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U.S. DEPARTMENT OF ENERGY

Hydrogen

RFI Themes Overview

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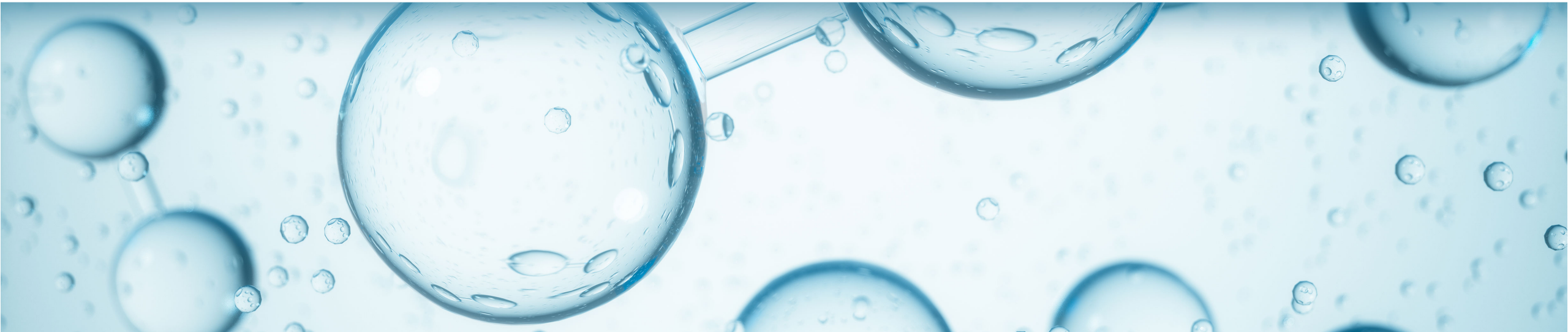
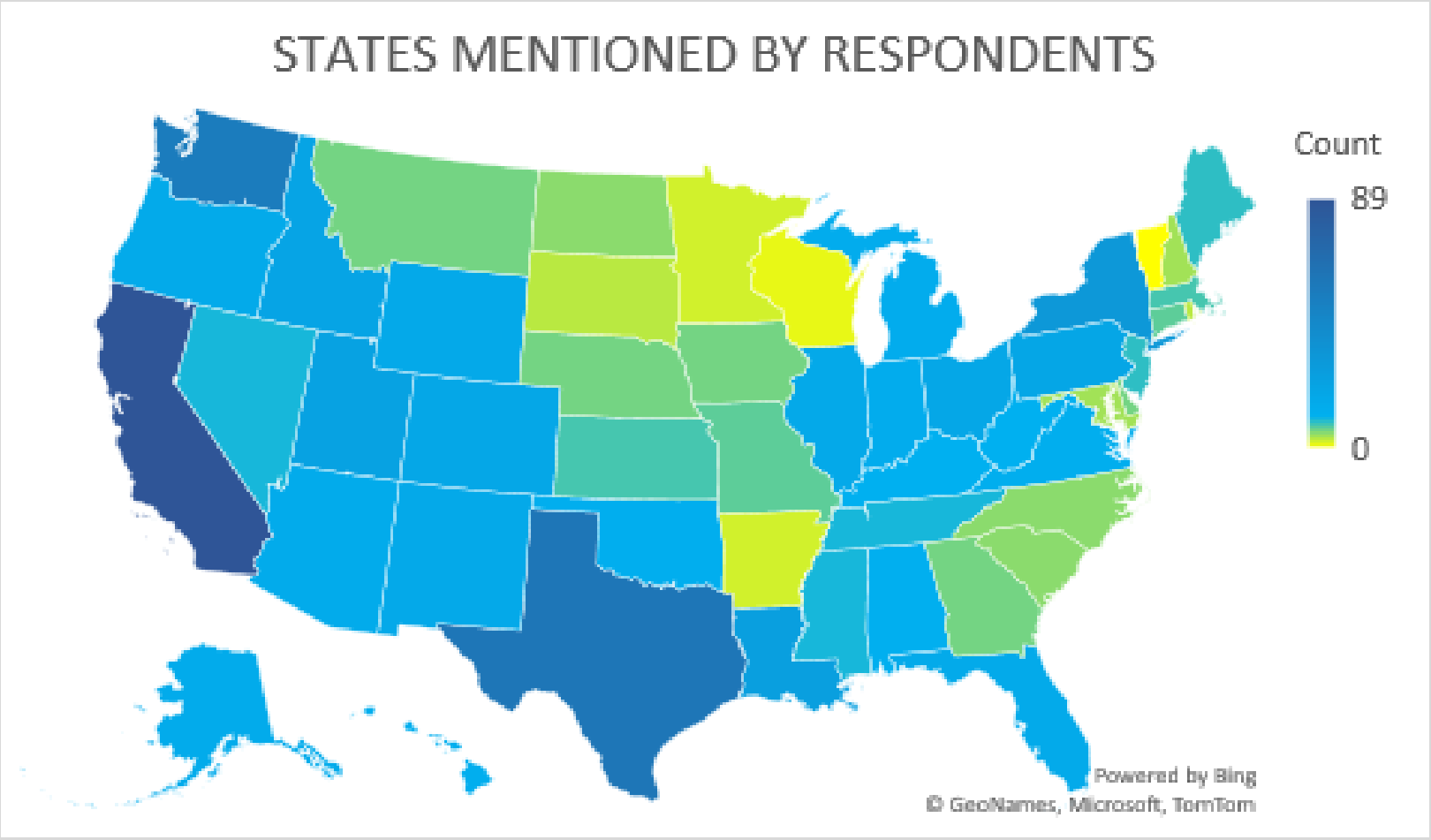
Hydrogen Shot Summit



Breakout Session 4: Deployment and Financing

Includes regional, EJ, tribal, investor, and industry perspectives



Over 200 RFI responses described diverse resources, end-uses and impact potential in various regions

RFI findings: Regional clusters and geographic factors

Pacific Northwest

- *Port communities*
- *Tribal communities*
- *Extensive renewables*
- *8 jobs per $1M invested in H_2*

