GLOBAL ENERGY SOLUTIONS SUMMIT

March 28 to 29, 2019

Location (Embassy of Canada, 501 Pennsylvania Ave NW)
Washington, DC

NGA
NATIONAL GOVERNORS ASSOCIATION

EMBASSY OF DENMARK
Washington D.C.

Canada

Embassy of Australia
Washington, D.C.

Welcome to Day 2: Carbon Capture, Utilization and Storage (CCUS)

Rachel McCormick
Counsellor and Head
Energy and Environment Section,
The Embassy of Canada

CCUS Opening Keynote

Hon. Bronwyn Eyre

Minister of Energy and Resources

Saskatchewan

State of the CCUS Market

MODERATOR

Jeff Erikson
General Manager – Client Engagement
Global CCS Institute

Samantha McCulloch
Head, CCUS Unit
International Energy Agency

Trude Sundset
CEO
Gassnova

Sarah Forbes
Scientist
Office of Fossil Energy, U.S. Department of Energy

John Harju
Vice President for Strategic Partnerships
University of North Dakota's Energy and Environmental Research Center (EERC)

Robert Niven
CEO
CarbonCure

Global Energy Solutions Summit: CCUS Roundtable

Samantha McCulloch

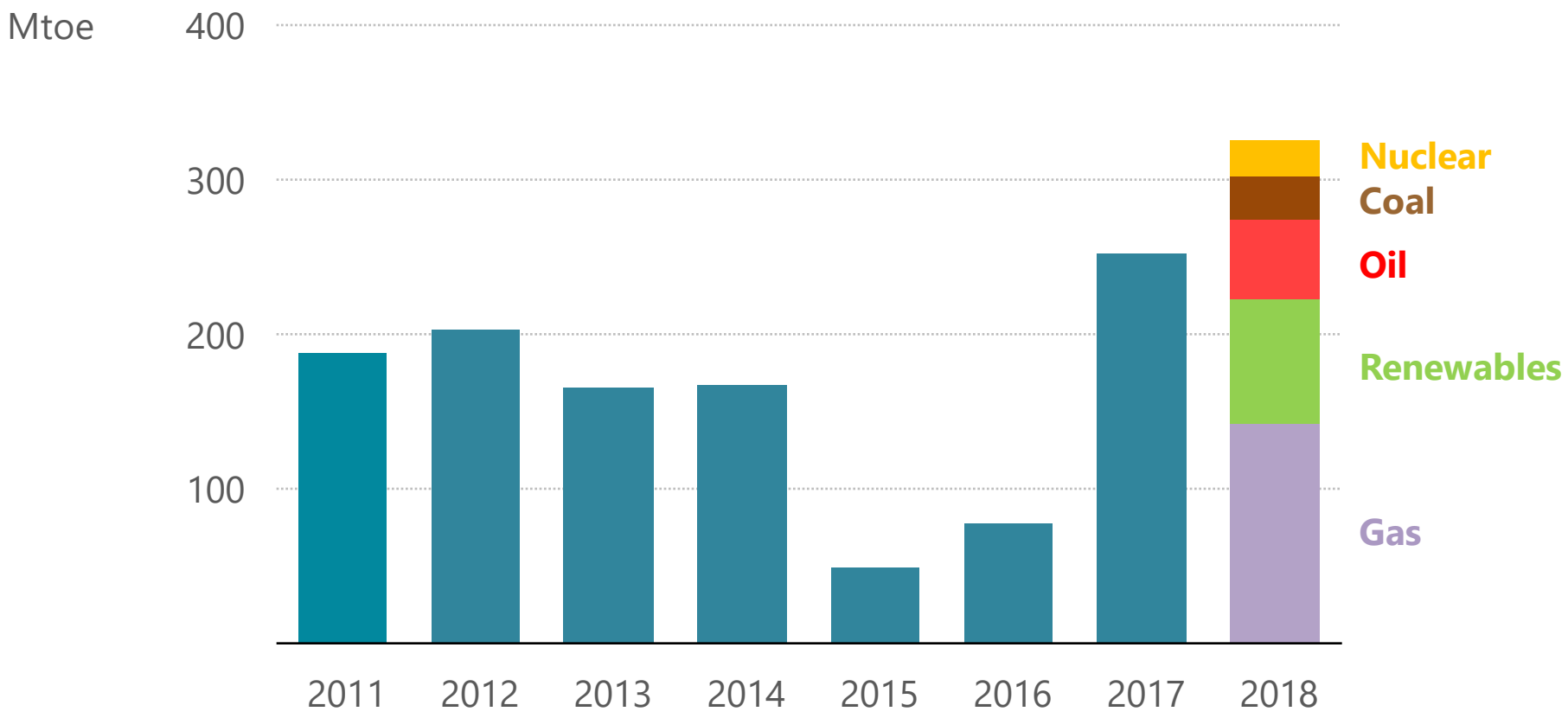
Head of CCUS

29th March 2019

IEA

2018 – a remarkable year for energy

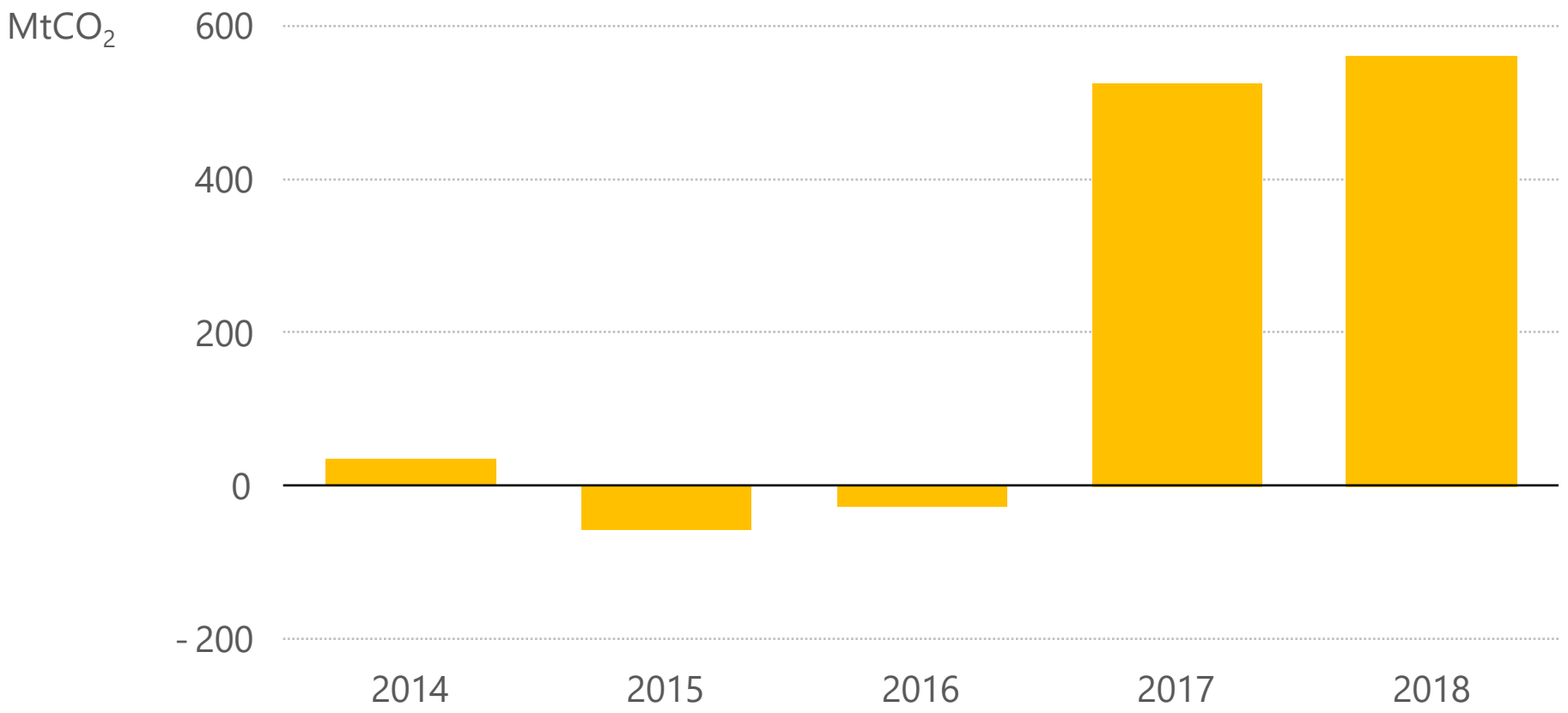
Annual change in global primary energy demand, 2011-18



Global energy demand last year grew by 2.3%, the fastest pace this decade, an exceptional performance driven by a robust global economy, weather conditions and moderate energy prices.

Energy-related CO_2 emissions hit a record high…

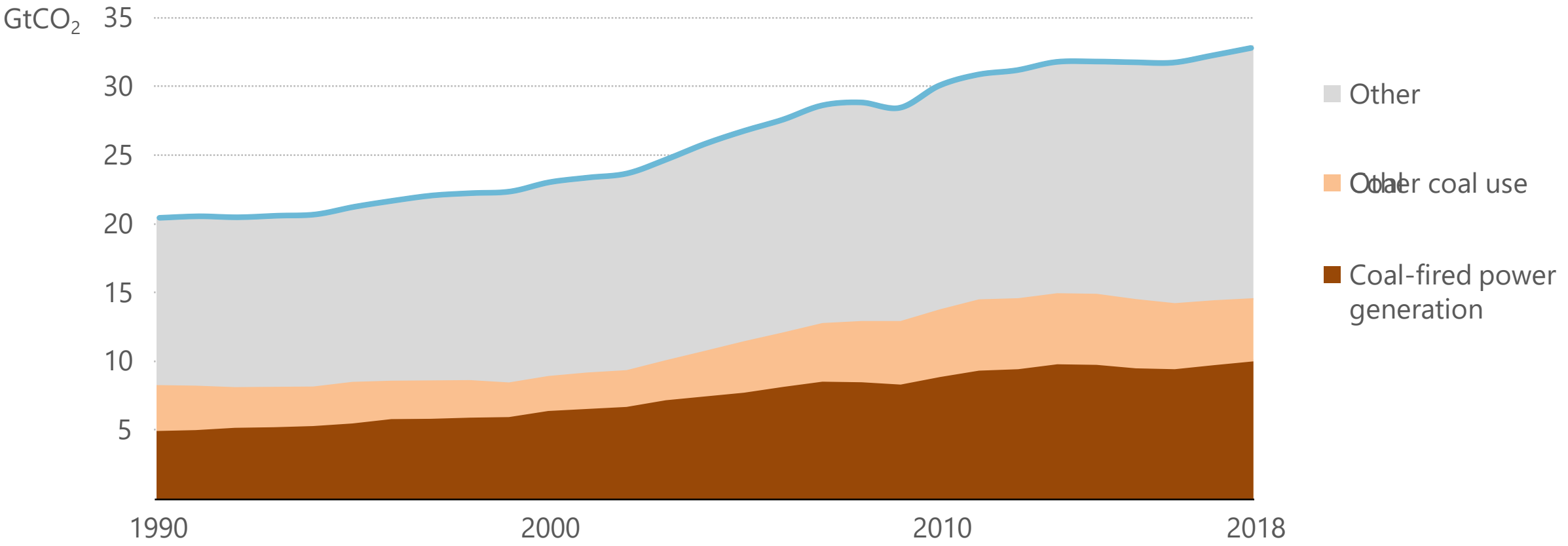
Annual change in global energy-related CO_2 emissions, 2014-2018



Higher demand for fossil fuels drove up global CO_2 emissions for a second year after a brief hiatus. Increases in efficiency, renewables, coal-to-gas switching and nuclear avoided 640 Mt of CO_2 emissions.

