Clean Energy and Post-COVID Workforce

Yale Center for Business and the Environment

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ENERGY FUTURES INITIATIVE

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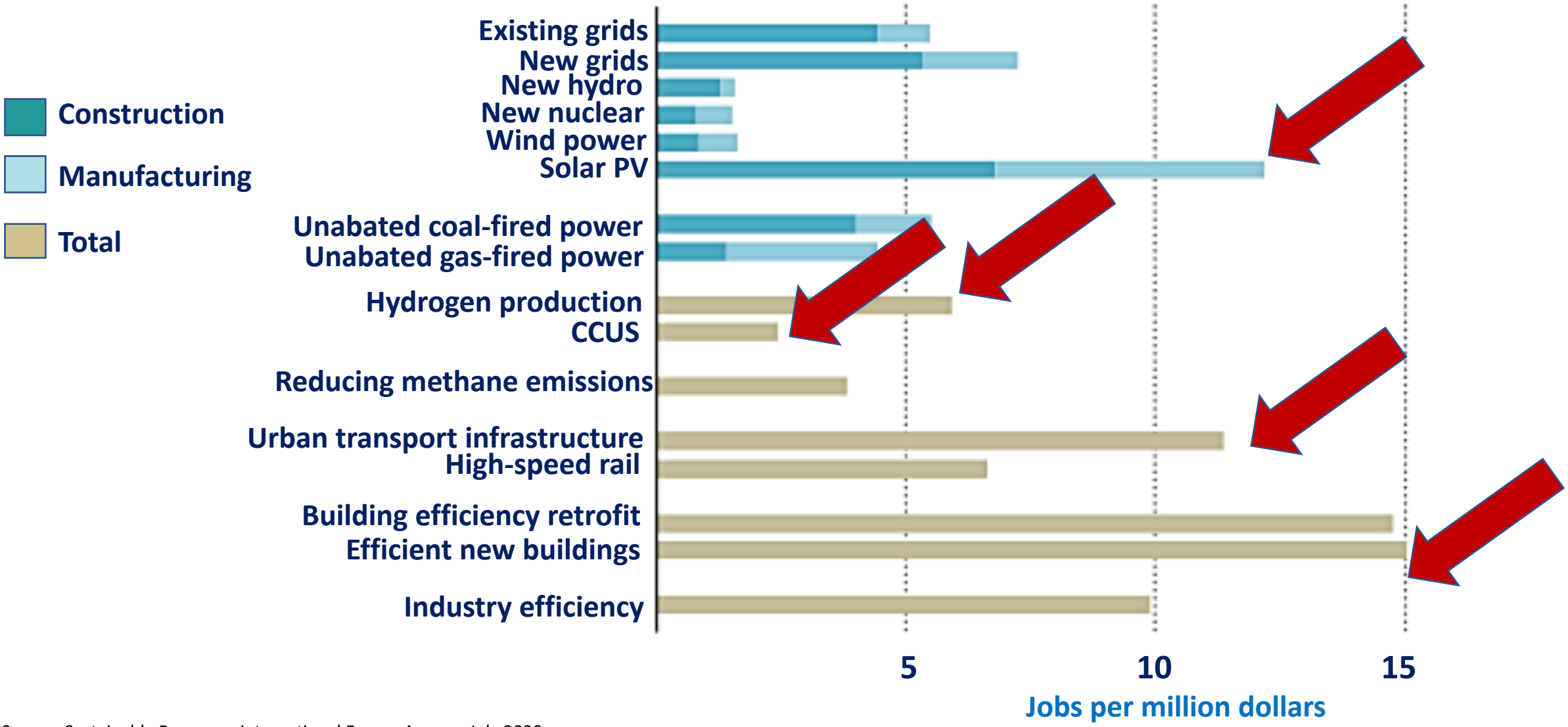
Construction & Manufacturing Jobs Created per $million of Capital Investment