California

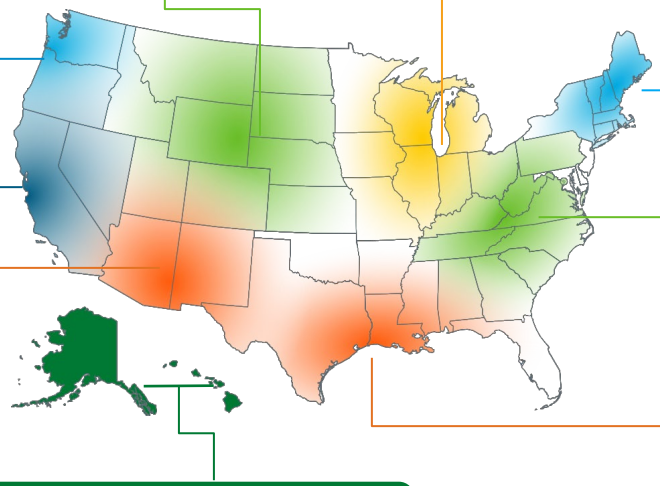
- *Diverse populations*
- *Extensive infrastructure*
- *Emissions regulations*
- *40,000+ jobs*

Southwest

- *Tribal and Hispanic communities*
- *Underutilized solar*
- *Nuclear power*
- *Up to 2B tonnes/yr emission reduction potential*

Central U.S.

- *Ample wind*
- *Geological storage*
- *Railway transport*
- *Nuclear resources*
- *>630,000 tonnes/yr CO_2 reduction*



Alaska and Hawaii

- *Extensive renewables – geothermal, solar, ocean*
- *Backup power*
- *Isolated communities*
- *86,000 tonnes/yr emission reduction*

Great Lakes

- *Major national corridors* • *Nuclear power* • *60,000+ jobs*

New England

- *Offshore wind*
- *Fishing communities*
- *Backup power and winter heating*
- *~120K tons CO_2/year reduction*

Appalachia

- *Retiring fossil plants*
- *Mining, refining transferable skills*
- *Carbon capture and sequestration*
- *70,000 tons/yr H_2 production*

Gulf Coast

- *Existing infrastructure*
- *Multiple opportunity zones*
- *Renewable resources*
- *1,000s of jobs*
- *Chemical industry*

Details by Region

See Backup Slides for Additional Regions

California Regional Cluster Responses

Regional resources for production and infrastructure

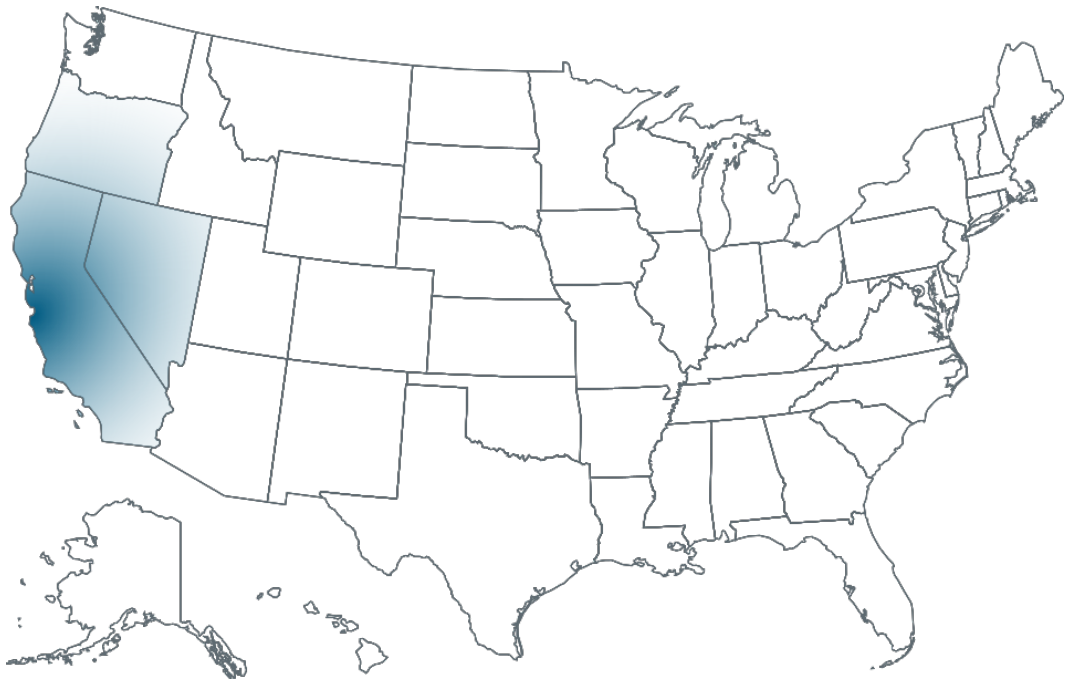
- >200 MT/day of gray H_2 in LA
- ~19.2 MT/year of H_2 from curtailed renewables
- >15 miles of dedicated H_2 pipeline in LA Basin
- 5 power stations to use H_2: Scattergood (~800 MW), Haynes (~1580 MW), Valley (~600 MW), Harbor (~450 MW) and Intermountain Power Plant (840 MW)
- Potential natural reservoirs: Pleasant Creek Storage field (2.3 BCF) and Los Medanos Storage field (17.9 BCF)

Emissions Reduction Potential

- ~0.2 MMT CO_2eq/year – 1.3 MMT CO_2eq/year for each project

End Users, Cost, Value Proposition

- Proposed unit cost of green H_2 in LA basin at $1.50/kg
- CAPEX per project $48-$86M and OPEX of $20-$63M/year, depending on location
- Blending H_2 with natural gas, LDVs, HDVs, stationary power, aviation, ports, forklifts, industrial (steel) applications



DEI, Jobs, EJ

- Demonstration projects, and unpaid training programs
- Improves air quality in Port of LA
- ≥ 41,000 peak construction and more than 2,500 ongoing operations-skilled clean energy jobs
- Diverse racial/ethnic representation

Co-location Potential

- Co-locating hydrogen refueling stations to support MD/HDVs

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Gulf Coast Regional Cluster Responses

End Users, Cost, Value Proposition

- Current: ~ 50 SMR petrochemical/refining plants producing ~3.6 MT/year of H_2
- Future: city transit, industrial forklifts, phosphate industry supporting agricultural sector, green ammonia for marine fuel
- Oil refining and processing, ammonia and methanol production, metallic ore production, food processing, industrial use

