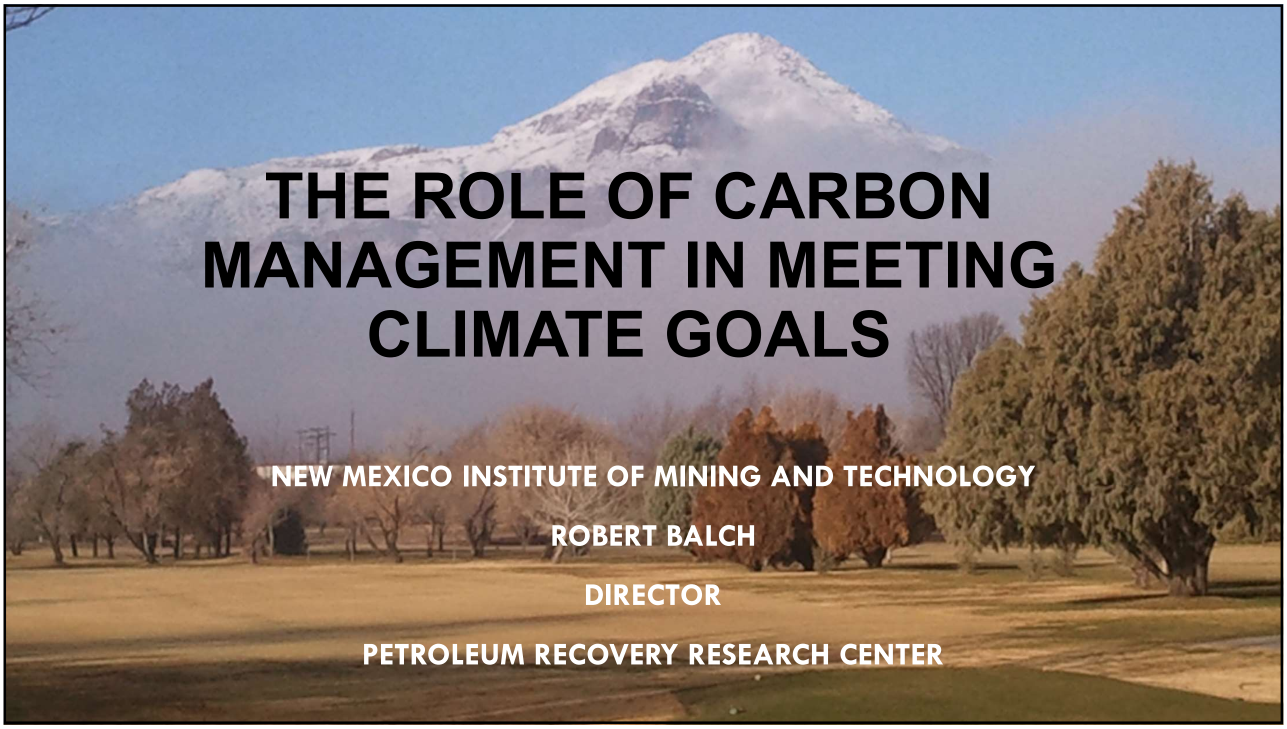

THE ROLE OF CARBON MANAGEMENT IN MEETING CLIMATE GOALS

NEW MEXICO INSTITUTE OF MINING AND TECHNOLOGY

ROBERT BALCH

DIRECTOR

PETROLEUM RECOVERY RESEARCH CENTER

Short Biography

- 1997: PhD Earth and Environmental Sciences (Geophysics) – NMT
- 2012-2020: Oil Conservation Commisioner
- 2016- Present: Director Petroleum Recovery Research Center
  - Focus has evolved towards sustainability, carbon storage, water cleanup
- ANSI Representative to ISO TC 265 (Geologic Storage of Carbon)
  - US Mirror Committee (ISO) have brought in 3 standards to US
- Member Class VI Advisory Group (Groundwater Protection Council)
- Lead: Southwest Partnership on Carbon Sequestration (7 SW States)
- Lead: Carbon Utilization and Storage Partnership (15 Western states)
- New Mexico Lead: Intermountain West Energy Sustainability & Transitions
  - (I-WEST) Los Alamos
- Involved in 24 Carbon Storage Projects in SW and Western USA
  - 5 Completed with >1.2 Million Tonnes Stored
  - 19 Active, targeting more than 15 million tonnes per year of active storage

What Do We Mean by Carbon Management?