Source: Sustainable Recovery, international Energy Agency, July 2020

Top 10 States Unemployment Claims (3/21-06/6), Top 10 States for Employment in Key Energy Job Categories (2019)

Ranking of Top 10 States, Highest to Lowest	Total Unemploy-ment Claims (03/16-06/06)	Claims as % of Workforce	Natural Gas and Oil Fuels Jobs Actual	Natural Gas and Oil Fuels Jobs as % of Workforce	Efficiency Jobs Actual	Efficiency Jobs as % of Workforce	Gas/Oil Generation Actual	Gas/Oil Generation as % of Workforce	Solar Generation Jobs Actual	Solar Generation Jobs as % of Workforce	Wind Generation Jobs Actual	Wind Generation Jobs as % of Workforce
1	CA	GA (47.8%)	**TX**	WY	**CA**	VT	**CA**	KS	**CA**	**NV**	**TX**	ND
2	FL	KY (44.3%)	**LA**	ND	**TX**	WY	**FL**	**HI**	MA	**HI**	**IL**	SD
3	NY	HI (38.4%)	OK	**AK**	**NY**	DE	**TX**	NH	**NY**	**CA**	CO	CO
4	GA	AK (34.6%)	**CA**	OK	**FL**	**RI**	KS	UT	**FL**	VT	IN	IA
5	TX	WA (33.6%)	**PA**	**LA**	**IL**	MA	**NY**	**FL**	**TX**	UT	**CA**	IN
6	PA	LA (32.9%)	CO	NM	MA	MD	MA	**AK**	**NV**	MA	**FL**	ME
7	OH	NV (31.8%)	NM	**TX**	NC	WI	**IL**	MA	AZ	NM	**MI**	**TX**
8	MI	MI (31.8%)	**IL**	WV	**MI**	OR	AZ	SC	NJ	OR	IA	NH
9	WA	RI (31.1%)	ND	CO	**OH**	UT	**MI**	AZ	NC	AZ	**NY**	KS
10	IL	OK (31.1%)	**OH**	KS	VA	CT	**OH**	MS	**OH**	CO	**WA**	**IL**
Total US*	40,754,311		906,998		2,378,893		128,031		345,393		114,774	

Bold denotes top 10 states that are in top 10 for actual unemployment claims or claims as percent of workforce and are also in top 10 jobs for specific energy sector, both actual an/or as % of workforce. *Includes DC and Puerto Rico

Source: Department of Labor, "Unemployment Insurance Weekly Claims" https://www.dol.gov/ui/data.pdf