Regional resources for production and infrastructure

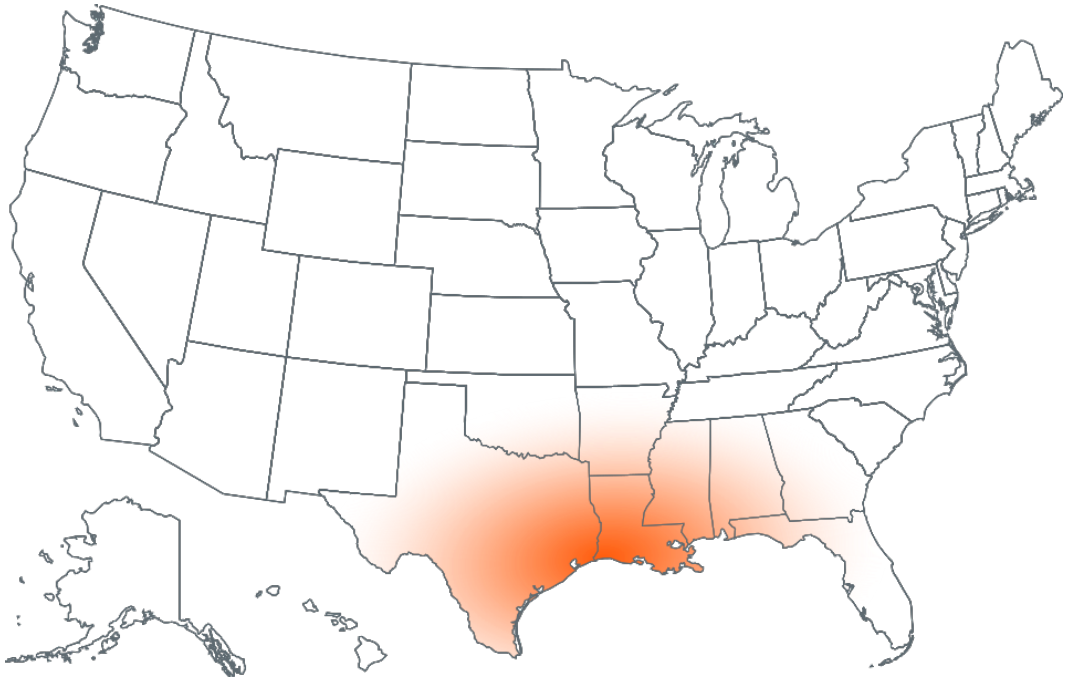
- Legacy oil and gas wells, reclaimed water sites, natural gas pipelines, saline aquifer, salt domes and caverns

DEI, Jobs, EJ

- Creation of 2000+ jobs for Opportunity Zones in Gulf Region, e.g., 240 new jobs for Donaldsonville, LA in “Cancer Alley” region

Emissions Reduction Potential

- Geologic storage accessibility could accommodate >1B tonnes/year in emissions



Co-Location Potential

- Large electricity capacity, electrolysis and SMR capability with inland marine shipping
- Storage in salt caverns and depleted oil fields

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Pacific Northwest Regional Cluster Responses

Regional resources for production and infrastructure

- Ample hydropower, nuclear, and wind
- Sites: Port of Tacoma, Richland, Boardman, Centralia
- Production of 20 – 400 tons/day, 3-4 H_2 fueling stations funded and planned in WA in the next year
- High-capacity electrical infrastructure - up to 100 MW electrolyzer complexes

End Users, Cost, Value Proposition

- Estimated $3.50-$18/kg production cost
- CAPEX/project between $12.5-100M and OPEX ~$200K
- Portable and back-up power, data centers, oil refining and port cargo handling, chemicals, FCEVs

Emissions Reduction Potential

- 35% emissions reduction and up to 75% reduction when CCS is used
- 15,000 - 92,000 tons of CO_2 reduction potential per year

DEI, Jobs, EJ

- Diverse tribal and Hispanic communities
- Fugitive gas and CCS can transition current oil and gas jobs

Co-location Potential

- Projects on land owned by local tribe
- Estimates 8 jobs per $1m invested in H_2 infrastructure
- Projects in areas with 30%-65% non-white population

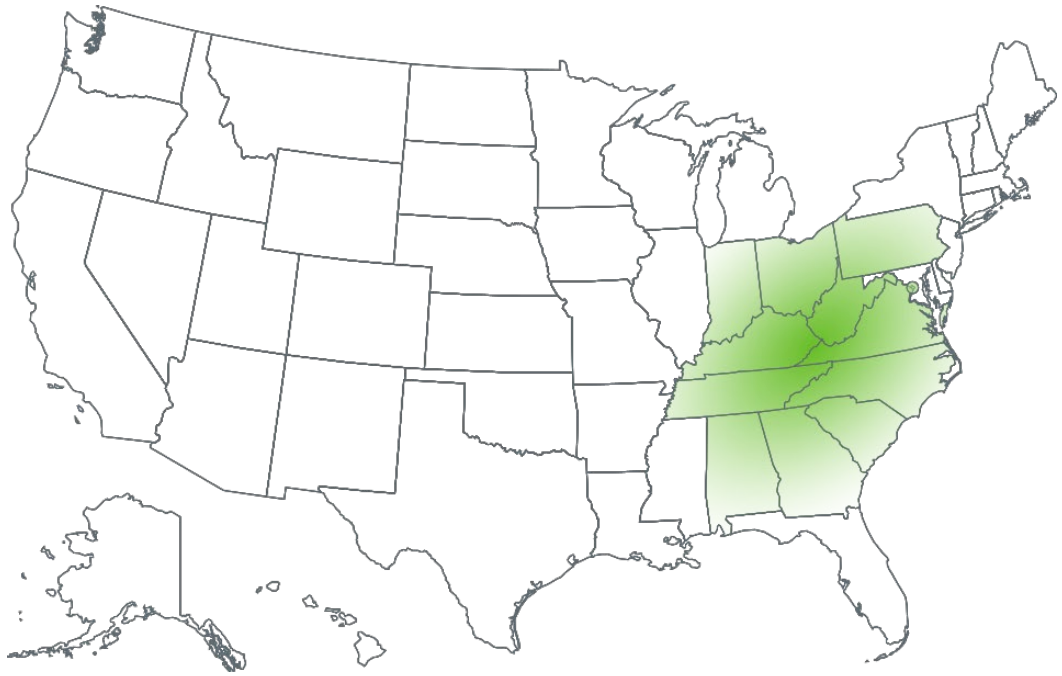
Appalachia Regional Cluster Responses

Regional resources for production and infrastructure

- Overlap with Great Lakes region, especially Western OH
- Primarily fossil resources with CCS, with future transition to renewables
- Access to significant NG and saline storage of CCS
- Salt, limestone, and sandstone formations for potential CCS or H_2 storage throughout