..led by coal in power generation in Asia

Global energy-related CO_2 emissions, 1990-2018



Emissions from coal continue to rise, driven by increasing coal use mostly for power generation in Asia. CCUS is a critical solution and is showing signs of a revival.

www.iea.org

IEA

1.4 million

School Climate strikes

Photo: NRK

Technology Centre Mongstad


CCS Infrastructure

Robert Niven

CEO/Founder
rniven@carboncure.com

CCUS Projects Map

THIRD WAY

Intermission

Join Us On Twitter!

#WeTheStates

Join Us On Twitter!

#WeTheStates

Case Study on Boundary Dam Project

Beth Hardy
Vice President, Strategy & Stakeholder Relations
International CCS Knowledge Centre

INTERNATIONAL CCS KNOWLEDGE CENTRE

Knowledge Transfer from Commercial Scale Projects – Boundary Dam CCS Facility

C. Beth Hardy, VP Strategy & Stakeholder Relations

Our Organization

THE INTERNATIONAL CCS KNOWLEDGE CENTRE

Facilitates in an advisory role
Based on expertise and lessons learned

Mandate:
Advance the understanding and use of CCS as a means of managing greenhouse gas emissions

Sponsored jointly by global resource leader, BHP and CCS pioneer, SaskPower

Sharing lessons learned from hands-on operations ensures for experienced-based decision making

Our Story for CCS

Large Scale Deployment (Boundary Dam 3)

↓

Operational & Policy Understandings

↓

Second Generation Application

↓

Trends & Gaps for Large-Scale Deployment

↓

Driving Future Opportunities

BOUNDARY DAM

LEARNING STARTS HERE

THE WORLD'S 1ST INTEGRATED LARGE SCALE POST-COMBUSTION CCS FACILITY

Large Scale Deployment (Boundary Dam 3)

- Post-combustion chosen from several studies
- CCS on coal-fired power operating since 2014
- Projected 90% capture rate & 30 yr life extension
- Initial investment = approximately CDN$1.5 billion
- CO_2 is used for EOR or sequestered at Aquistore

CCS at Boundary Dam Power Station allowed for long-term production of over 110 MW of clean, base-load electricity in a fully integrated and full chain process

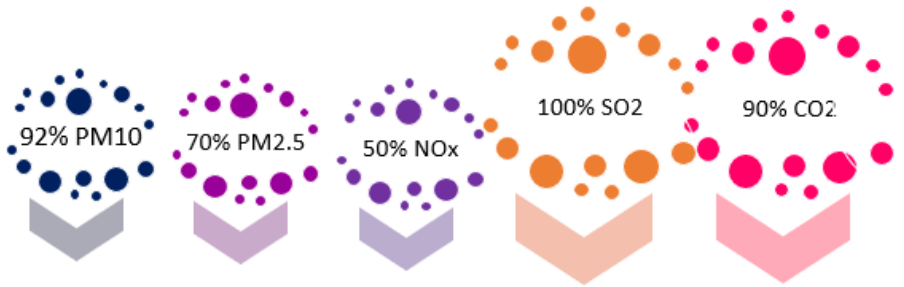
Overview of BD3 Project

The project consisted of two major parts:

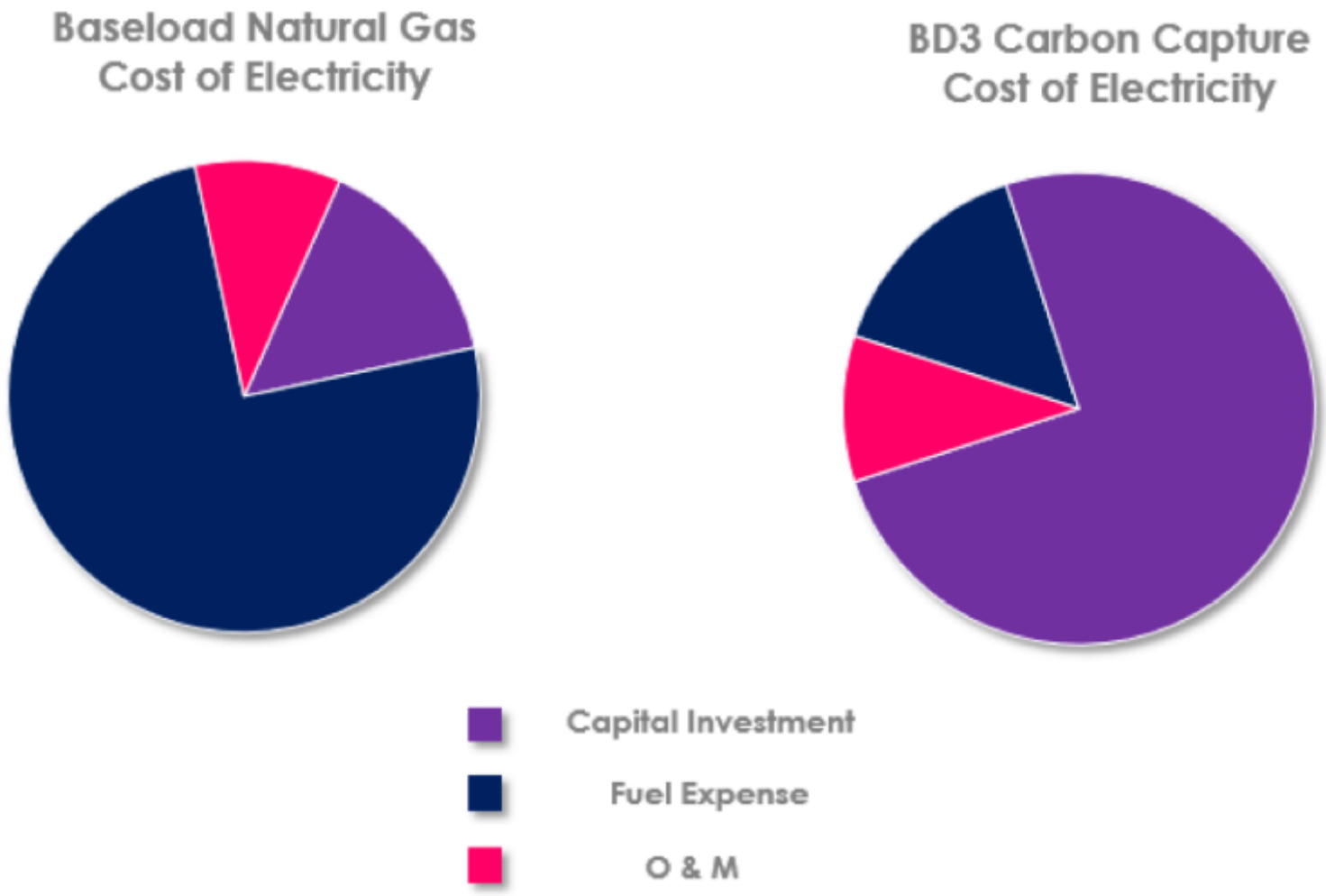
Refurbishment included a complete replacement of the steam turbine and generator, which were at their end of life.

Capture involves taking out other components before the amine removes the CO_2.

- Design deficiencies and construction quality issues had to be managed, as well as amine issues.
- *Trend of higher capture rate and reduced outages over time*
- Has captured & stored over 2Mt



Comparing Costs



Operational Understandings: Exceeding Federal Regulations

1100 t/GWh = Lignite Coal Plant

550-500 = Current Natural Gas Plant

420 = Canadian Regulations on Coal Plant

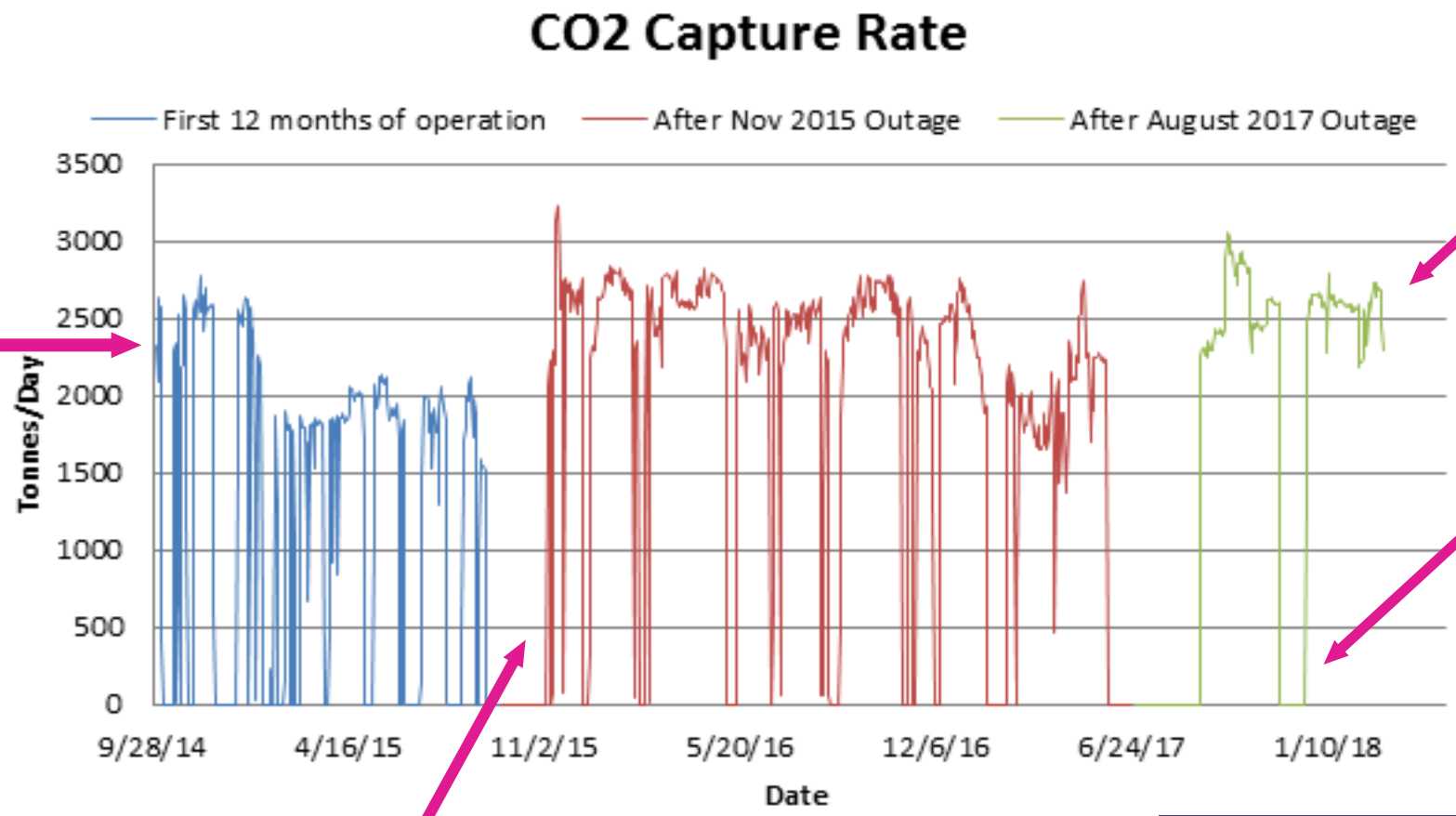
375-400 = New Natural Gas Plant

300-325 = Wind (with peakers)

120-140 = CCS on Boundary Dam 3*

*Name plate capacity

Performance: Reliability



INITIAL OPERATION

Learning about amines

MAXIMUM CAPACITY HIT: 3240 t/day
Better operations.