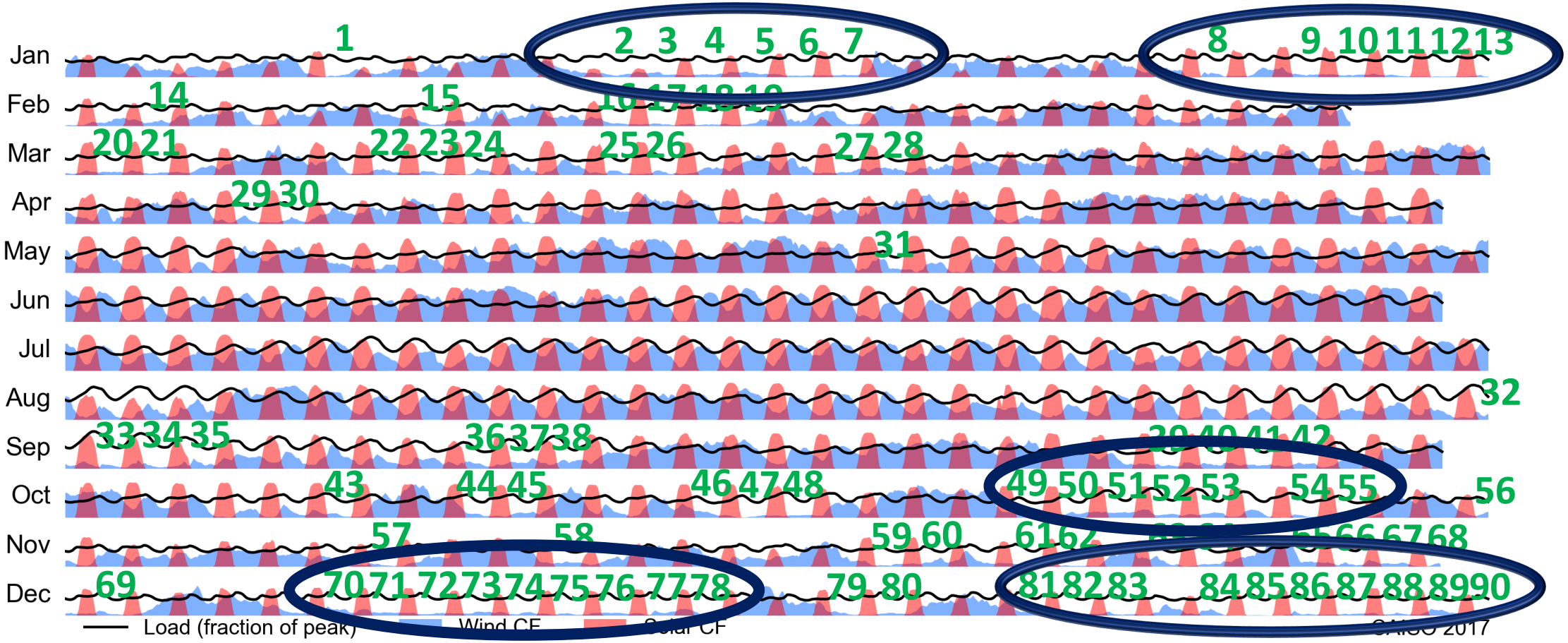
Leveraging Existing Carbon Infrastructure to Support Decarbonization Pathways

Negative Emissions Technologies /Carbon Capture, Utilization, and Storage (CCUS)	• Applying industry expertise to CCUS technologies for direct-air capture (DAC) and bioenergy with carbon capture and storage (BECCS)	• Applying industry expertise: CCUS technologies for DAC and BECCS	• Using compression technologies similar to those in NG infra-structure for CO_2 • Rail and roadway = existing infrastructure • Leveraging pipeline rights-of-way	port of LPG/LNG for liquid CO_2 • Marine vessels for CO_2 using the same technology as existing LPG or LNG tankers • Port infrastructure for loading • Offshore facilities for subsea injection	formations • Using industry expertise in large-scale CO_2 separation and sequestration • Applying technologies for drilling and injection, subsurface characterization, and site monitoring, same as in the O&G sector • Leveraging similarities with NG storage, acid gas disposal, and CO_2-EOR
Renewable Natural Gas (RNG)	• Processing technologies are similar to NG processing	• Minimal processing for using RNG for power generation in gas turbines	• Doping in NG pipelines • Leveraging pipeline rights-of-way	• Utilizing existing fuel storage and transportation hubs	• Leveraging industry expertise with NG storage
Smart Systems/ Platforms	• Applying process automation for improved refinery performance	• Creating smart generation solutions: NG-battery and NG-solar	• SCADA expertise • Improving the efficiency of transport of RNG, H_2, CO_2 • Enhanced leak detection	• Using transport management systems and other IoT applications • Data tracking of supply chains	• Optimizing revenues from grid-scale storage systems

Decarbonization pathways are as much about infrastructure as they are about technology. The transition to a low-carbon future could potentially be improved by seeking opportunities to leverage California's existing physical and intellectual infrastructure, technological expertise and its skilled and ready workforce.

