Evolving Energy Realities: Adapting to What's Next

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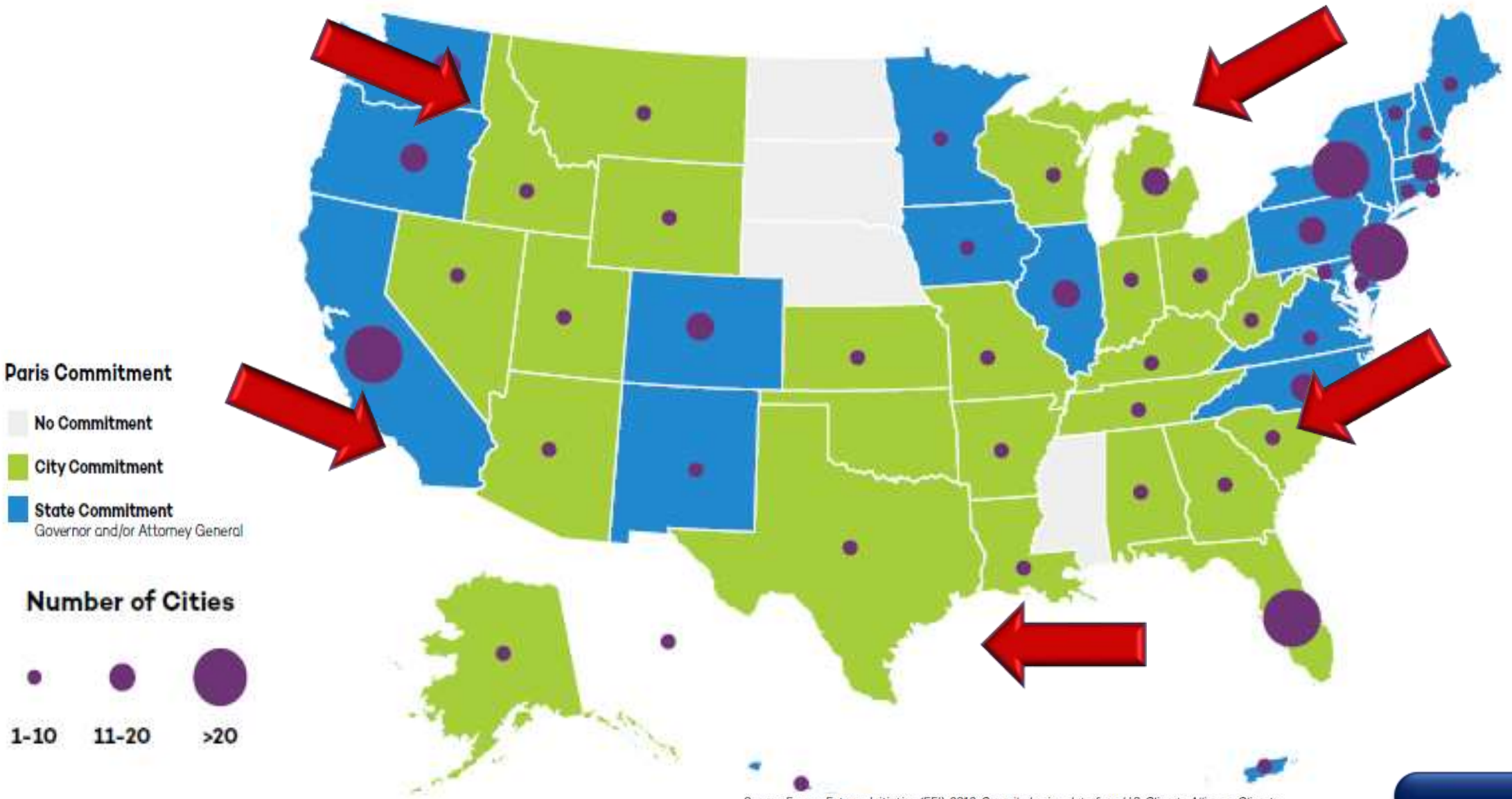
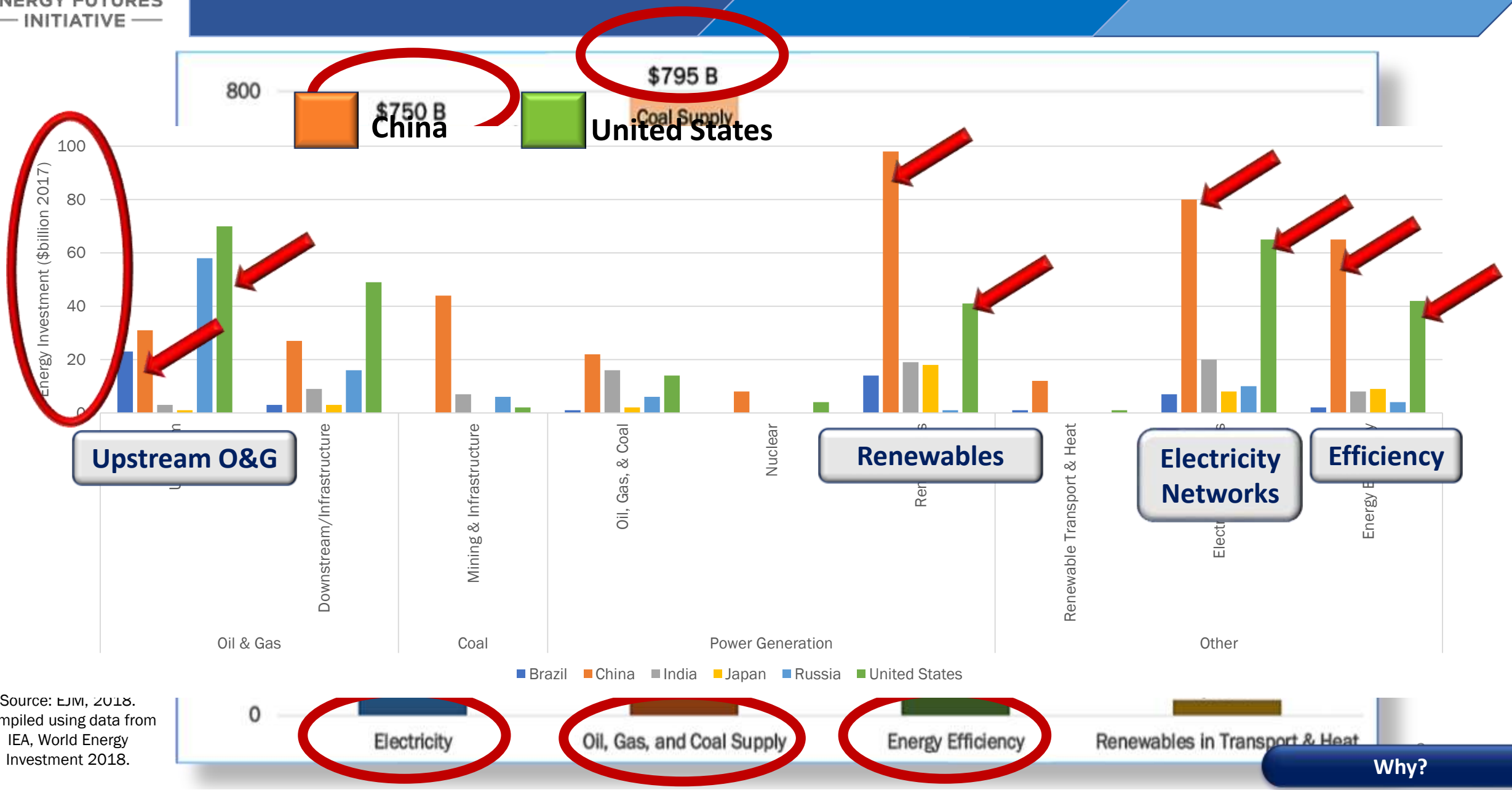
Sub-national Players in Climate, Non-traditional Players in Energy