Capture plant has been reliable

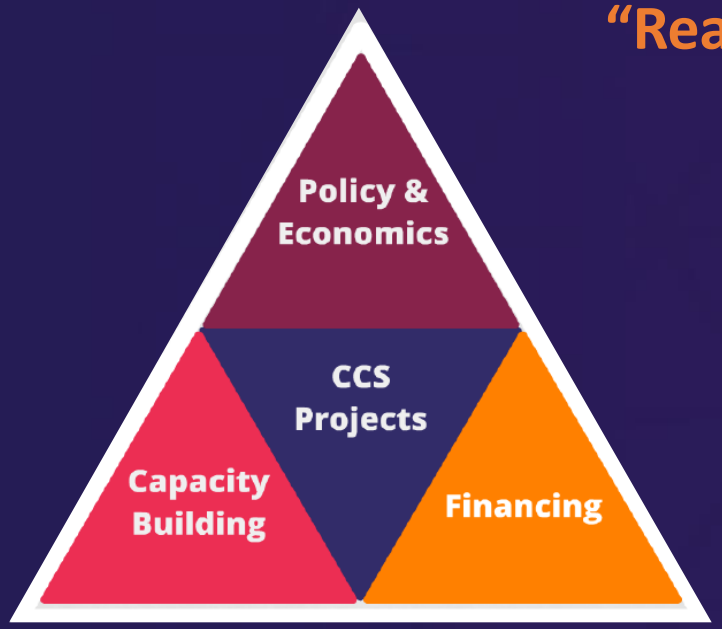
Power plant maintenance resulted in no CO_2 production

NOT CAPTURE PLANT RELATED

What's next for Boundary Dam CCS?

- Improve efficiency and reliability
- Reduce operation & maintenance costs
- Increase capacity

Operational Understandings: Sharing Lessons Learned



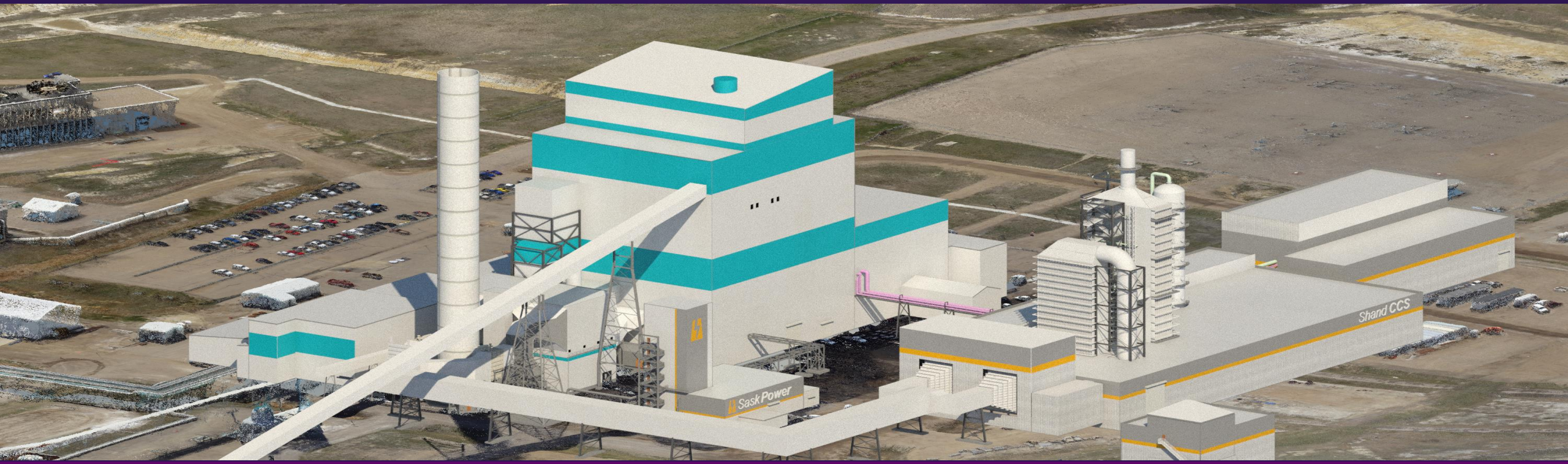
"Real world" considerations for using CCS are important.

We must COLLABORATE -
Not just talk about collaborating.

- Stimulate development
- Bring down costs
- Promote greater knowledge exchange

SECOND GENERATION DESIGN

SASKPOWER SHAND POWER STATION



HIGHLIGHTS OF FEASIBILITY STUDY:

- Designed to capture 2Mt
- 67% cost reduction (per tonne CO_2)
- Can capture up to 97% and integrates well with renewables

About the Shand Feasibility Study

Feasibility Study evaluates the economics of a CCS retrofit & life extension on 300MW coal fired power plant in Saskatchewan

- Projected capture capacity of **2Mt/yr**
- Capital cost to be **67% less** per tonne of CO_2 captured
- Cost of capture at **$45US/t CO_2**
- Capture rate can reach **up to 97%** with reduced load (i.e. renewables on grid)
- Fly ash sales can further reduce CO_2 (potential 125,000t CO_2/yr reduced)

Carbon neutral?

HOW DID COSTS COME DOWN?

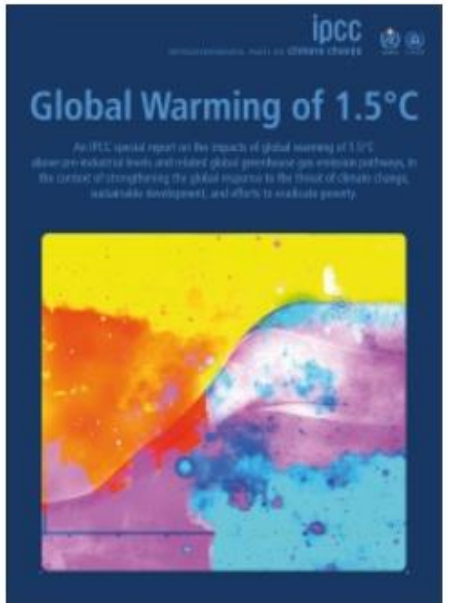
- Lessons learned from building and operating BD3
- Construction at a larger scale using extensive modularization
- Integration of the bigger unit's steam cycle

Second Generation Application to Coal and Other Sources

- IPCC's 5th Assessment Report: median increase in mitigation cost is 138% without CCS
- Almost all IPCC 1.5°C pathway scenarios include CCS

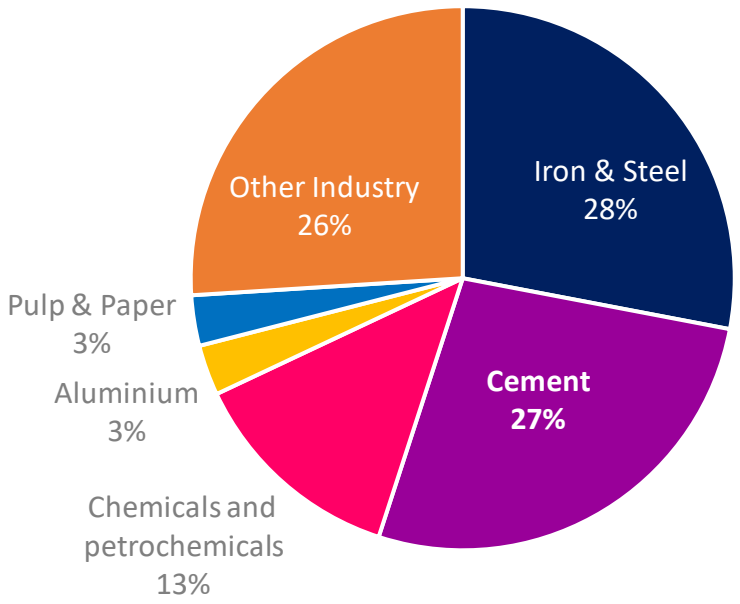
CCS technology is proven;
so de-risked deployment can occur

- *Reliable* and *affordable* energy with reduced emissions are imperative for energy security.
- Implementation of CCS can:
  - allow existing generating assets to operate cleanly and
  - aid to decarbonize industrial emissions.



Second Generation Application to Industrial Emissions

Direct industrial CO_2 emissions (2014)



Information on this slide is sourced from International Energy Agency, Energy Technology Perspectives 2017

Industrial CO2 emissions represent 24% of global CO2 emissions at 8.3 Gt CO_2 (2014)

- Lessons learns from operational experience at Boundary Dam CCS Facility and findings from the Shand CCS Feasibility Study can be applied to other industrial sources of emissions
- Size and layout considerations / integration are key considerations
- Costs can be saved with CO_2 infrastructure hubs, cost recovery with EOR, modularization and byproduct sales decisions
- Optimization is still required for particular flue gas characteristics to save operating costs

Driving Future Opportunities

Cooperative Approaches:

- Multi-stakeholder initiatives are important to drive development
- Government funding goes farther when leveraged with private funding
- **Don’t reinvent the wheel!**

Business Case:

- Account for economic considerations and energy security issues
- Find value in by-products
- Use enhanced oil recovery & align with oil companies where possible

Reduce Administrative Burden:

- Build on existing regulations as much as possible
- Create flexible enforcement regulations

Incentives & Financing:

- Enable support for first-movers
- Create a variety of financial incentives for projects
- Drive policy parity with other clean energy technology (ex. subsidies)
- Multilateral Development Bank involvement is critical for Asia

INTERNATIONAL
CCS KNOWLEDGE
CENTRE

Thank You

For more information please visit our website at:

ccsknowledge.com

Contact us by email:

info@ccsknowledge.com

Don’t forget to follow us on Twitter

@ccsknowledge

Trivia & Transition

Join Us On Twitter!

#WeTheStates

Join Us On Twitter!

#WeTheStates

Training Session: Workforce Development for Emerging Energy Technologies

SHARE OUR MESSAGE.

SEND A LETTER.