Challenges with Integrating Intermittent Renewables

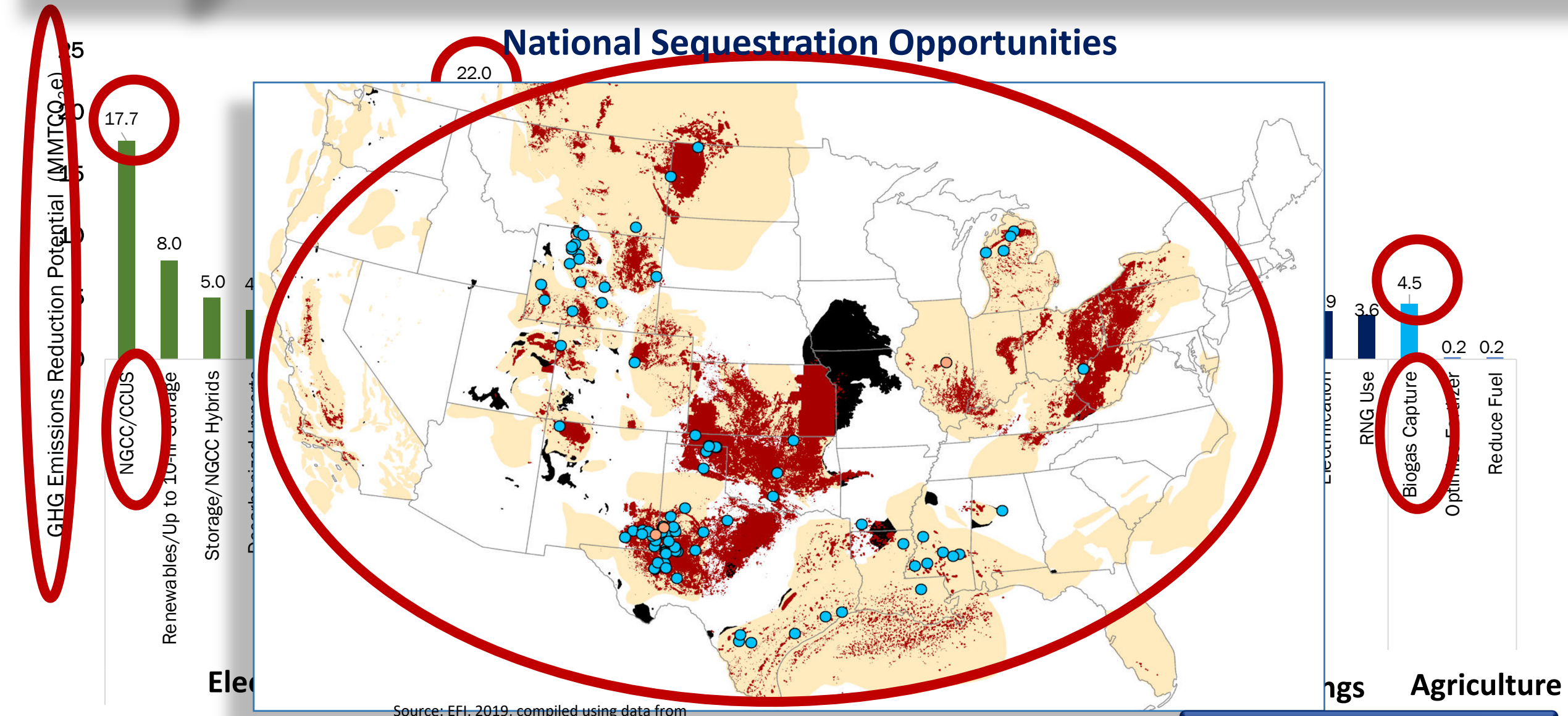
Over the course of a year large-scale dependence on both wind and solar will result in significant periods requiring very large-scale back-up options



Hourly trends in solar and wind capacity factors in CA for 2017 aligned to normalized variation in hourly load relative to peak daily load