The reduction and/or removal of CO_2 across all sectors and nations to a value which ideally adds up to zero globally

Scale Matters: It is simpler for a single person, industry, city, or state to accomplish this than it is for the entire world to do so simultaneously

Timing Matters: The Paris Accord says we have until 2050 to reduce to 40% of current emissions, yet still have a 1.5^{o}C change. 100% reduction required to further minimize impacts. Time is running out

Why is Carbon Reduction Important?

- World carbon emissions from human activities is ~33 Billion Tonnes of CO_2 per year as of 2020
  - Increased from ~2 billion tonnes of CO_2 per year in 1900
- World leaders meet periodically to assess the hazards of these emissions and make agreements about what can be done to mitigate the effects
  - Paris Accord, Kyoto Protocol, are two recent examples
- Reduction to pre-industrial atmospheric levels would mitigate the effect of humanity on the Earth's climate
  - Direct Air Capture with storage necessary to remove CO2 from atmosphere
- Climate impacts are unpredictable and may have broad consequences for life on the planet

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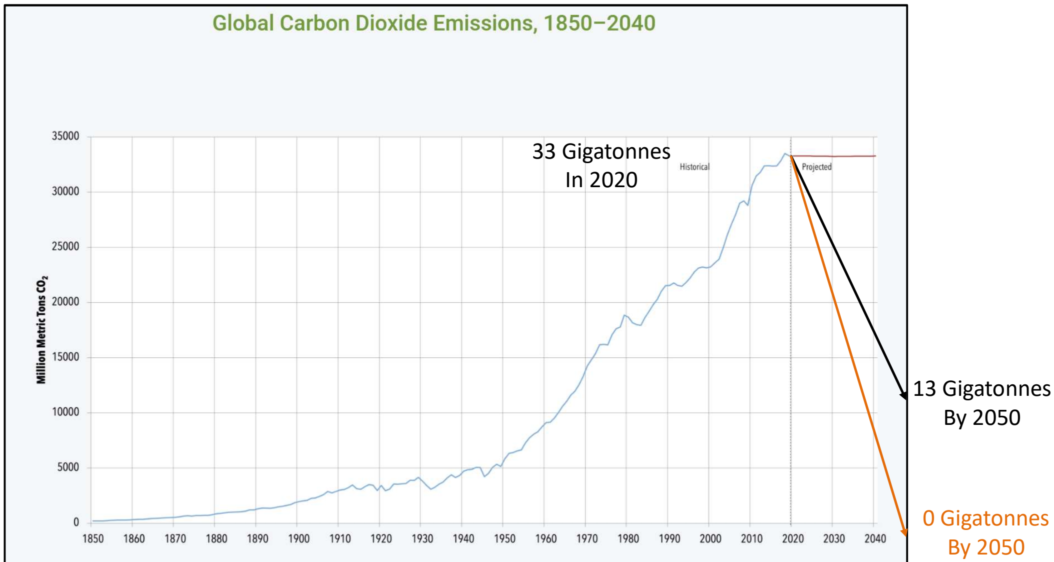
Paris Accord: A Steep Challenge