CCS Bridge to a Cleaner Future
International Brotherhood of Boilermakers
https://vimeo.com/278701159

Opportunities & Next Steps: State & International Perspectives on CCUS

MODERATOR

Jeff Bobeck
Director of Energy Policy Engagement
Center for Climate and Energy Solutions

Shannon Angielski
Executive Director
Carbon Utilization Research Council

Adam Schafer
Policy Director
Office of Montana Governor Steve Bullock

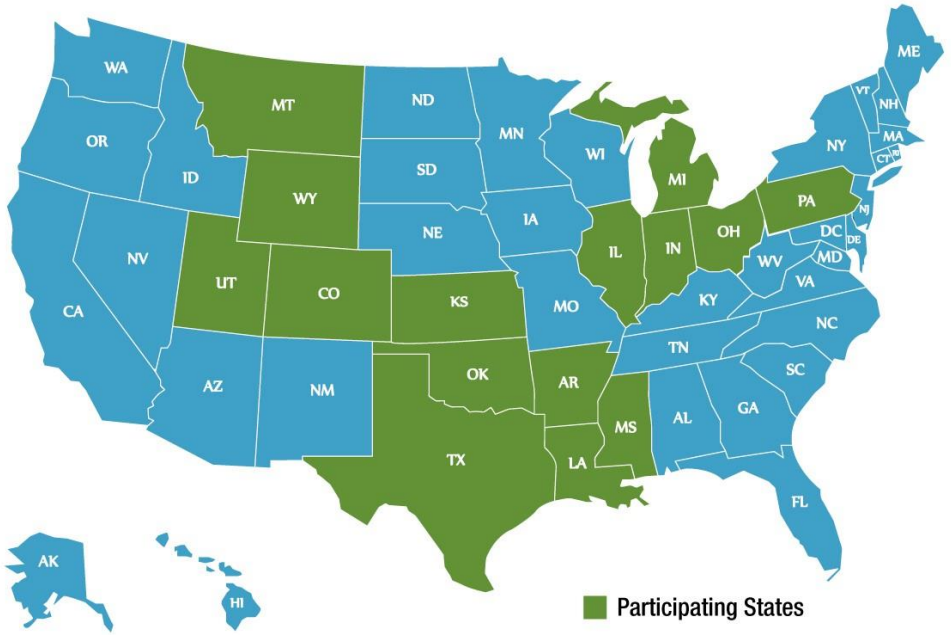
Brad Crabtree
Vice President, Carbon Management
Great Plains Institute

Jason Lanclos
Director, Technology Assessment Division
Louisiana State Energy Office

Chris Romans
Executive Director
Energy Advance Center

STATE CARBON CAPTURE WORK GROUP

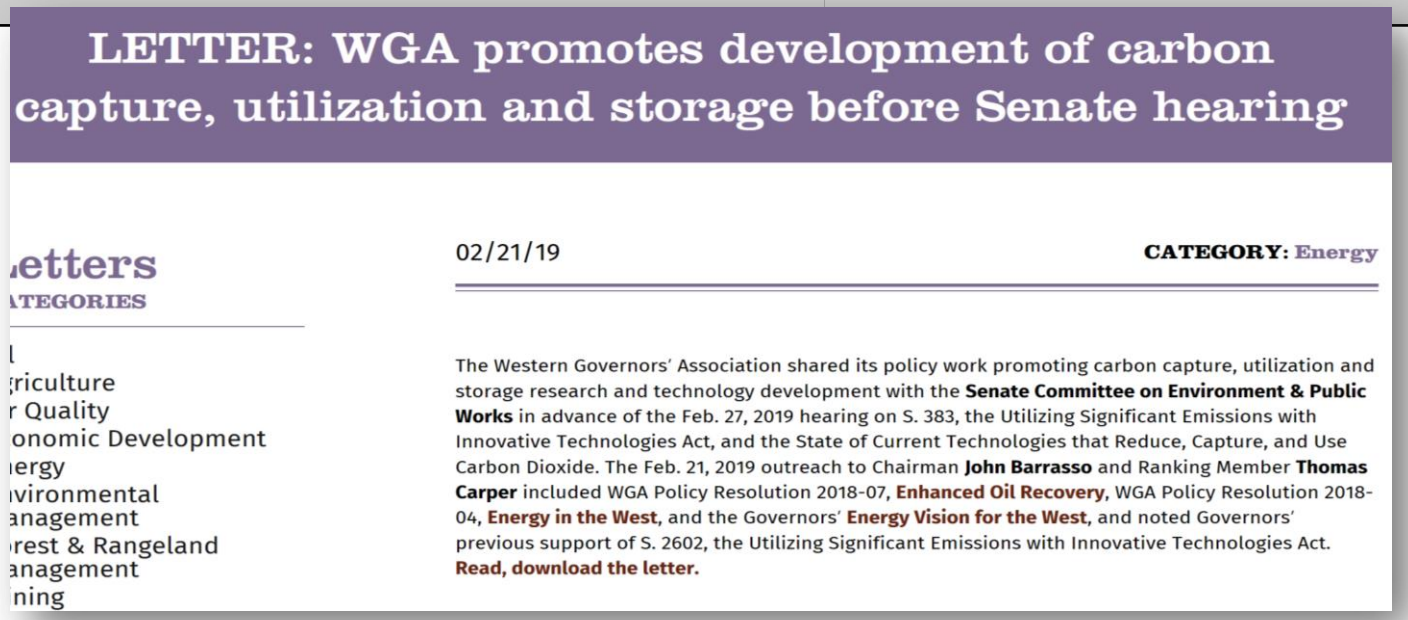
- Co-convened by former Governor Matt Mead (R-WY) and Governor Steve Bullock (D-MT). Staffed by Great Plains Institute.
- Launched in 2015:
  - Officials from 15 states*
  - Leading industry and NGO stakeholders and experts
- Objectives:
  - Help policymakers better understand states' potential for carbon capture, CO_2-EOR and other storage and utilization;
  - Recommend state and federal strategies and policies;
  - Support implementation of policy recommendations and project deployment.



*State participation varies and includes governors' staff, cabinet secretaries, utility commissioners and agency and commission staff.

Growing State Support for Carbon Capture

Year	Organization	Resolution Highlights
2015	Western Governor's Association	Recognizes economic and environmental benefits of carbon capture and CO_2-EOR; called on Congress to extend and strengthen the federal Sec. 45Q tax credit.
2015	Southern States Energy Board	Emphasizes need for federal incentives and state policy measures.
2016	National Association of Regulatory Utility Commissioners	Highlights economic, energy production and carbon mitigation benefits, and the importance of state and federal action.



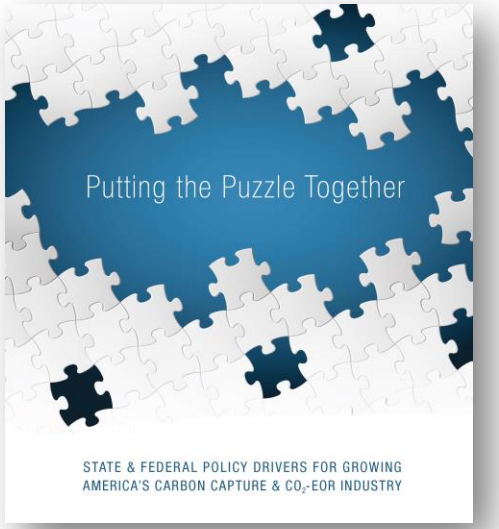
LETTER: WGA promotes development of carbon capture, utilization and storage before Senate hearing

letters
ATEGORIES
l
griculture
r Quality
onomic Development
ergy
vironmental
anagement
rest & Rangeland
anagement
ning

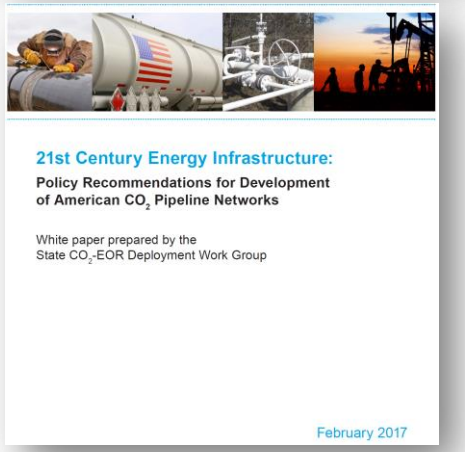
02/21/19 CATEGORY: Energy

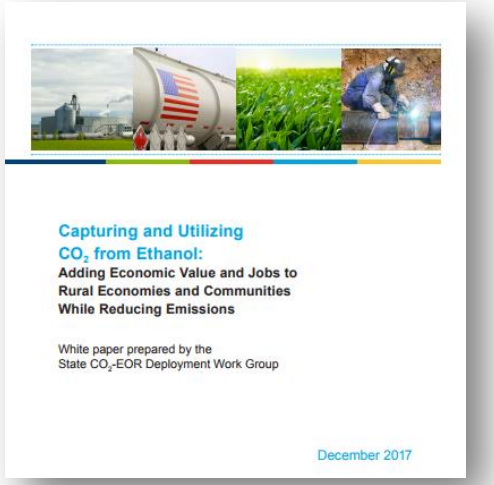
The Western Governors' Association shared its policy work promoting carbon capture, utilization and storage research and technology development with the **Senate Committee on Environment & Public Works** in advance of the Feb. 27, 2019 hearing on S. 383, the Utilizing Significant Emissions with Innovative Technologies Act, and the State of Current Technologies that Reduce, Capture, and Use Carbon Dioxide. The Feb. 21, 2019 outreach to Chairman **John Barrasso** and Ranking Member **Thomas Carper** included WGA Policy Resolution 2018-07, **Enhanced Oil Recovery**, WGA Policy Resolution 2018-04, **Energy in the West**, and the Governors' **Energy Vision for the West**, and noted Governors' previous support of S. 2602, the Utilizing Significant Emissions with Innovative Technologies Act. **Read, download the letter.**

Four Major Work Group Deliverables To Date



- ***Putting the Puzzle Together: State and Federal Policy Drivers for Growing America's Carbon Capture and CO2-EOR Industry***
- ***21st Century Energy Infrastructure: Policy Recommendations for Development of American CO_2 Pipeline Networks***
- ***Electricity Market Design and Carbon Capture Technology: The Opportunities and the Challenges***
- ***Capturing and Utilizing CO2 from Ethanol: Adding Economic Value and Jobs to Rural Economies and Communities While Reducing Emissions***





Regional Cooperation to Support Carbon Capture & CO_2 Pipeline Infrastructure Deployment

- Development of two cooperative regional efforts to harness the federal 45Q tax credit for deployment:
  - Western and Midwestern regions.
  - Former Governor Mead invited 17 governors to have their states participate.
  - Governors Mead and Bullock announced Regional Deployment Initiative in Jackson Hole, WY in June 2018, together with officials from other states.
  - State Carbon Capture Work Group coordinating effort.

STATE CARBON CAPTURE WORK GROUP

REGIONAL CARBON CAPTURE DEPLOYMENT INITIATIVE

Three-Phased Approach to Fostering Project Deployment

Phase I (complete)

- Baseline mapping of sources and sinks;
- Preliminary cost analysis; and
- Pipeline modeling.

Phase II (complete)

- Convened state officials and stakeholders to launch Initiative in Midwestern and Western regions.

Phase III (underway)

- Modeling and planning to support project deployment.
- Identification of additional state and federal policies to close remaining cost gaps for projects.