Source: CAISO data, EFI analysis

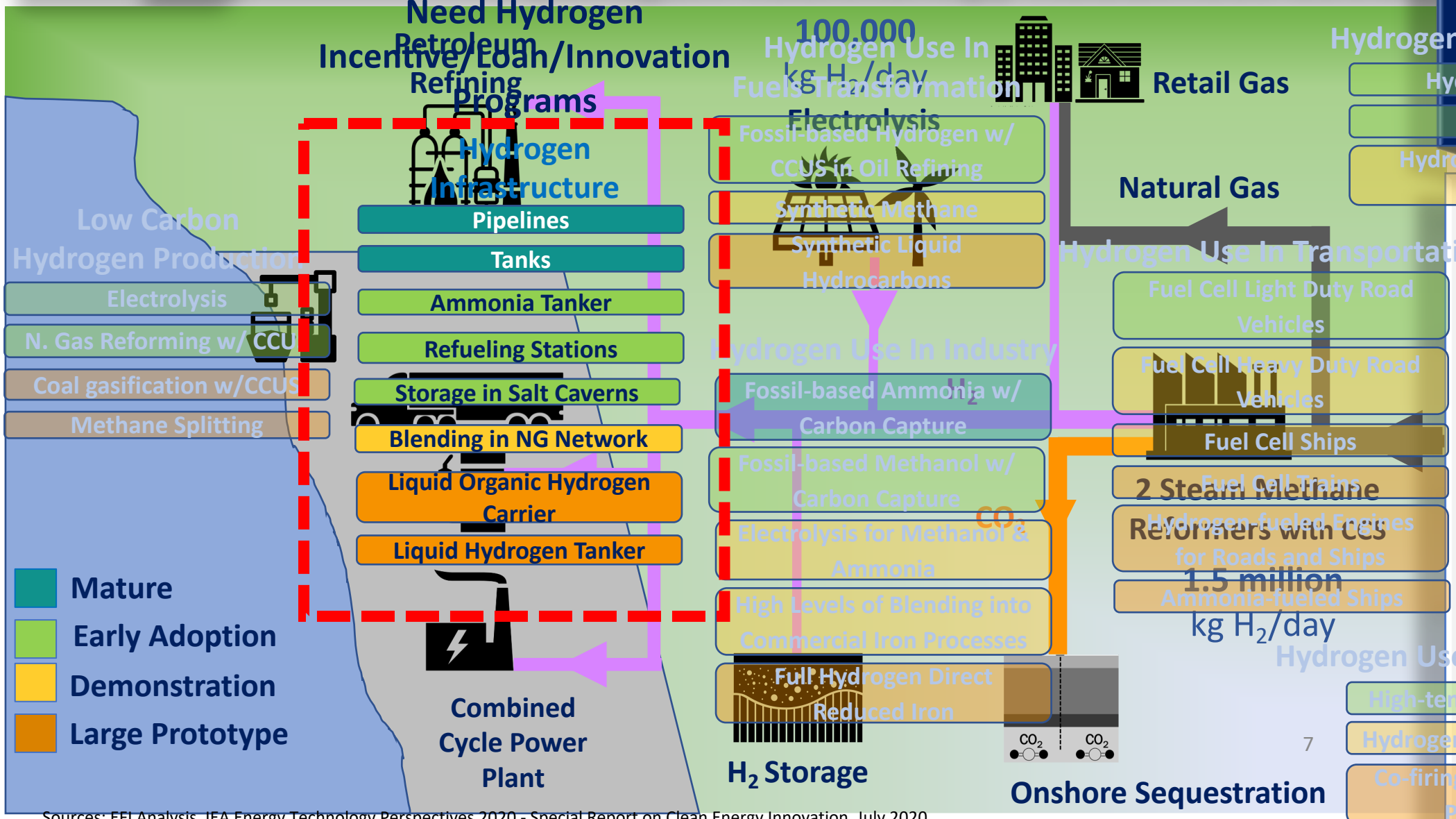
Identified Emissions Reduction Potential of Sector-Specific Pathways for Meeting CA's 2030 Targets



Source: EFI analysis

Source: EFI, 2019, compiled using data from the EPA and NETL

Example of a "Hydrogen Hub": Ports of LA and Long Beach, Hydrogen Technology Readiness Levels