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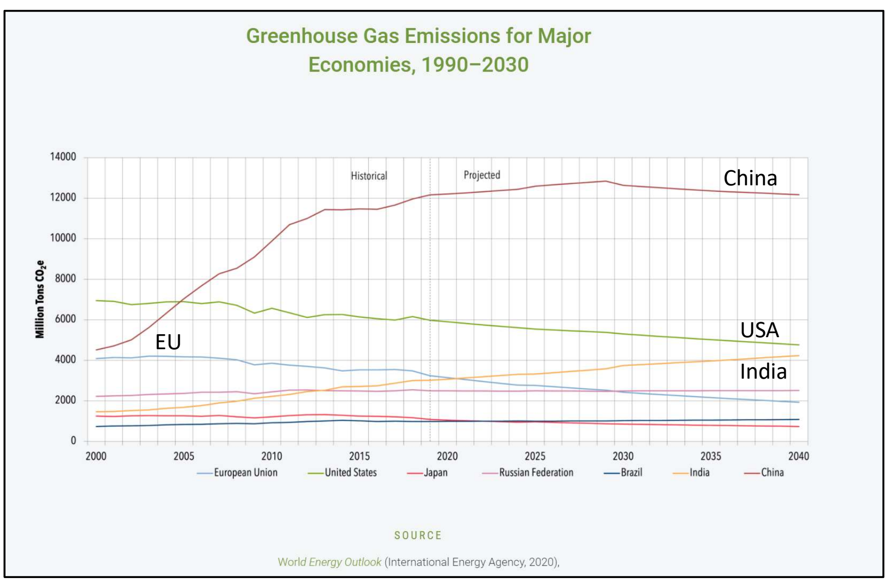
Paris Accord – Projected Progress

Projected drops in CO_2 emissions fail to meet Paris Accord goals for industrialized countries

USA projected to drop CO_2 emissions by 35% in next 30 years from 6.8 Gigatonnes today to 4.4 Gigatonnes

Good news! But is it enough?

What about the Rest of the World?



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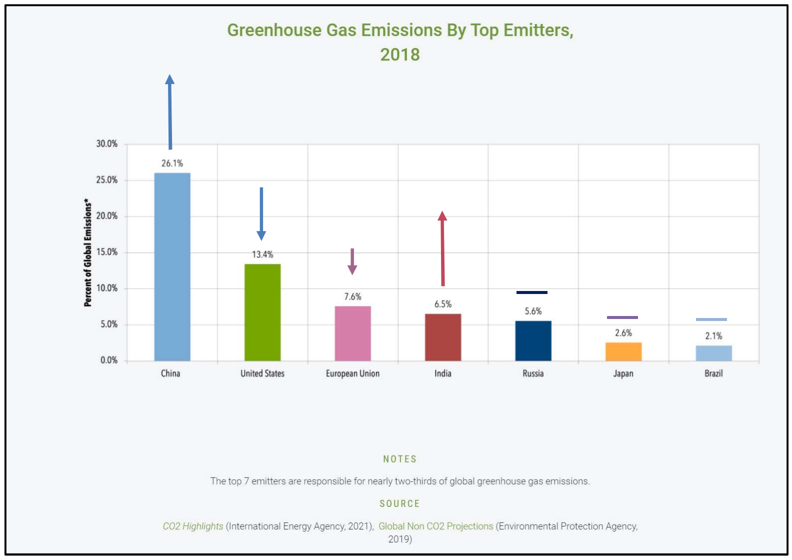
Where Do We Stand Today?

US Total emissions are ~6.8 Gigatonnes per year today

EU Total emissions are ~2.51 Gigattones per year today

To meet Paris Accord US needs to drop to 1.4Gigatonnes per year, and the EU to 0.5Gigatonnes per year, by 2050

Net Zero requires both to drop to zero in the same 28 year period



* Center for Climate and Energy Solutions

How Do We Meet these Goals?