STATE CARBON CAPTURE WORK GROUP

REGIONAL CARBON CAPTURE DEPLOYMENT INITIATIVE

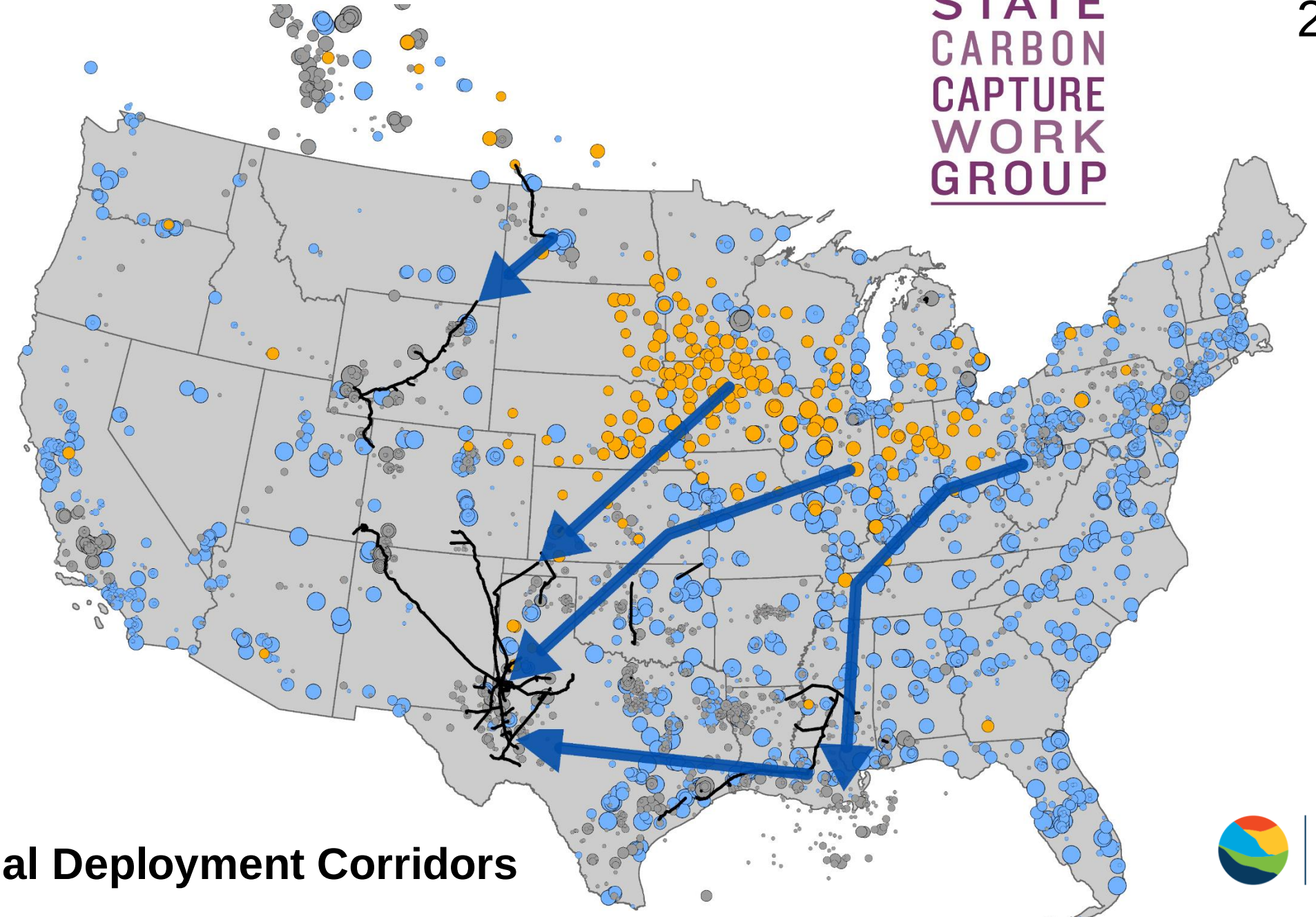
Objectives in 2019

REGIONAL CARBON CAPTURE DEPLOYMENT INITIATIVE

- Prioritize key carbon capture and CO_2 pipeline project opportunities revealed in the modeling.
- Determine cost gaps, where applicable, for priority projects after accounting for federal 45Q tax credit.
- Identify state policies to help close cost gaps.
- Engage stakeholders, policymakers and media to marshal support for projects to meet 45Q timeline of beginning construction by end of 2023.
- Prepare for 2020 state legislative sessions.

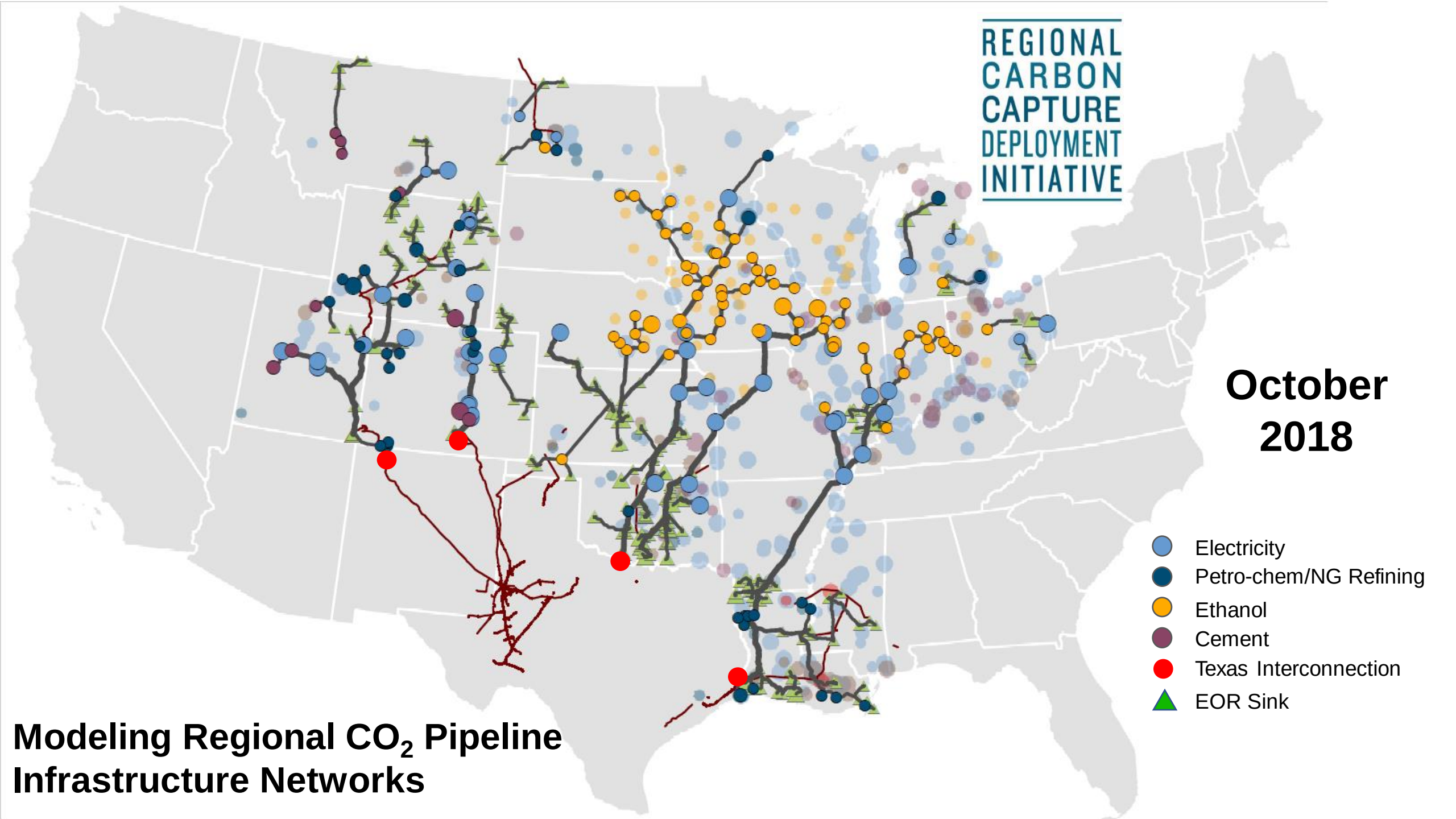
STATE CARBON CAPTURE WORK GROUP

2016

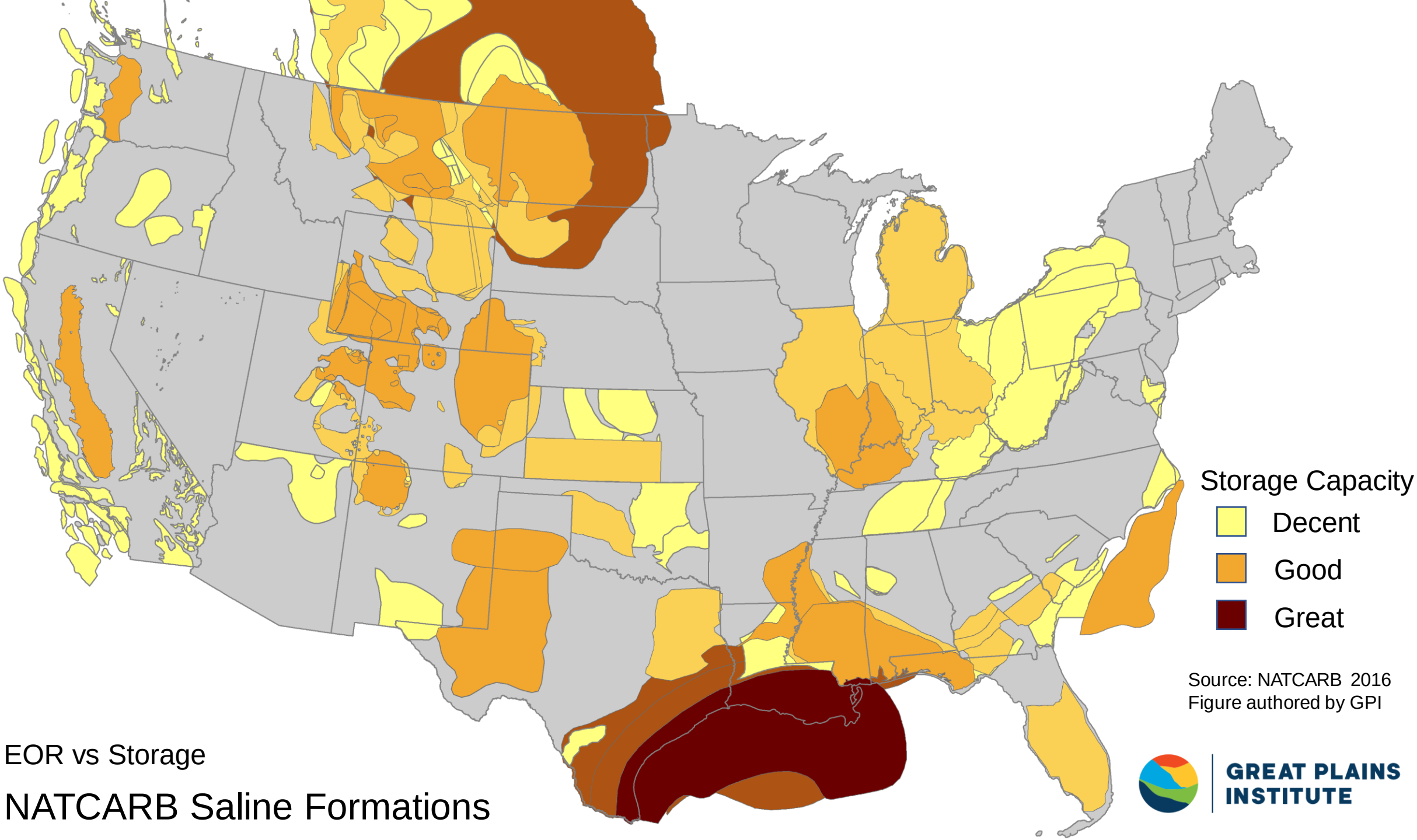


Regional Deployment Corridors

GREAT PLAINS INSTITUTE



Modeling Regional CO_2 Pipeline Infrastructure Networks



Source: NATCARB 2016
Figure authored by GPI

EOR vs Storage

NATCARB Saline Formations

GREAT PLAINS INSTITUTE

Opportunities & Next Steps: State & International Perspectives on CCUS

MODERATOR

Jeff Bobeck
Director of Energy Policy Engagement
Center for Climate and Energy Solutions