End Users, Cost, Value Proposition

- H_2 for power generation, industry, backup power
- Steel, cement, and chemical industries; decarbonizing refining facilities
- Need for policy incentives to address cost premium versus traditional fossil



Emissions Reduction Potential

- 0.9 MT CO_2/year with NG reforming + 1-4 MT with additional CCS in a single project
- Decarbonization of current processes and possible negative emissions

DEI, Jobs, EJ

- Many distressed communities based on unemployment rates, per capita market income, and poverty rates.
- Coal industry employment in that period has declined 54% in 15 years
- High dependence on mining as a portion of overall economic activity, e.g., one mine closure lost 2000 jobs

Co-location Potential

- Nuclear plants near transportation arteries, warehouses, and distribution facilities
- Wastewater treatment, ammonia production
- Environmental, architectural, archaeological studies completed; active work site for powerplant and other facility developments

Example: Deep Dive on Fossil + CCS Responses

A. How many responses involved fossil resources (coal, NG) – 92 of 195

B. How many involve any type of gasification or high temperature thermal conversion (any fuel) – 59 of 195

C. Provide a breakdown of interest by region – See Summary in Slide

D. Identify any trends in what is suggested for R&D needs; any specific technology areas?
   - Improving the Reforming Process
   - More research on possible Hydrogen storage (both Geologic & On-Site)
   - More research on CCS. CCUS, and Cryogenic Carbon Capture (CCC) to make more economic

E. How many showed interest in Geologic Hydrogen Storage or CCUS? – 53 of 195

Deep Dive: Responses on Specific Qs

A total of 92 out of 195 were found to have interest in categories below:

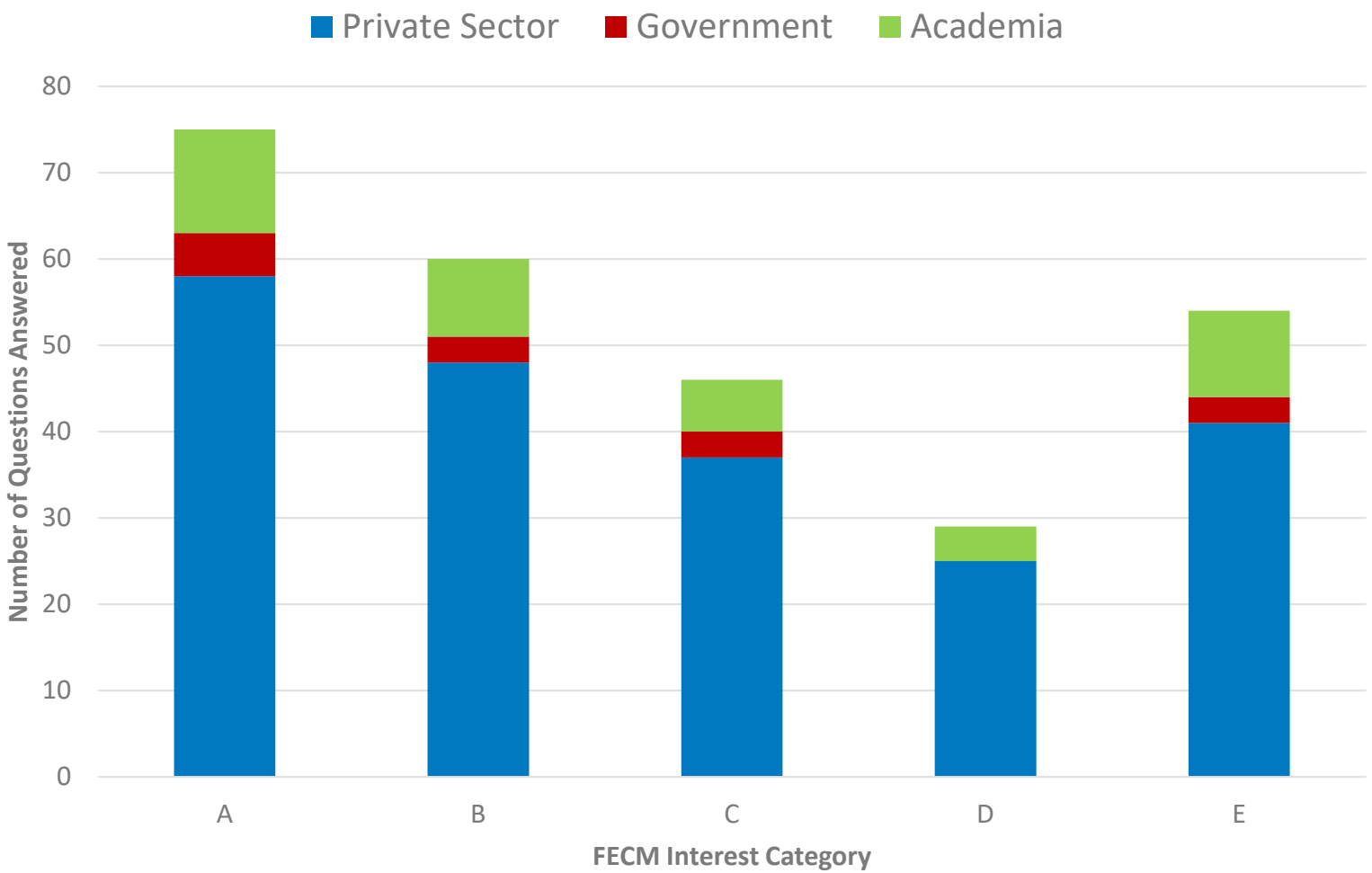
A. How many responses involved fossil fuel (coal, NG)