Simply stated this is an immense challenge

- **Hydrocarbon Energy:** Is pervasive and impacts every aspect of modern life
  - Coal-fired power (~30% of world CO_2 emissions)
  - Natural gas (~22%)
  - Vehicle Fuel (~9%)
- **Critical Building Materials:** Drive economic development
  - Steel (~9% of world emissions)
  - Cement (~8%)
- **Strategic Minerals are Scarce:** Relative to new demands we lack sufficient supplies to meet demand for renewables, renewable power storage, and 0 emissions vehicles

While rapidly evolving, Technology may not answer all of these needs in the time we have left

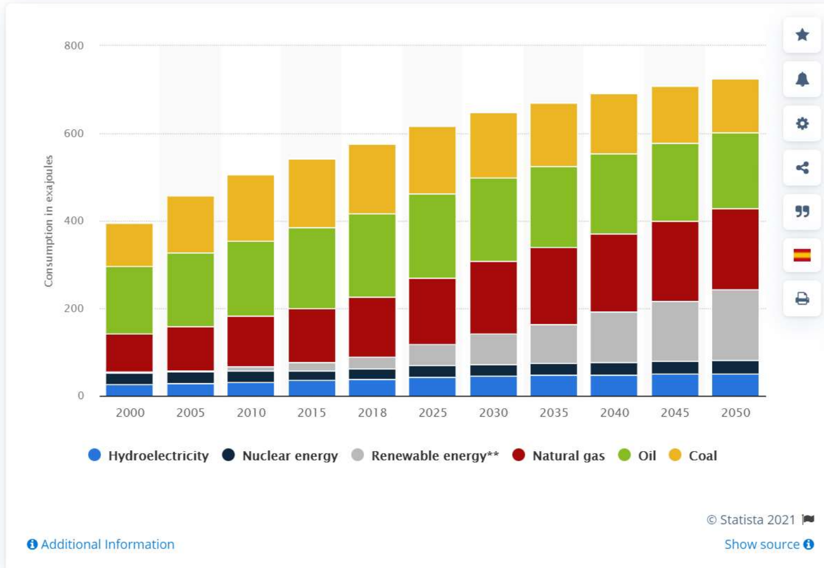
Hydrocarbons: An Uncomfortable Truth

By 2050 we will h*ave broader* adoption of renewables but it will still leave more than 60% of world energy coming from Hydrocarbons

Similar use of Coal/Oil/Natural Gas in 30 years, as we have Today

Hydrocarbon energy emits CO_2

Carbon Capture with Storage is not only a good idea but is necessary to meet climate goals



How Do We Achieve Carbon Reduction?

- Switching completely to renewables is a multi-generational change, and we only have a generation to accomplish this
  - Need major advances in Energy storage, Grid Management, and Power Electronics
  - Huge infrastructure ask, solar panels to power the US would completely cover the states of NM and AZ, and would require Terawatt sized batteries with longer cycle times than current Lithium-Ion
  - Need to rapidly develop new sources of strategic minerals or alternate technology to use more common materials
- Will need to be able to use existing energy sources while this transition is made
- Mitigation (storage and reductions by efficiency)will have to dominate the near term to buy time for new technology to be developed
- Fortunately we can leverage existing energy assets and subsurface experience, with a highly trained workforce of energy workers

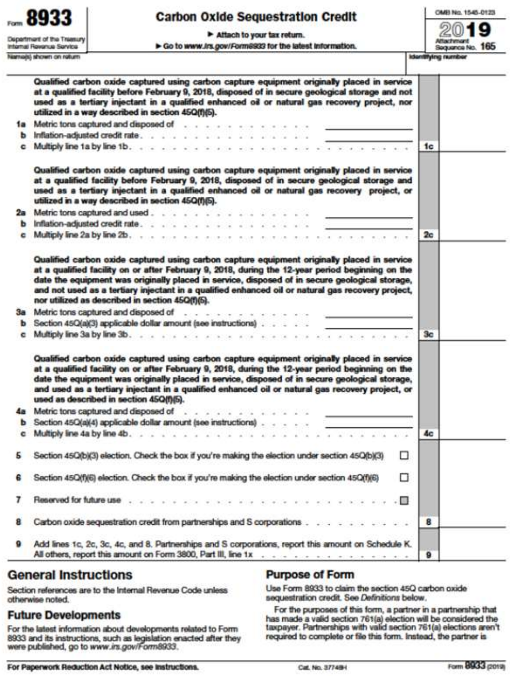
Emission Penalties (Stick) and Tax credits like 45Q in USA (Carrot) are impactors

What is 45Q?