One central steam methane reforming facility and one central electrolysis facility could supply:

- Half of ports' drayage fleet (5,000 trucks)
- Entire ports' electricity requirement (50MW/h)
- 80% of SCG's petroleum refiner demand
- 10% of SCG's residential gas demand (as blend)
- CO_2 sequestration equivalent to half an average coal plant emissions

Sources: EFI Analysis, IEA Energy Technology Perspectives 2020 - Special Report on Clean Energy Innovation, July 2020

Electricity Generation Mix Through 2050, US Energy Information Administration, Reference Case, AEO 2020

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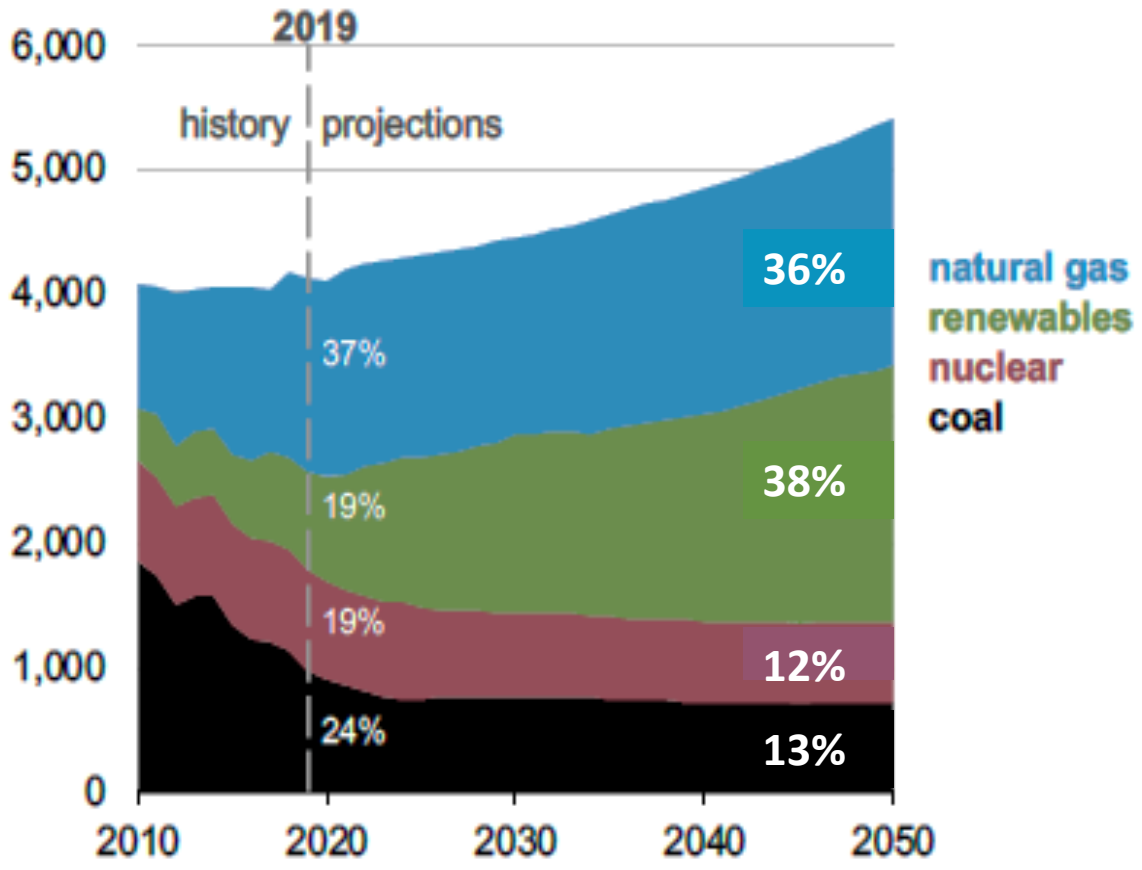
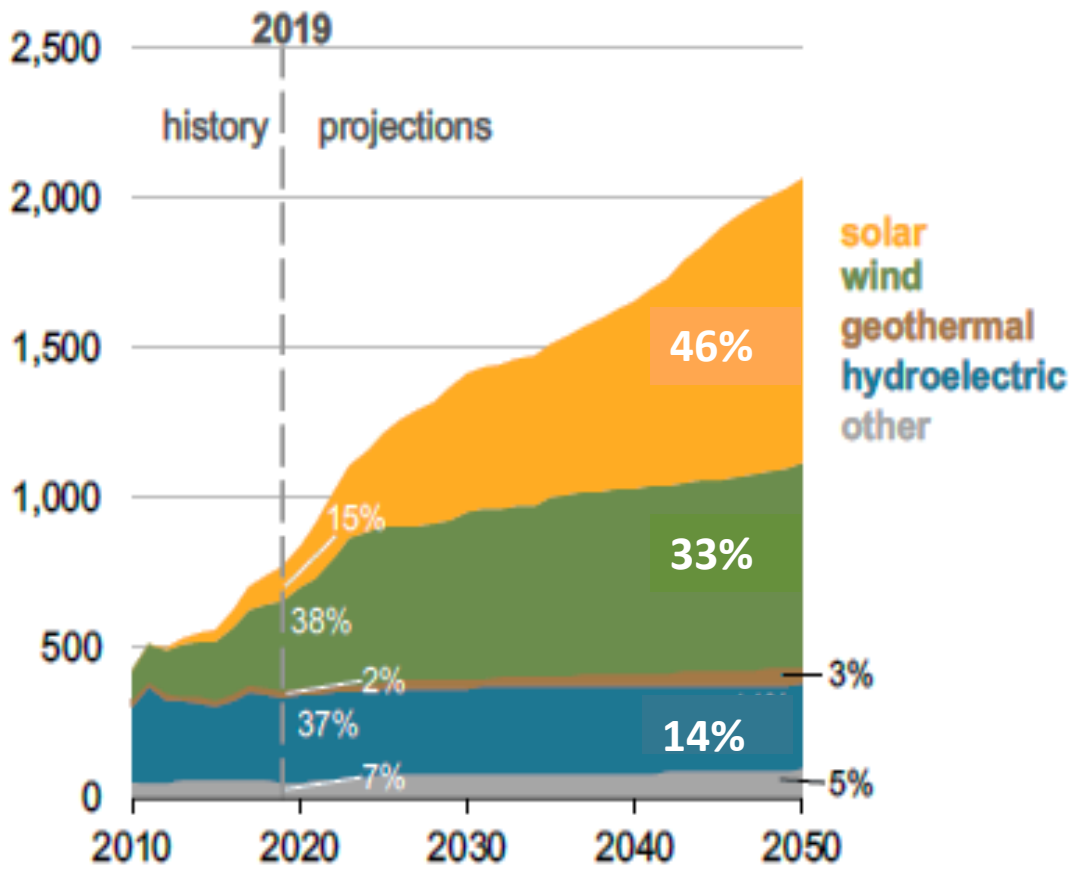
Electricity Generation from Selected Fuels, billion kilowatt hours



Renewable Electricity Generation, including end use billion kilowatt hours



Source: Energy Information Administration, AEO,2020

Lithium, Cobalt, Nickel Production/Reserves, Need for Expertise in Global Supply Chains

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US should –

- *Increase its diplomatic and investment focus on Western Hemisphere and Africa*
- *Protect supply chains for minerals/metals needed for wind, solar and batteries*
- *Support new domestic environmentally-responsible mining activities for key minerals/metals*
- *Support innovation in mining efficiency and in earth abundant materials for wind, solar and batteries*
- *Use renewable energy for electricity needed in mining operation*
- *Promote humane mining conditions around the world*
- *Start metals and minerals recycling programs now*

Source: USGS, 2019

https://www.schedulereader.com/blog/oil-and-gas-industry-overview