B. How many involve any type of gasification or high temperature thermal conversion (any fuel)

C. Provide a breakdown of interest by region (related to fossil, large storage, infrastructure)

D. Identify any trends in what is suggested for R&D needs; any specific technology areas?

E. Any discussion of Geologic Hydrogen Storage or CCUS?



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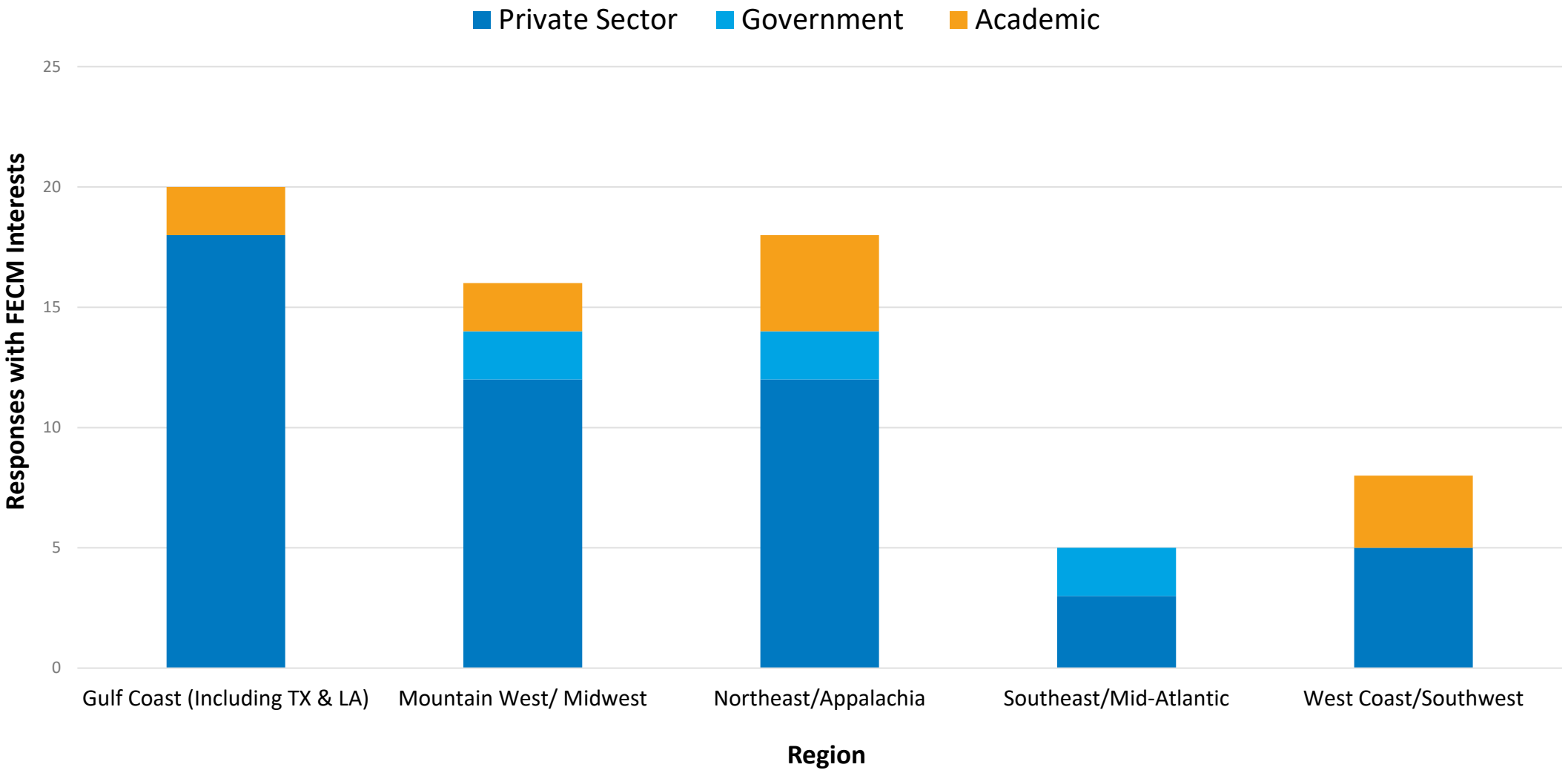
Responses related to storage, infrastructure, fossil resources by region



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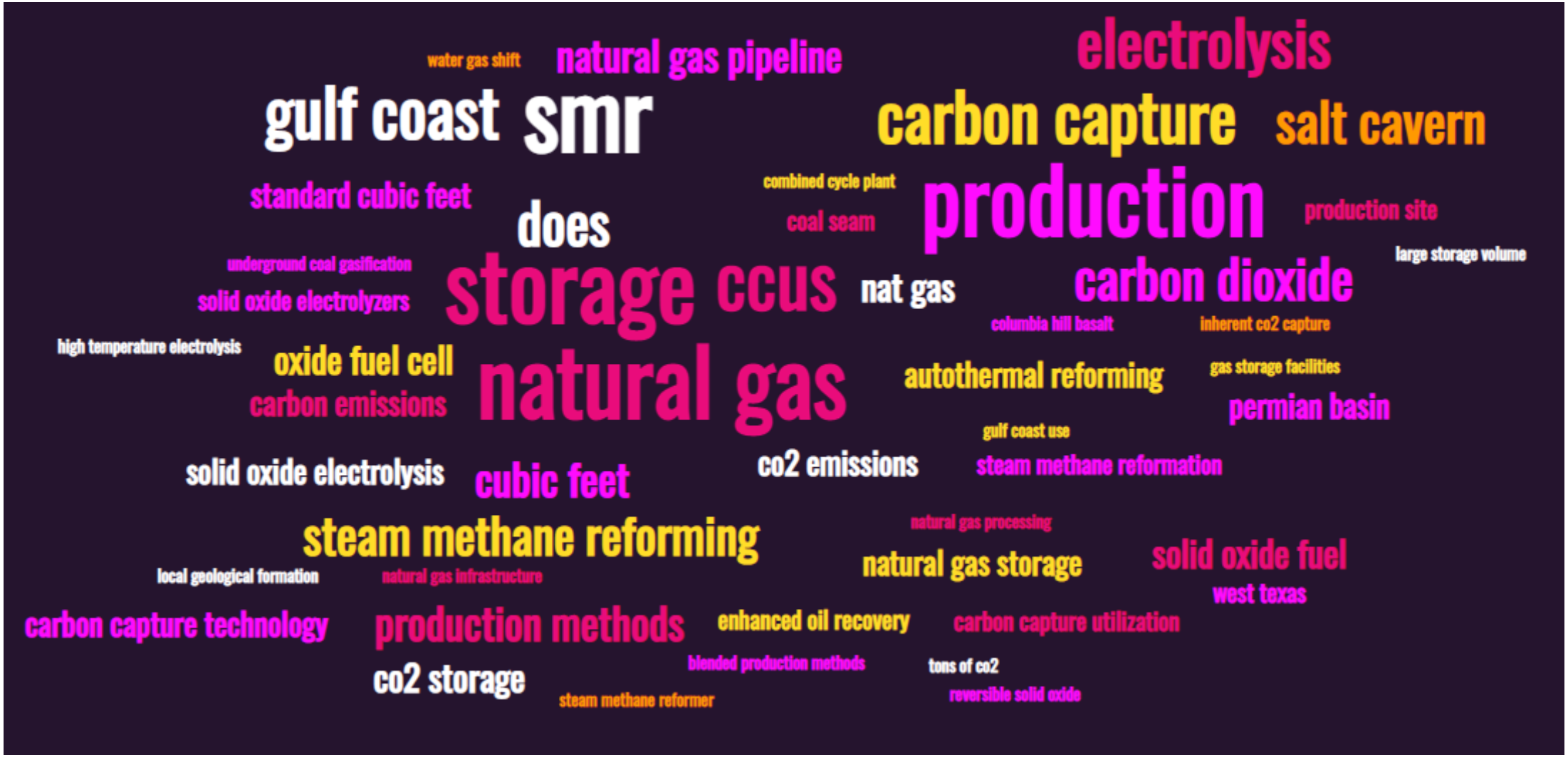
Examples of Popular Terms used by Respondents