- 45Q is a part of the US tax code authorized in 2017 by a bipartisan congress
- 45Q provides tax credits for geologic storage of Carbon Oxides (CO_2)
  - $50/tonne (initially $35) of CO_2 stored in EOR projects
  - $85/tonne (initially $50) of CO_2 stored in other formations such as saline aquifers
- 45Q is designed to jumpstart carbon storage projects in the US
  - Industry involvement necessary for rapid de-carbonization projects
  - Geologic storage of carbon is perceived as a needed solution to address climate change

Why Should Anyone be Interested in 45Q?

- Economic benefits of tax credit can be substantial
  - 1 tonne of CO2 is approximately 18 mmcf of gas
  - 1 million tonnes per year from each of 4 gas plants in San Juan, for example
  - **If stored this could generate a tax credit of $50-85 million a year per plant**
    - Pays for expensive infrastructure required
  - **If stored this reduces emissions to the Atmosphere!**
- Other tangible benefits of reducing carbon emissions
  - Stored CO2 does not count as emissions for EPA reporting purposes
  - Reduces CO2 footprint of the company
- Sustainability of operations for oil and gas producers
  - Improved public perception of operations
  - Reduced economic risk from future regulatory or policy changes



Form **8933**

Department of the Treasury
Internal Revenue Service

Carbon Oxide Sequestration Credit

► Attach to your tax return.

► Go to www.irs.gov/Form8933 for the latest information.

OMB No. 1545-0123

2019

Attachment Sequence No. 165

Name(s) shown on return | Identifying number

Qualified carbon oxide captured using carbon capture equipment originally placed in service at a qualified facility before February 9, 2018, disposed of in secure geological storage and not used as a tertiary injectant in a qualified enhanced oil or natural gas recovery project, nor utilized in a way described in section 45Q(f)(5).

1a Metric tons captured and disposed of

b Inflation-adjusted credit rate

c Multiply line 1a by line 1b — 1c

Qualified carbon oxide captured using carbon capture equipment originally placed in service at a qualified facility before February 9, 2018, disposed of in secure geological storage and used as a tertiary injectant in a qualified enhanced oil or natural gas recovery project, or utilized in a way described in section 45Q(f)(5).

2a Metric tons captured and used

b Inflation-adjusted credit rate

c Multiply line 2a by line 2b — 2c

Qualified carbon oxide captured using carbon capture equipment originally placed in service at a qualified facility on or after February 9, 2018, during the 12-year period beginning on the date the equipment was originally placed in service, disposed of in secure geological storage, and not used as a tertiary injectant in a qualified enhanced oil or natural gas recovery project, nor utilized as described in section 45Q(f)(5).

3a Metric tons captured and disposed of

b Section 45Q(a)(3) applicable dollar amount (see instructions)

c Multiply line 3a by line 3b — 3c

Qualified carbon oxide captured using carbon capture equipment originally placed in service at a qualified facility on or after February 9, 2018, during the 12-year period beginning on the date the equipment was originally placed in service, disposed of in secure geological storage, and used as a tertiary injectant in a qualified enhanced oil or natural gas recovery project, or used as described in section 45Q(f)(5).

4a Metric tons captured and disposed of

b Section 45Q(a)(4) applicable dollar amount (see instructions)

c Multiply line 4a by line 4b — 4c

5 Section 45Q(b)(3) election. Check the box if you're making the election under section 45Q(b)(3) ☐

6 Section 45Q(f)(6) election. Check the box if you're making the election under section 45Q(f)(6) ☐

7 Reserved for future use ☐

8 Carbon oxide sequestration credit from partnerships and S corporations — 8

9 Add lines 1c, 2c, 3c, 4c, and 8. Partnerships and S corporations, report this amount on Schedule K. All others, report this amount on Form 3800, Part III, line 1x — 9

General Instructions

Section references are to the Internal Revenue Code unless otherwise noted.