Shannon Angielski
Executive Director
Carbon Utilization Research Council

Adam Schafer
Policy Director
Office of Montana Governor Steve Bullock

Brad Crabtree
Vice President, Carbon Management
Great Plains Institute

Jason Lanclos
Director, Technology Assessment Division
Louisiana State Energy Office

Chris Romans
Executive Director
Energy Advance Center

Lunch and Keynote on the Future of CCUS

Julio Friedmann
Senior Research Scholar at the Center for Global Energy Policy
Columbia University

COLUMBIA | SIPA
Center on Global Energy Policy

The essential nature of CCS and CO_2 removal: convergence of policy, technology & commerce

Dr. S. Julio Friedmann
Senior Research Scholar, Center for Global Energy Policy
March 529, 2019

@CarbonWrangler

A few key points

CCS and CO_2 removal are required to hit key targets

- Mitigation: CCS is required to achieve 2°C (IPCC, IEA, UNEP)
- Additional mitigation: CO_2 removal (CDR) is required to achieve 1.5°C
- Critically important for heavy industry & “hard to mitigate” sections

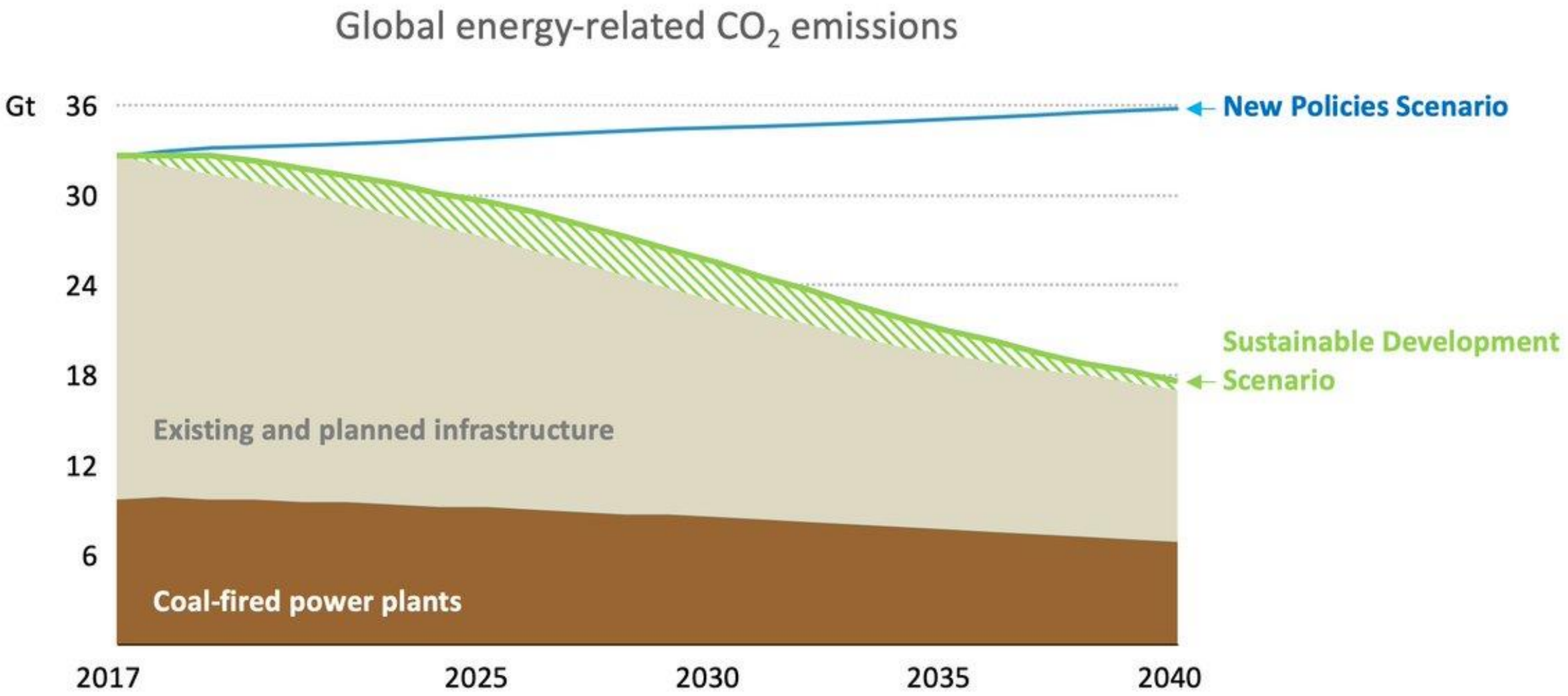
Tech gets better

- Like solar, wind, LEDs, batteries – we know the recipe
- Dramatic cost reductions within 5-7 years

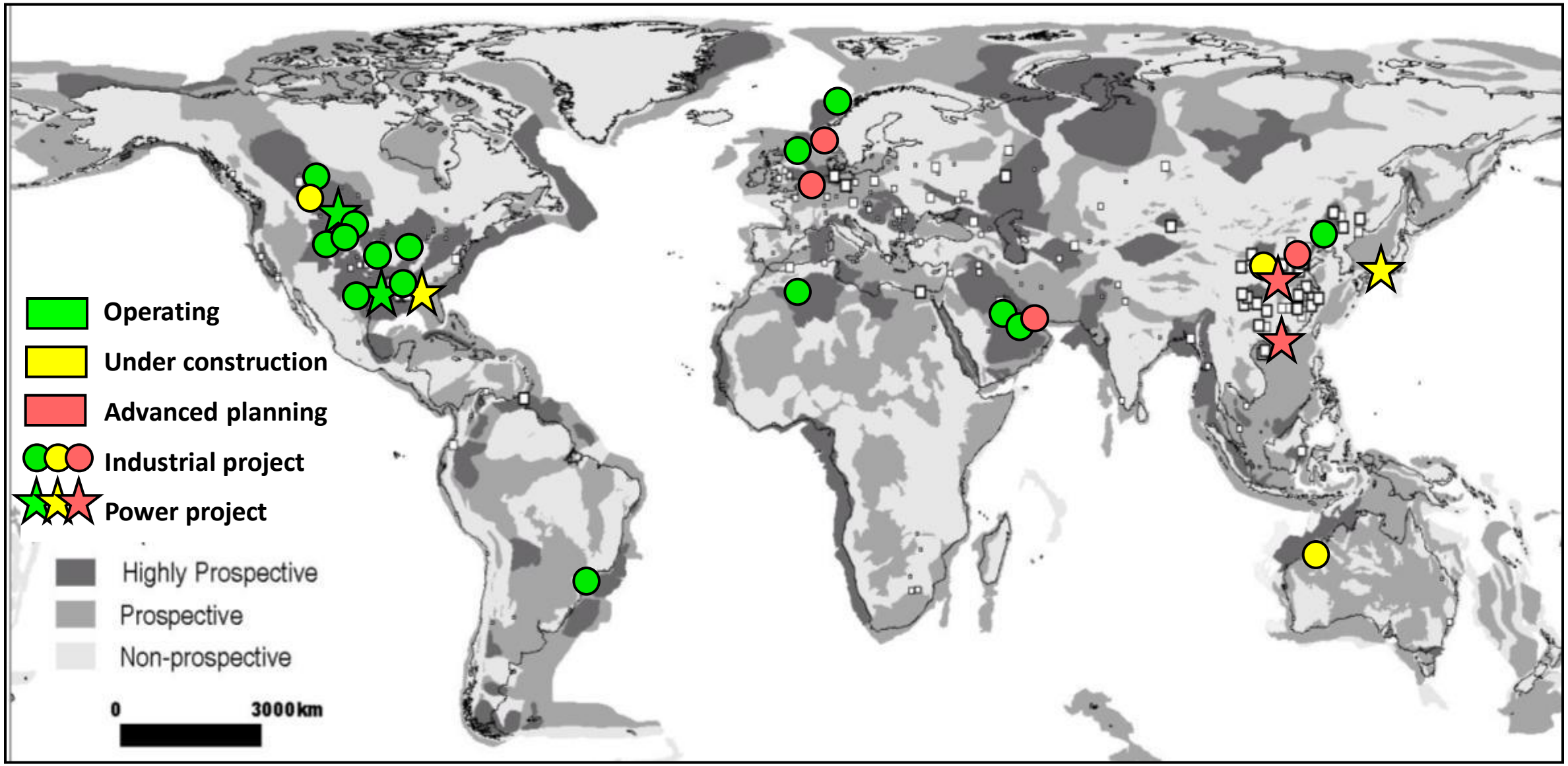
Policy is needed

- Should focus on creating markets for carbon products and services
- Lots of policy options: C Tax not required

Already at 95% lock-in. All IPCC pathways 2ºC or less require CCS



IEA: World Energy Outlook 2018



18 operating plants, storing ~30 Mtons CO_2 each year

Estimated storage worldwide: ~10 trillion tons

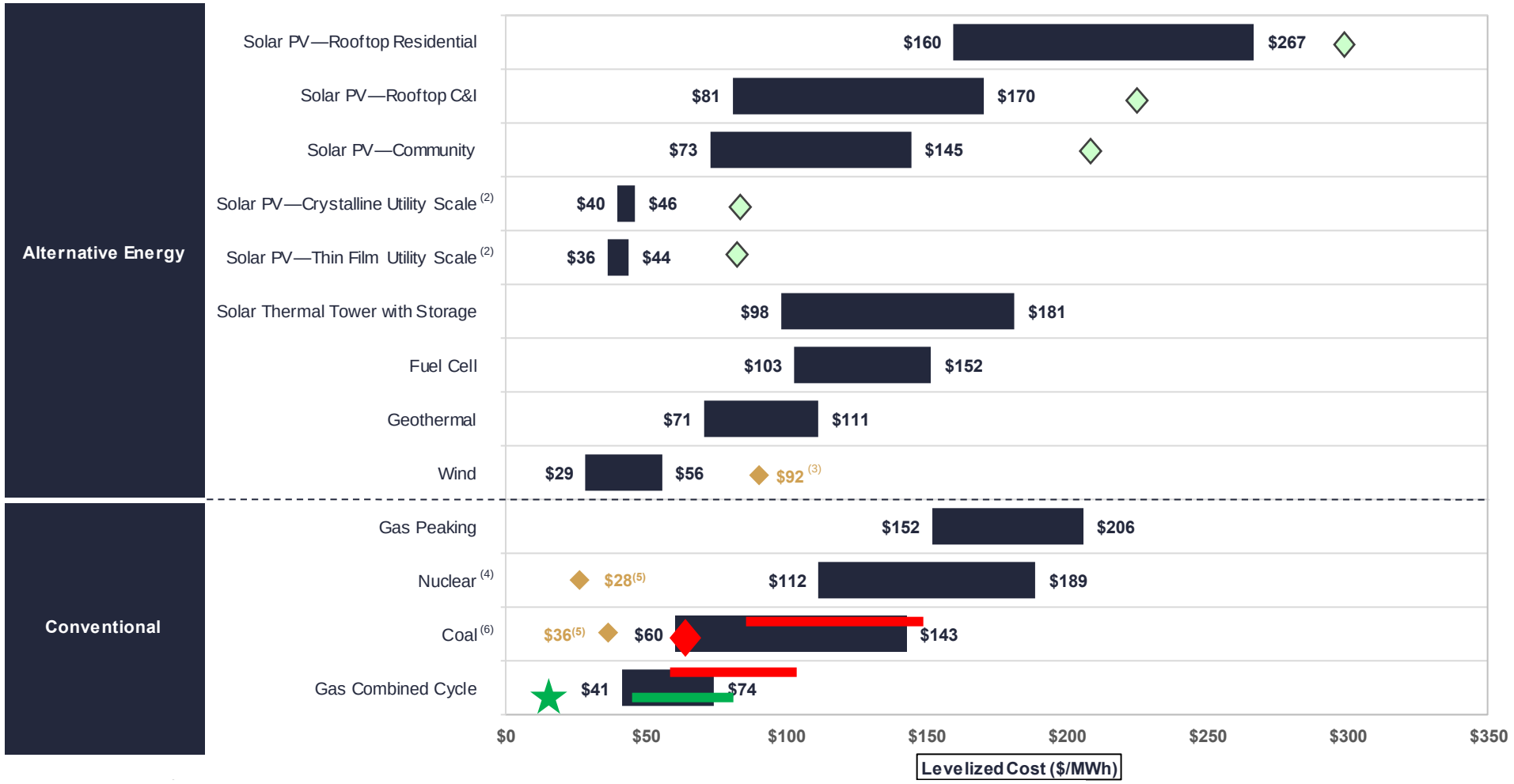
The world, especially North America, has plenty of storage