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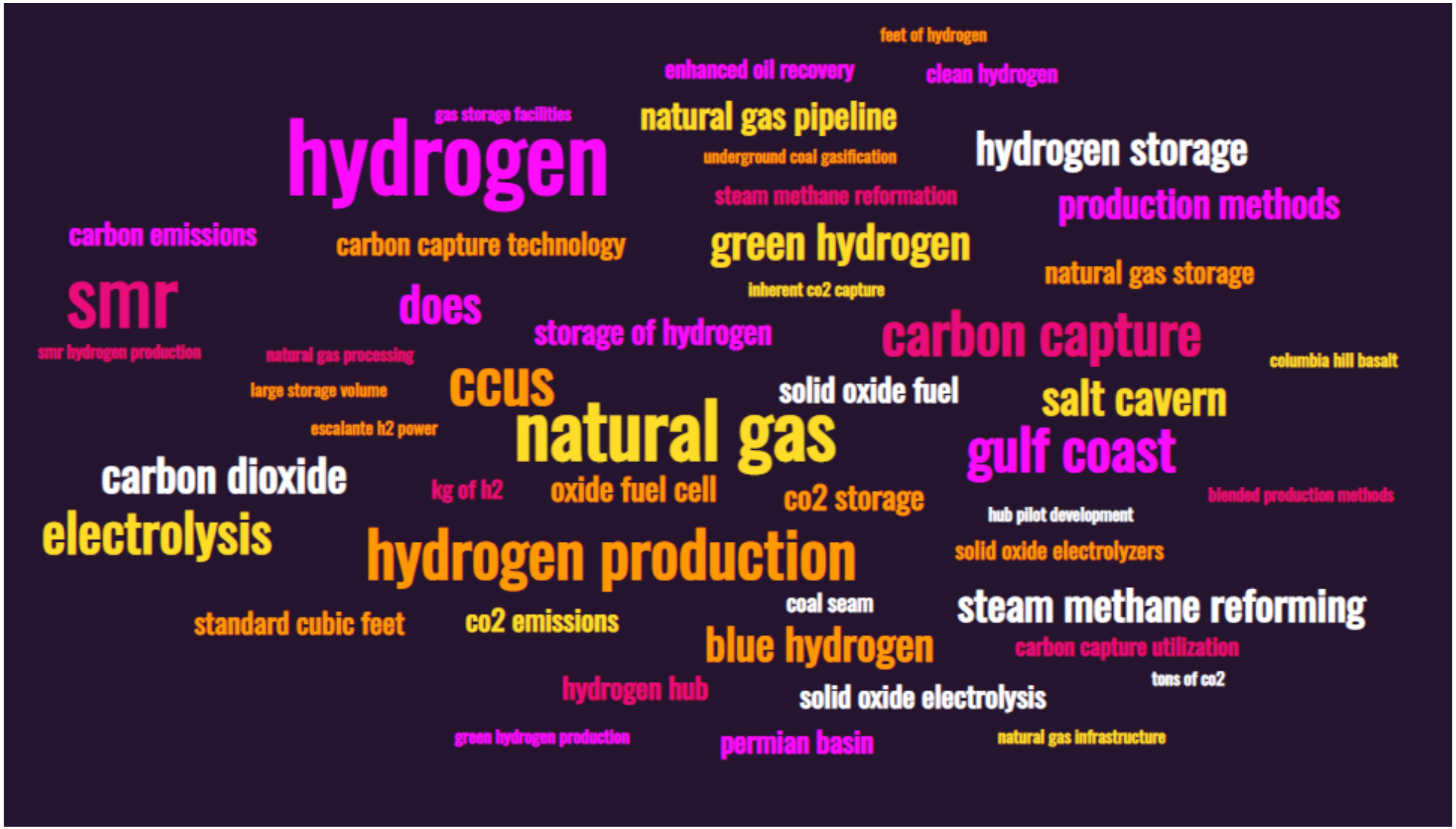
Examples of Popular Terms using “Hydrogen” in Response



We gratefully acknowledge the RFI Team

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Next Steps

1. **Present in-depth findings through webinars and workshops**
2. **Organize a series of regional workshops/webinars**
    - *Include broad stakeholder base in each region*
    - *Foster communication/collaboration between respondents with common regional focus and conduct analysis & pathway studies*
    - *Examples of factors to consider:*
        - Feedstock, end use, infrastructure, and regional diversity
        - Emissions, economic, and environmental benefit potential
        - Employment and community impact potential
        - Scalability, replicability, sustainability

Thank you!