Future Developments

For the latest information about developments related to Form 8933 and its instructions, such as legislation enacted after they were published, go to *www.irs.gov/Form8933*.

Purpose of Form

Use Form 8933 to claim the section 45Q carbon oxide sequestration credit. See *Definitions* below.

For the purposes of this form, a partner in a partnership that has made a valid section 761(a) election will be considered the taxpayer. Partnerships with valid section 761(a) elections aren't required to complete or file this form. Instead, the partner is

For Paperwork Reduction Act Notice, see instructions. Cat. No. 37748H Form 8933 (2019)

How to Access 45Q Tax Credit: IRS Form 8933

Key elements are:

- "Qualified Carbon Oxides"
- "Qualified Facility"
- "Secure Geologic Storage"

Also:

- Enough tax burden to utilize the credit
- Can form partnerships to manage this

Qualified Carbon Oxides

"Carbon dioxide captured from an industrial source… which would otherwise be released into the atmosphere…"

- Must be *"**measured** at the source of capture and **verified** at the point of disposal, injection, or use"*
- No cap on CO_2 captured with equipment installed after BBA was established

Qualified Facility

"Any industrial facility… the construction of which begins before January 1, 2026, and the construction of carbon capture equipment begins before that date, or the original planning and design of the facility includes carbon capture equipment…"

- Electrical generating facilities must capture at least 62,500 tonnes per year
- **Other facilities must capture at least 12,500 tones per year**

Secure Geologic Storage

"This includes storage in deep saline formations, oil and gas reservoirs and unminable coal seams…"

- A storage site requires approval by the EPA of a **monitoring, reporting, and verification plan** submitted by the operator of the storage site
- Amounts applied for the credit must align with GHG reporting quantities
- In the case of EOR, only new CO_2 brought to the site, not recycled gas qualifies for the credit

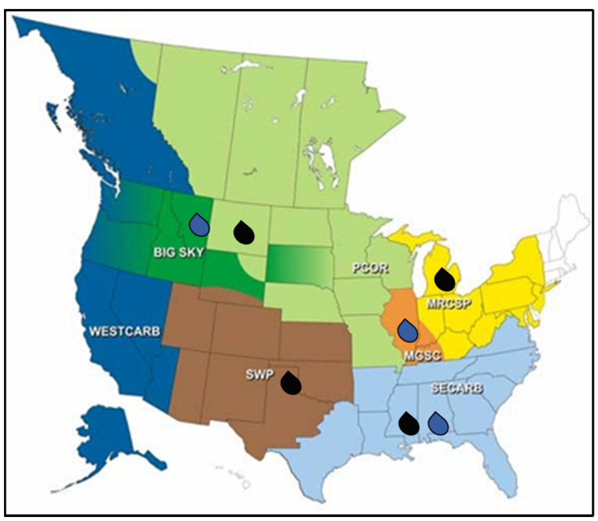
Where do we Start? First, Some History

- EOR has been doing this for years
  - More than 1.3 Gigatonnes of CO2 stored in Permian basin over 40 years
- Regional Carbon Storage Partnerships (2003)
  - US DOE established regional partnership program to understand regional and national storage potential, technologies, and to perform demonstration projects
- Carbonsafe
  - DOE program to promote large scale capture and storage for coal plants
- New Regional Partnership program
  - DOE doubled down and is continuing the work of the RCSP's

18

USA Case Studies for CCS (2003-2022)

