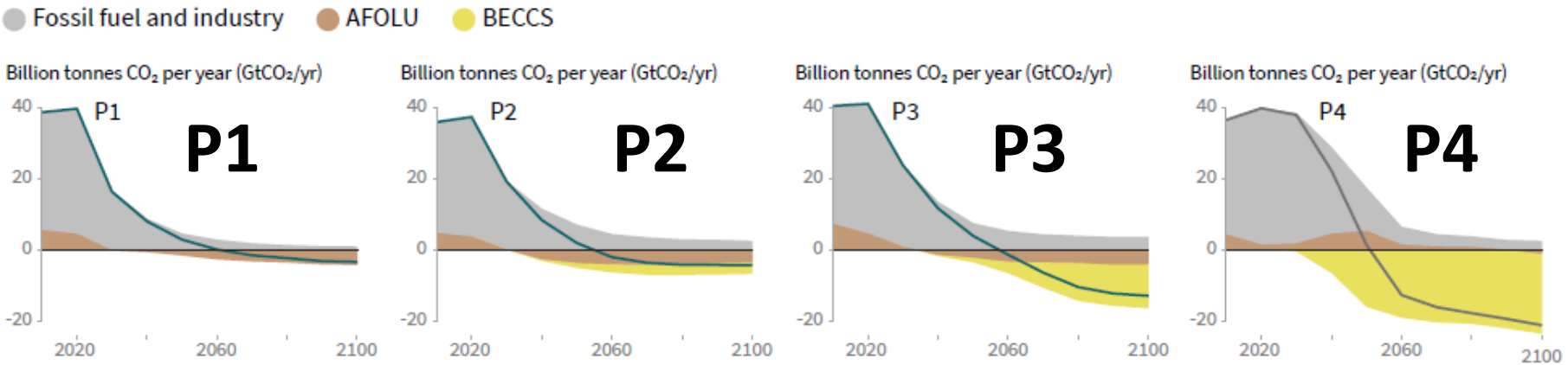
Also at research stage: Enhanced weathering of rocks/minerals, and seawater capture

https://www.wri.org/publication-series/carbonshot-creating-options-carbon-removal-scale-united-states

FOUR ILLUSTRATIVE PATHWAYS – ROLE OF CDR

- **Carbon dioxide removal (CDR) needed via AFOLU (Agriculture, Forestry, Other Land Use), BECCS (Bioenergy with CCS), and/or other technologies and processes (e.g. DACS (Direct Air Capture and Storage))**
- **P1, P2 and P3: "no or limited overshoot" P4: "high overshoot"**

Breakdown of contributions to global net CO_2 emissions in four illustrative model pathways



P1: A scenario in which social, business, and technological innovations result in lower energy demand up to 2050 while living standards rise, especially in the global South. A down-sized energy system enables rapid decarbonisation of energy supply. Afforestation is the only CDR option considered; neither fossil fuels with CCS nor BECCS are used.

P2: A scenario with a broad focus on sustainability including energy intensity, human development, economic convergence and international cooperation, as well as shifts towards sustainable and healthy consumption patterns, low-carbon technology innovation, and well-managed land systems with limited societal acceptability for BECCS.

P3: A middle-of-the-road scenario in which societal as well as technological development follows historical patterns. Emissions reductions are mainly achieved by changing the way in which energy and products are produced, and to a lesser degree by reductions in demand.

P4: A resource and energy-intensive scenario in which economic growth and globalization lead to widespread adoption of greenhouse-gas intensive lifestyles, including high demand for transportation fuels and livestock products. Emissions reductions are mainly achieved through technological means, making strong use of CDR through the deployment of BECCS.

https://www.ipcc.ch/site/assets/uploads/sites/2/2018/07/SR15_SPM_version_stand_alone_LR.pdf

EXAMPLES OF FEDERAL AND STATE GOALS: 100% RENEWABLE VS 100% CLEAN *(WITH RPS BOOST…)*

	100% Renewable	100% Clean (zero carbon)
Federal	• ***By 2035**: **Climate Solutions Act**, H.R. 330 (Lieu), 2019.* • ***By 2050: "100% Renewable" - Sanders***	• ***By 2030: Green New Deal Resolution**, (AOC-Markey)2019.* • ***By 2050: Clean Energy Standard Act (**Smith/Lujan), 2019.*
State	• **By 2045**: **Hawaii**, H.B. 623, 2015. • **By 2050**: **Puerto Rico**, P.S. 1121, 2019. • **By 2032: District of Columbia**, Clean Energy DC Omnibus Act, 2018 • ***By 2040**: **Colorado**, Governor's proposal for 100% renewable electricity.*	• **By 2045**: **California** S.B.100, 2018. • **By 2045**: **New Mexico** S.B. 489, 2019. • **By 2045: Washington** S.B. 5116, 2019 • **By 2050: Nevada** S.B. 358, 2019 • ***By 2040**: **New York**, Governor's Green New Deal proposal, 2019.* • ***By 2050: New Jersey**, Governor's E.O. #28 on Energy Master Plan* • ***By 2050:** Campaign commitments from governors in CT, IL, ME, MI, WI.*

Black = enacted
Blue = proposed

KEY MESSAGES

- 100% renewables vs. 100% clean energy
  - 100% RE for corporate/city/other buyers is OK – an incremental boost to demand for RE – but should evolve to 100% CE
  - 100% RE requirement for a state or country poses challenges in terms of performance, reliability, cost.
  - A broad portfolio of zero-carbon electricity options is valuable from cost and risk management perspectives (*"spread your chips"*).
  - CCS for carbon dioxide removal is critical to meeting 1.5 or 2 degree goals. CCS must be fully commercialized in the 2020s.
- Importance of RD&D programs with a broad portfolio.
- An expanded transmission system is critical in any scenario.
- Role of existing nuclear plants *(UCS report, Nov. 2018)*
- Global perspectives – food for thought…
  - Nuclear power
  - CCS

WORLD RESOURCES INSTITUTE

THANK YOU

Karl Hausker, Ph.D.
Senior Fellow
khausker@wri.org