2.5-21.8 trillion tons (median ~8.5 trillion tons) North America

Estimates of CO_2 Stationary Source Emissions and Estimates of CO_2 Storage Resources for Geologic Storage Sites

RCSP or Geographic Region	CO_2 Stationary Sources		CO_2 Storage Resource Estimates (billion metric tons of CO_2)								
	CO_2 Emissions (million metric tons per year)	Number of Sources	Saline Formations			Oil and Gas Reservoirs			Unmineable Coal Areas		
			Low	Med***	High	Low	Med***	High	Low	Med***	High
BSCSP	115	301	211	805	2,152	<1	<1	1	<1	<1	<1
MGSC	267	380	41	163	421	<1	<1	<1	2	3	3
MRCSP	604	1,308	108	122	143	9	14	26	<1	<1	<1
PCOR*	522	946	305	583	1,012	2	4	9	7	7	7
SECARB	1,022	1,857	1,376	5,257	14,089	27	34	41	33	51	75
SWP	326	779	256	1,000	2,693	144	147	148	<1	1	2
WESTCARB*	162	555	82	398	1,124	4	5	7	11	17	25
Non-RCSP**	53	232	--	--	--	--	--	--	--	--	--
Total	3,071	6,358	2,379	8,328	21,633	186	205	232	54	80	113

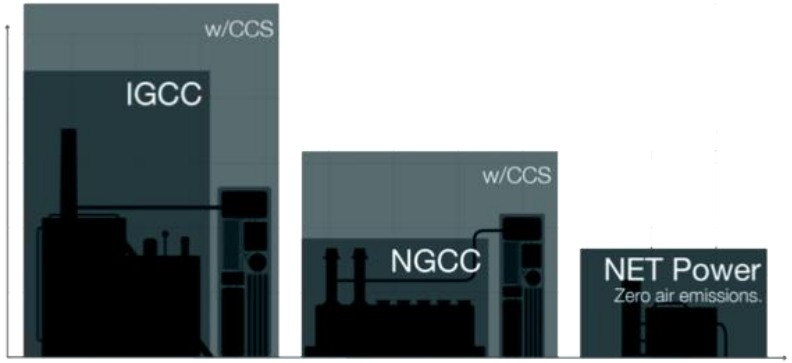
The market today (Unsubsidized LCOE – Lazard 2018)



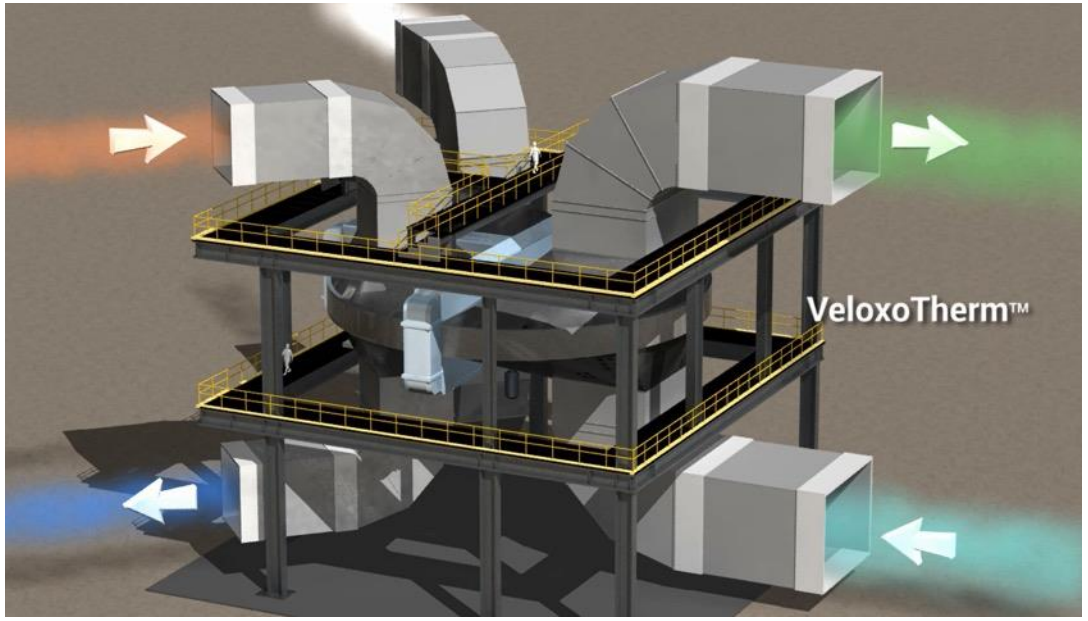
Red bars: Range of 90% CCS for new plants
Red diamond: median retrofit for coal on supercritical coal plant with local storage
Green bar: projected costs for NetPower, unsubsidized
Green star: project costs for NetPower, unsubsized Nth of a kind OR 1st of a kind with 45Q
Green diamonds: PV + battery storage

New Tech: NetPower

- 100% CO_2 stream, at pressure
- Produces water
- N^{th} plant: ~price parity to NGCC
- Can ramp up & down
- Addl. potential revenues



New Tech: Inventys & Fuel Cell Energy (both NG focus)



- Solid sorbent + 3D printing
- Very low capital costs
- Nth plant: ~$30/t CO_2
- Modular design
- New CEO
- Can ramp up and down

- Molten carbonate “afterburner”
- Produces extra power
- Nth plant: unclear
- High efficiency, modular design
- Partnership with ExxonMobil & Southern Co.
- Can ramp up & down

JUST DO IT.

Policies options are required for market design and scaling

Policies to spur investment

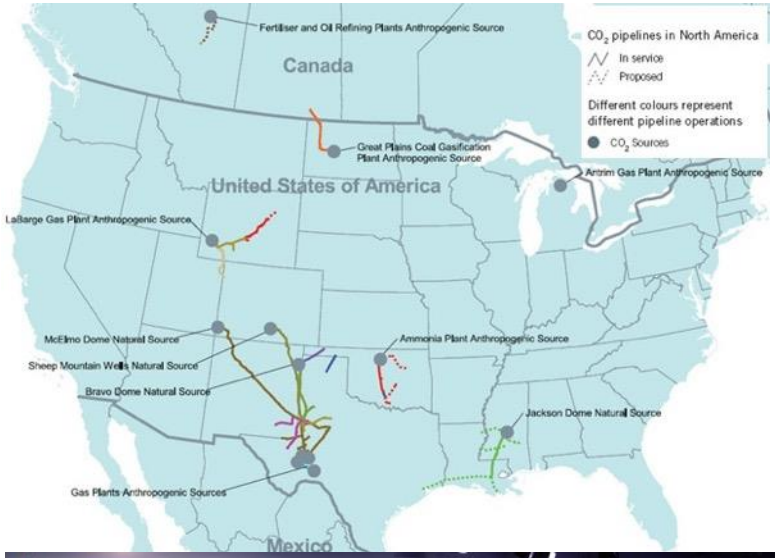
- Tax credits (45Q, ITC & PTC, bonus depreciation, economic activity zones)
- Other financial incentives (private activity bonds, MLP)

Policies to spur markets

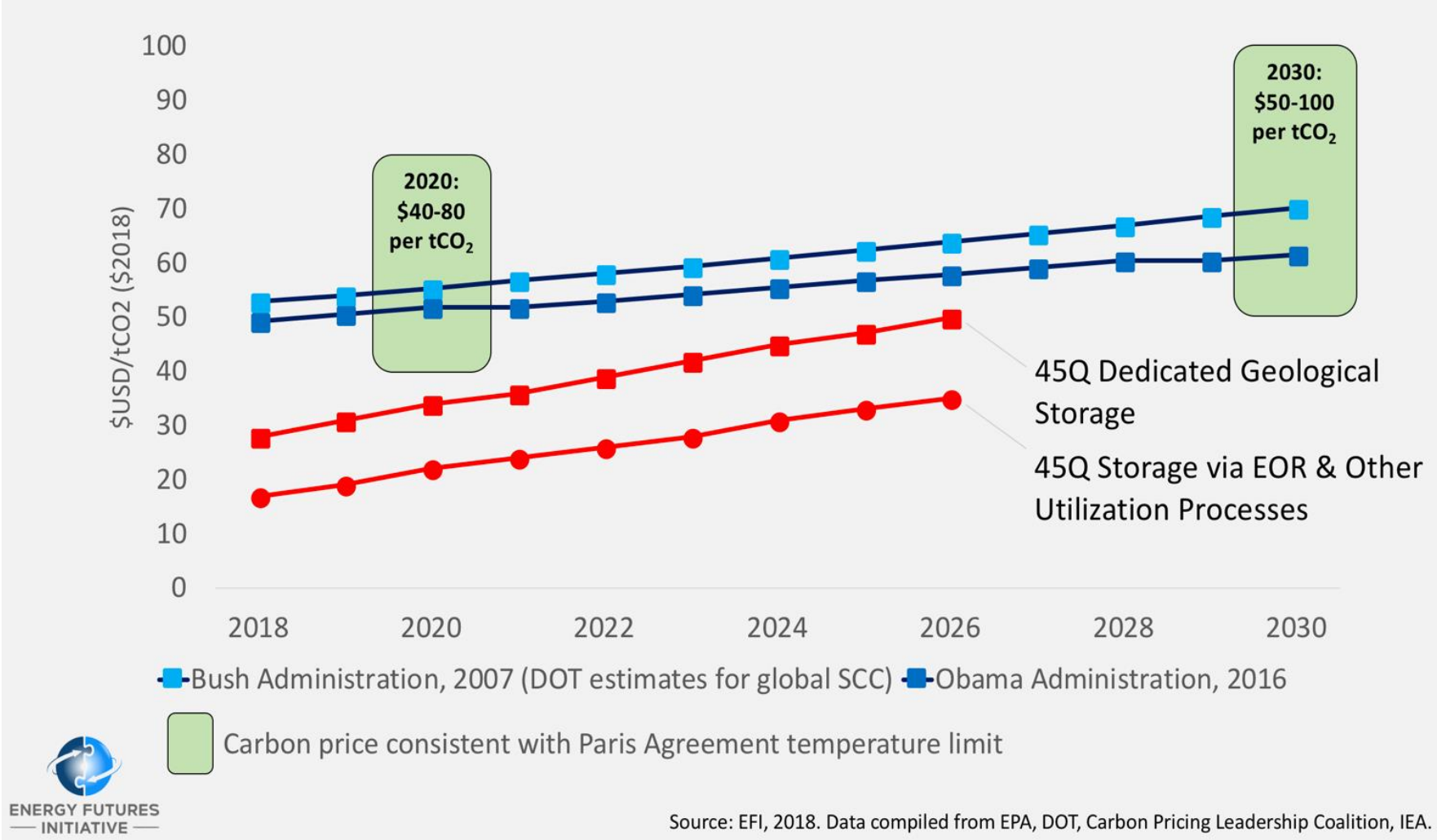
- Procurements (e.g., low-C building materials)
- Clean Energy Standards & Low-C Fuel Standards
- Critical infrastructure investments
- Carbon tax/cap & trade