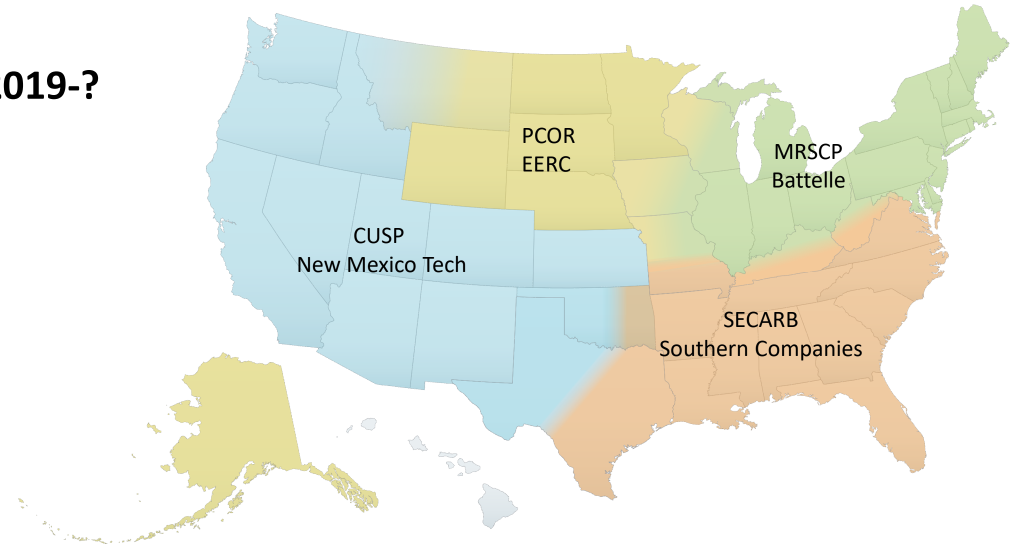
- US Department of Energy Regional Carbon Sequestration Partnerships
  - Seven regional partnerships
  - Dozens of pilot projects
- Each partnership tasked with demonstrating injection of at least 1,000,000 metric tons of CO_2 as a final project
- Four projects demonstrated storage in conjunction with EOR
- **Developed "best practices" for storing captured CO_2**



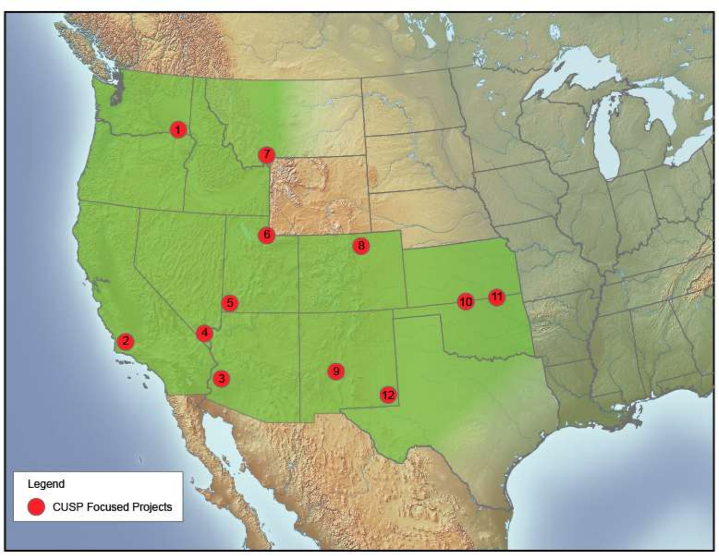
Modified from http://energy.gov/fe/science-innovation/carbon-capture-and-storage-research/regional-partnerships

Regional Initiatives to Accelerate CCUS Deployment

2019-?



CUSP 2021 Focus Projects



- Most projects have industry partners have timelines of 1-3 years
  - Includes a unique study for injection into basalts
  - Includes bench scale work on the use of CO2 as Geothermal working fluid
  - Includes development of regional Storage Hubs
  - Includes a unique study for capturing at an Iron Smelter
  - Includes a uniqe study for capture from a Blue Hydrogen facility
- Not mapped are 3 additional completed projects and 4 projects funded wholly by industry

Questions and Discussion

21

Critical Building Materials

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- Work is being done on reducing emissions from these sources, but these solutions are in the realm of **Science**, not **Engineering**

- These are difficult materials to replace and are also essential for renewables
  - Wind Tower materials include (NREL):
    - 71-95% steel and Iron by mass (150 metric tonnes
    - 11-16% fiberglass resin or plastic my mass (950 barrels of oil)
    - Concrete (400 m^3)
    - Copper for turbines (1% by mass)
    - Does not consider fuel for trucking and manufacturing