Active on social media?

#HydrogenShot

Additional Slides

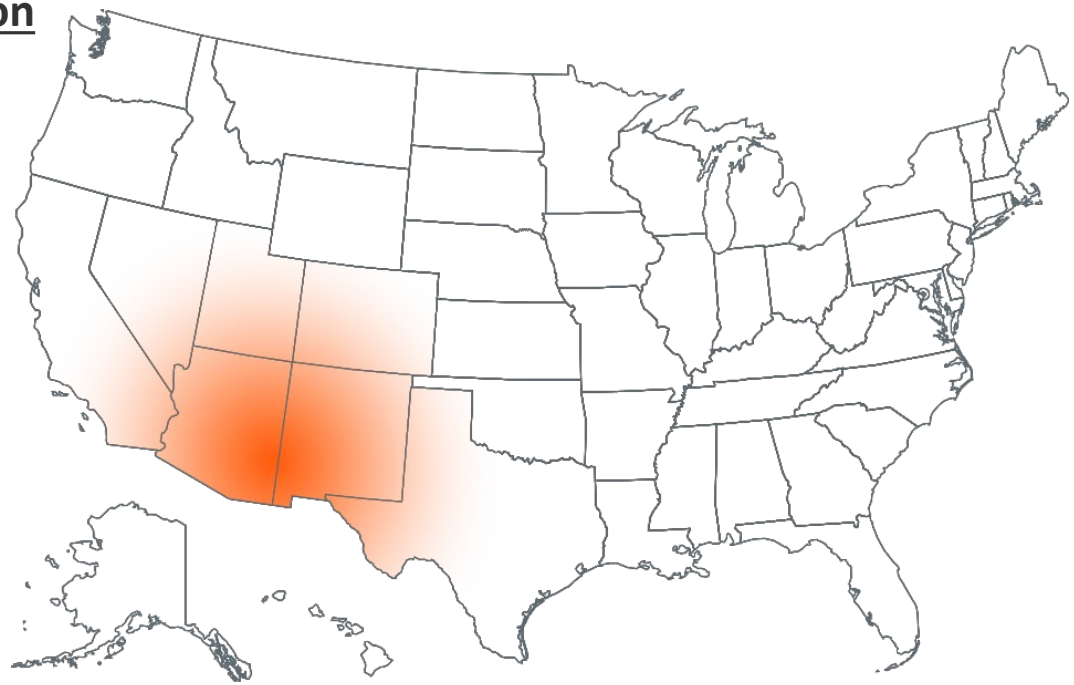
Southwest Regional Cluster Responses

Regional resources for production and infrastructure

- Nuclear or underutilized solar/wind power to produce H_2, salt deposits and abandoned potash mines for storage
- Renewable NG from farming and landfills, fugitive gas from shale oil
- Interstate natural gas pipelines as candidates for blending
- Growing H_2 fueling infrastructure along heavy freight routes to/from California

End Users, Cost, Value Proposition

- H_2 for renewable export to California
- Fuel cell electric buses in Las Vegas region and heavy-duty freight vehicles
- H_2 turbine power generation to supply power to grid
- Primary or backup power at remote posts, e.g., US Border Patrol



Emissions Reduction Potential

- Fugitive gas to H_2 with CCS over current diesel and gasoline nearly 2B tonnes/year decrease in emissions possible

DEI, Jobs, EJ

- Diverse tribal and Hispanic communities
- Fugitive gas and CCS can transition current oil and gas jobs

Co-location Potential

- Enhanced oil refining, nuclear plants, and connections to current NG pipelines
- Plans for cooperative H_2 production, fueling stations, and heavy-duty vehicle manufacture

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New England Regional Cluster Responses

Regional resources for production and infrastructure

- Gulf of Maine has high renewables (hydropower, solar, and wind – significant potential for offshore)
- Wood chip/waste pyrolysis + renewable H_2 to produce methane
- H_2 + HCl from wastewater or seawater treatment
- Cross-border cooperative projects with Canada

End Users, Cost, Value Proposition

- Blending of H_2 in MA, NH; with ultimate conversion of NG to 100% H_2 turbine – ~500 tons/yr H_2
- Backup power – e.g., 2020 Tropical Storm Isaias left 2.5M people in NY w/o power; winter storms –need heating
- Replace fuel oil for home heating
- Commercial fishing vessels (e.g., Maine)

Emissions Reduction Potential

- Wood to methane (with renewable H_2) -32k tons/year
- Replacing diesel fishing vessels with H_2 - ~120k tons CO2/year

DEI, Jobs, EJ

- Many communities are not readily accessible by major highways or pipeline
- Offshore floating wind installations would create thousands of new jobs

Co-location Potential

- Wastewater treatment facilities + dynamic heat production
- Renewable H_2 to methanol for simple storage and transport

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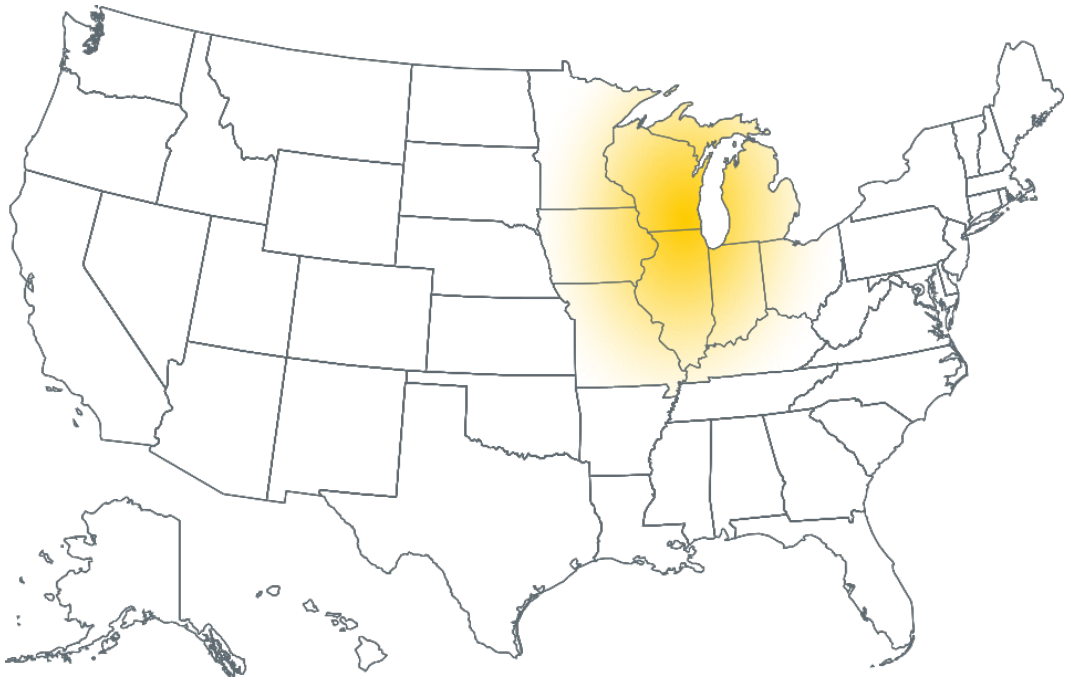
Great Lakes Regional Cluster Responses