Policies to spur innovation

- RD&D investment (Mission Innovation)
- Loan-program office
- Life-cycle assessments & performance standards



FUTURE Act is now law (45Q tax credit reform)



CA SB100: 100% Clean Energy Portfolio Standard by 2045

EO B-55-18: 100% decarbonized by 2045, net removal after

Federal R&D Programs: Unprecedented funding

Office of Fossil Energy: $727M total

Clean Coal and Carbon Management

Maintains carbon capture and advanced cycle programs

Maintains carbon storage, including CarbonSAFE assessments

Maintains CO2 Utilization, possibly expands

Office of Energy Efficiency and Renewable Energy: $2.3B

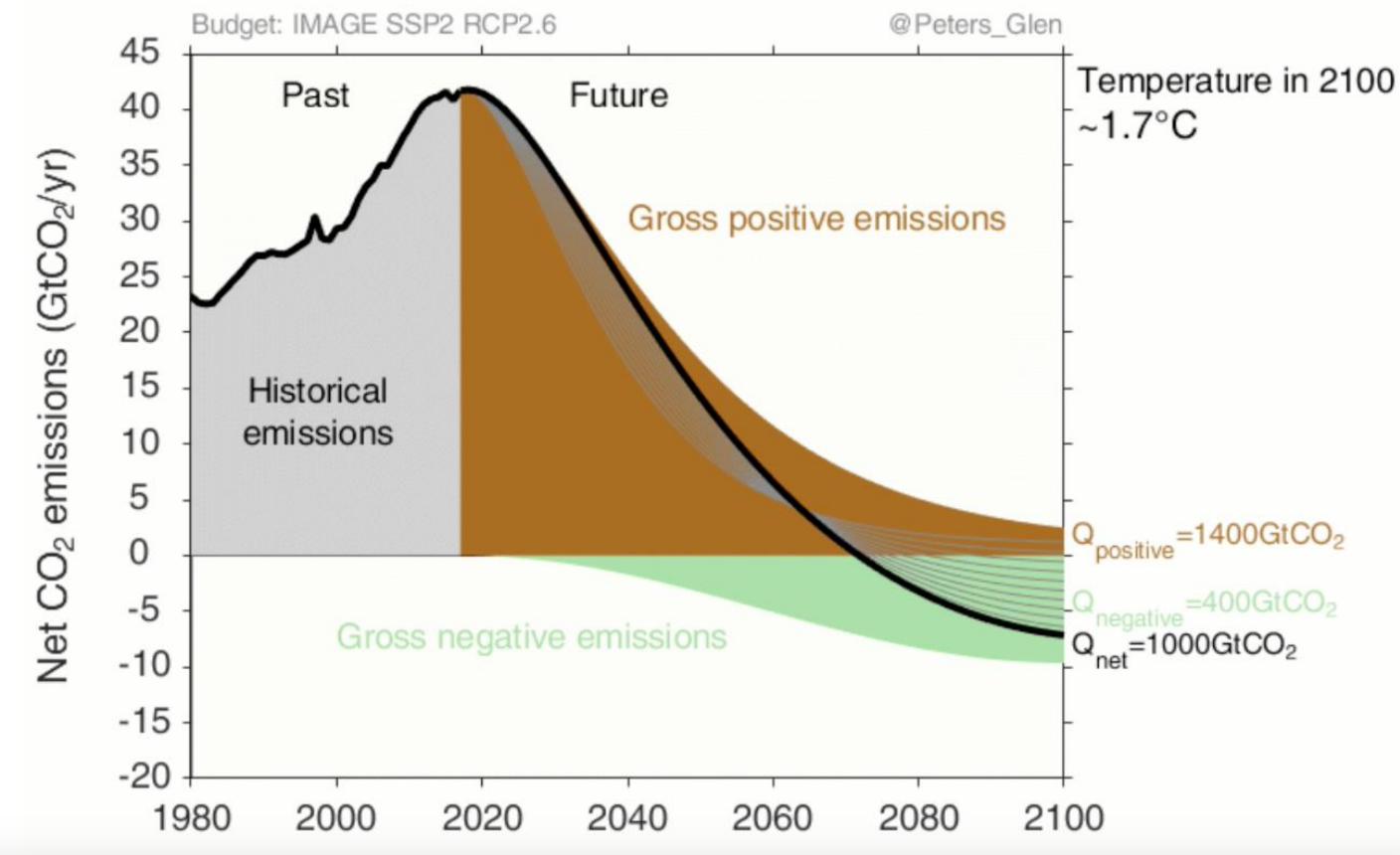
Bioenergy Technology Office (BETO)

- CO2 to products program (including algae and biochemicals)
- Engineered Carbon Reduction Report (Rewiring C Economy)

DOE Loan program Office

- Sustained current advanced fossil budget
- Added $2B authorities for rural cooperatives

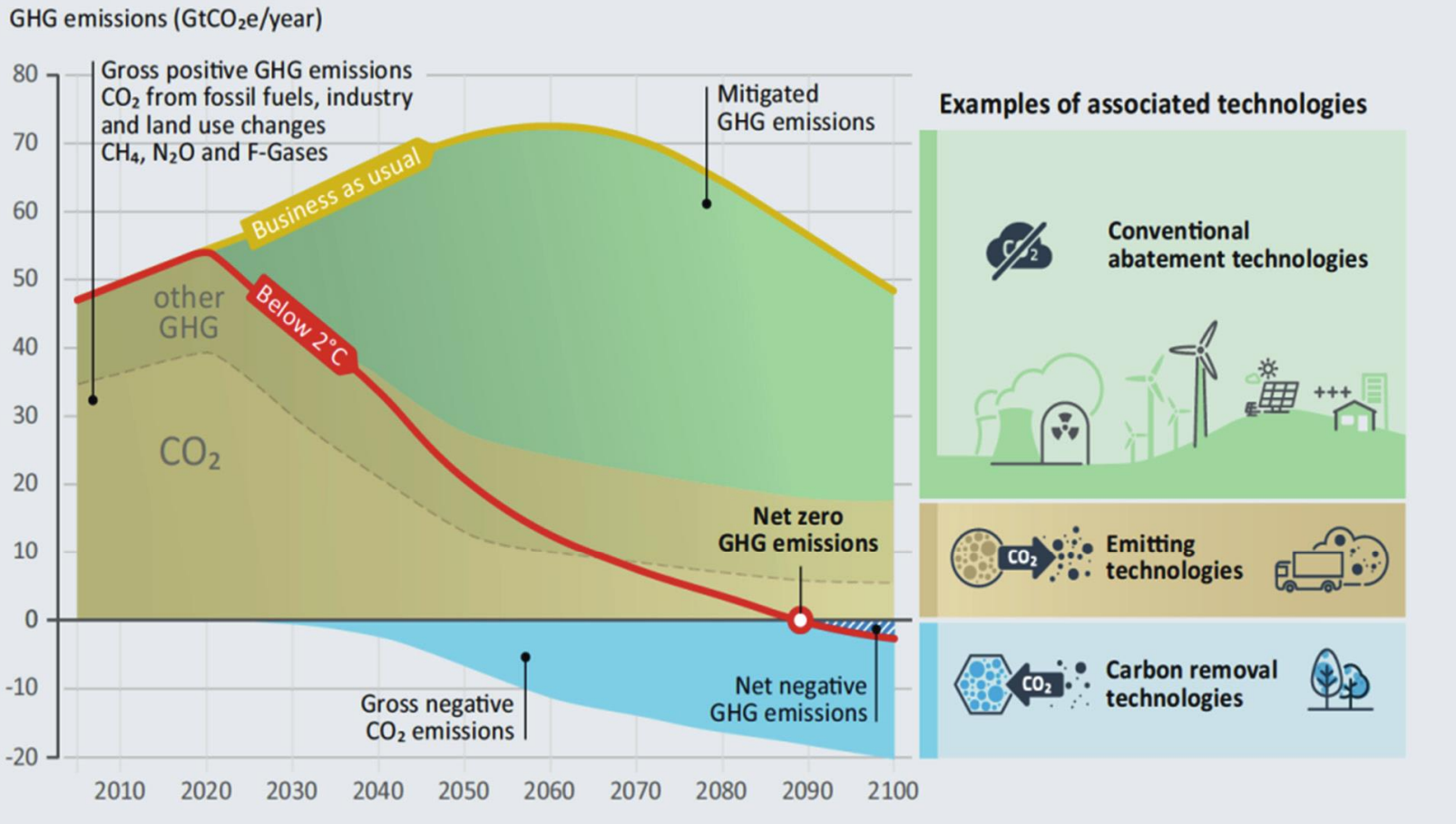
Carbon dioxide removal (CDR) essential for meeting climate goals

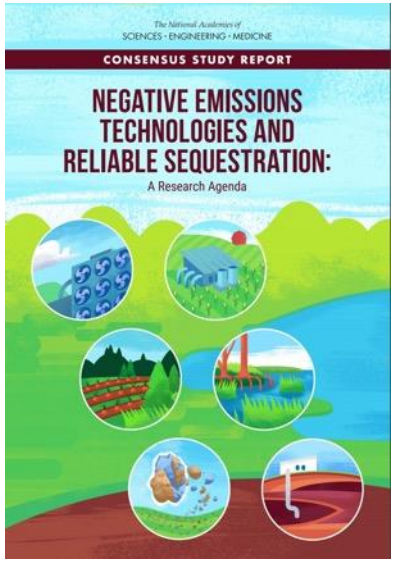


"All pathways that limit global warming to 1.5°C with limited or no overshoot project the use of carbon dioxide removal (CDR) on the order of 100–1000 GtCO2 over the 21st century." – IPCC 1.5°C Report (2018)

- ***CDR is additional and complementary to conventional mitigation***

National Academies: Natural Solutions + BECCS not enough





National Academies, 2018

https://nas-sites.org/dels/studies/cdr/


The world's first commercial direct air capture plant
Does the CO_2 work of 36,000 trees
This will improve


Generation Engine: turning CO_2 to fuel: Carbon Engineering & Greyrock
Squamish, British Columbia
This will improve

Third new species: Air-CO_2 for fun and profit

Global Thermostat, Alabama

This will improve

Closing Remarks & Thank You

Sue Gander
Division Director
Environment, Energy & Transportation,
National Governors Association

Thank You to the Summit Planning Team

NGA
Jessica Rackley
Abigail Hunter

Embassy of Australia
Sarah Storey
Anthony Orford
Meredith Jones

Embassy of Canada
Aaron Annable
Dan Abele

Embassy of Denmark
Jeppe Mathias Helsted
James Glennie

Closing Remarks

Join Us On Twitter!

#WeTheStates

Join Us On Twitter!

#WeTheStates