Likely need to mitigate rather than eliminate most of these emissions

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Strategic Minerals

- Materials needed for generators, catalysts (hydrogen), and batteries to build and store energy from renewables
- Minerals used include (futures prices):
  - **Copper** ($2.10 per lb in 2016, $4.48 per lb in February **2X**)
  - **Cobalt** ($16,205 per ton in 2016, $81,360 per ton in April **5X**)
  - **Nickel** ($7,148 per ton in 2016, $48,436 per ton in March **7X**)
  - **Rare Earths** (varies but typically has gone up **3-4X**)
  - **Lithium** ($83,054 per tonne in 2017, $468,500 in June **6X**)
  - **Silver** ($4.72 per oz in 2016, $21.91 per oz in May of 2022 **5X**)
- Batteries need vast quantities of materials
  - To electrify all 285 million vehicles in USA would require
    - 4 years of world annual Copper production
    - 8 years of world annual Lithium production
    - 15 years of world annual Cobalt production

Other countries and Industries also need these materials!

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And Then There is Geopolitics…

- Major emitting countries that are most likely to pursue Net Zero (USA/EU) do not produce the bulk of these materials because mining has major environmental concerns!
- **Where do these minerals come from?:**
  - **Copper** top 5 : Chile, Peru, ***China, DR Congo***, USA
  - **Cobalt** top 5 : ***DR Congo, Russia***, Australia, Phillipines, ***Cuba***
  - **Nickel** top 5: Indonesia, Phillipines, ***Russia***, Caledonia, Australia
  - **Rare Earths** Top 5: ***China,***USA, Myanmar, Australia, Thailand
  - **Lithium** top 5: Australia, Chile, ***China***, Argentina, Brazil
  - **Silver** top 5: Mexico, Peru, ***China, Russia***, Poland
- Also there are social costs:
  - Democratic Republic of Congo – Child Labor, dangerous conditions, lack of environmental protections

Renewables, Hydrogen, and associated new infrastructures, all need much more strategic minerals than are mined today, this means many new mines

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Is There a Path to Net Zero?

- **Locally, yes.** Communities, Cities, States, even Countries could conceivably do this with a healthy mix of:
  - Increased efficiency
  - Use all types of decarbonized powers depending on local needs
  - Carbon capture and storage from fixed emission sources
  - Direct Air Capture will still likely be needed to compensate for some sectors that are decentralized
- **Cost is an issue**
  - Cannot work in a vacuum when it comes to costs of global commodities
  - Significant portions of GDP will be required
  - Will become non-competitive with neighbors who do not, or cannot afford to, pursue these goals as aggressively

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Is There a Path to Net Zero?

- **Globally, not on present path.** most countries cannot afford the costs of these technologies
  - Technologies once developed have to be given away to countries that cannot afford to develop those technologies on their own
  - Carbon storage from fixed emission sources is the cheapest and has the lowest cost of entry in both technology and materials
- **Cost is a major issue**
  - Carbon problem in India is that they don’t have enough coal
  - Developing countries will not handicap themselves economically to solve what for them is a “First World Problem”
  - Hydrocarbons are very cost-effective, and will only become more so as some countries and regions stop using them

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How Can We Best Address Climate Goals Then?

- **Think of all-inclusive and regionally relevant solutions**
- Need to embrace *"Engineering Solutions"* available today, while we continue to work on *"Science Solutions"* for the future. **With current technology**:
  - Need to accelerate and embrace nuclear power
    - **Traditional, Thorium reactors, standing wave reactors, etc**
  - Develop renewables to the extent we can fully utilize them
    - **Adapt to intermittent power use to get better utilization**
  - Hydrocarbons are very cost-effective, and will continue to be used in vast quantities
    - **Those emissions must be captured and geologically stored**

Ultimately, we must be prepared to adapt to some climate change, as goals are not likely to be met, even at Paris Accord levels in the 1-2 generations we have left

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