Regional resources for production and infrastructure

- Limited infrastructure, production potential is from coal, nuclear plants
- Some access to depleted oil and gas fields, salt caverns
- NG pipelines available but limited H_2 storage potential

End Users, Cost, Value Proposition

- Long haul truck corridors motivate refueling structures
- Steel, cement, and chemical plants are dominant end users



Emissions Reduction Potential

- Ohio has non-attainment areas for air pollution
- Air quality improvement is a great benefit considering industrial plants

DEI, Jobs, EJ

- Estimated 60K+ jobs created
- Gary, Detroit, Cleveland, and Dayton are top 100 disadvantaged communities and opportunity zones with multiple EJ indices

Co-location Potential

- Nuclear plants near transportation arteries, warehouses, and distribution facilities

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Central US Regional Cluster Responses

Regional resources for production and infrastructure

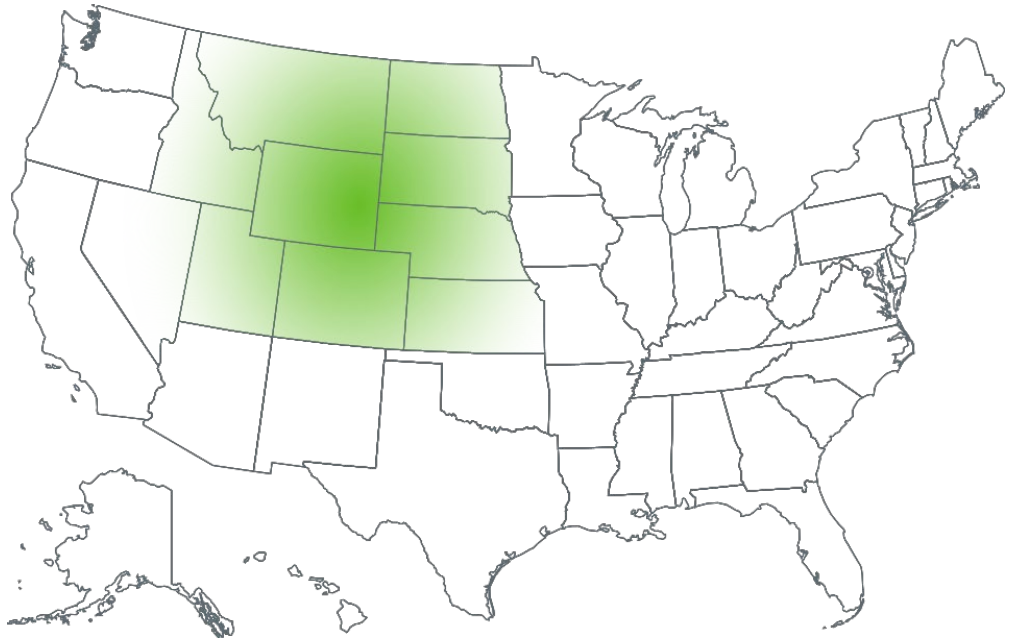
- Ample wind and moderate solar for H_2 production
- Coal resources; uranium ore and plans for nuclear H_2 projects; NH_3 production
- CNG infrastructure in WY and UT can support transition to H_2
- Numerous saline formations, salt caverns, and depleted oil fields for potential storage

Emissions Reduction Potential

- Emissions reduction dependent on effective CCS implementation

End Users, Cost, Value Proposition

- Low-carbon ammonia and ammonium nitrate for and fertilizer markets
- H_2 for hydrotreating for low-sulfur road fuels
- Conversion of over-the-road motor coaches to FCEV
- Montana, North Dakota, and other refineries using SMR could transition to renewable H_2



DEI, Jobs, EJ

- Economically distressed Northern Rocky Mountain and Yellowstone communities; crude oil and NG-producing Wind River Basin Reservation in need of transition
- Projects to create thousands of jobs in construction, installation, and operation

Co-location Potential

- Carbon sequestration sites and rail access points
- Nuclear plant in ID, new nuclear plants at retired coal locations
- Hydropower plants e.g., Missouri River

Alaska and Hawaii Regional Cluster Responses

Regional resources for production and infrastructure

- Geothermal, wind, biomass, solar and atmospheric water generation, landfill methane, solid municipal waste, and green waste to H_2
- 100 kW ocean thermal energy electrolyzer under development
- Existing H_2 station, pipelines for storage; distribution by trailers and trucks

End Users, Cost, Value Proposition

- Local and public transit, back up power with large scale hydrogen storage for natural disasters in HI
- Export liquid H_2 from geothermal plant with expected cost $3.00-3.35/kg in HI
- Potential for H_2 fueled fishing vessels on Alaskan coast

Emissions Reduction Potential

- Carbon capture from the atmosphere to produce kerosene under investigation in HI
- Goal to transform island in HI to zero emissions by 2030; converting public transit to H_2 would save 86,000 tonnes/year

DEI, Jobs, EJ

- Estimated 877 jobs for Oahu, which lags in economic and population health, and prosperity vs State and nation
- Bus assembly facilities on island will maintain 75% of capital within community

Co-location Potential

- Bio-energy plant with reforestation and tree farming in HI
- Assembly facilities with subassembly shops and recycling facilities, training centers, purity testing facilities, and maintenance and calibration centers
- Nuclear plant in AK

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