Source: Energy Futures Initiative (EFI), 2018. Compiled using data from U.S. Climate Alliance, Climate Mayors, and Office of the Attorney General for the District of Columbia.

Global Energy Investment, 2017

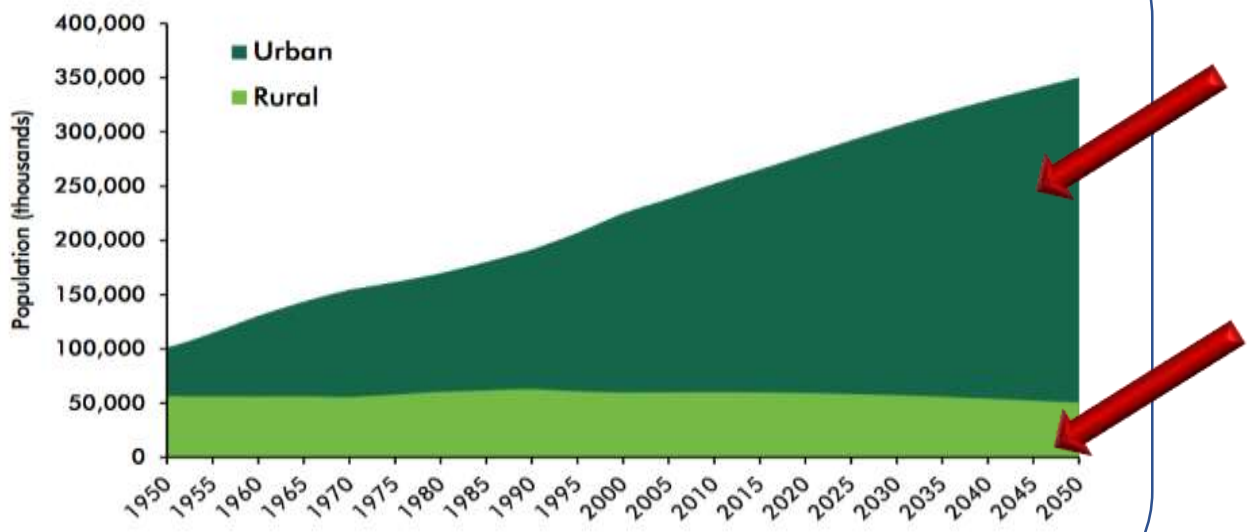


Source: EJM, 2018. Compiled using data from IEA, World Energy Investment 2018.

Why?

US Urbanization Trends

Urbanization of US population, 1950-2050



While the number of urban residents in the US has increased approximately 500 percent since 1910, the number of rural residents has only increased by 19 percent. The southern, western, and coastal areas of the U.S. continue to see greatest population increases.

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System Transformation? Trends, Boundary Conditions that Affect the Pathways and Pace

Overarching Trends in – and Affecting – Energy Systems

- changes in the U.S energy supply profile
- shift from resource- to technology -based energy systems
- digitalization, big data analytics and smart systems
- electrification and electricity-dependence
- demographics, urbanization, and the emergence of smart cities/communities; and
- decarbonization of the electricity sector

Boundary Conditions of Energy Systems

The energy industry is –

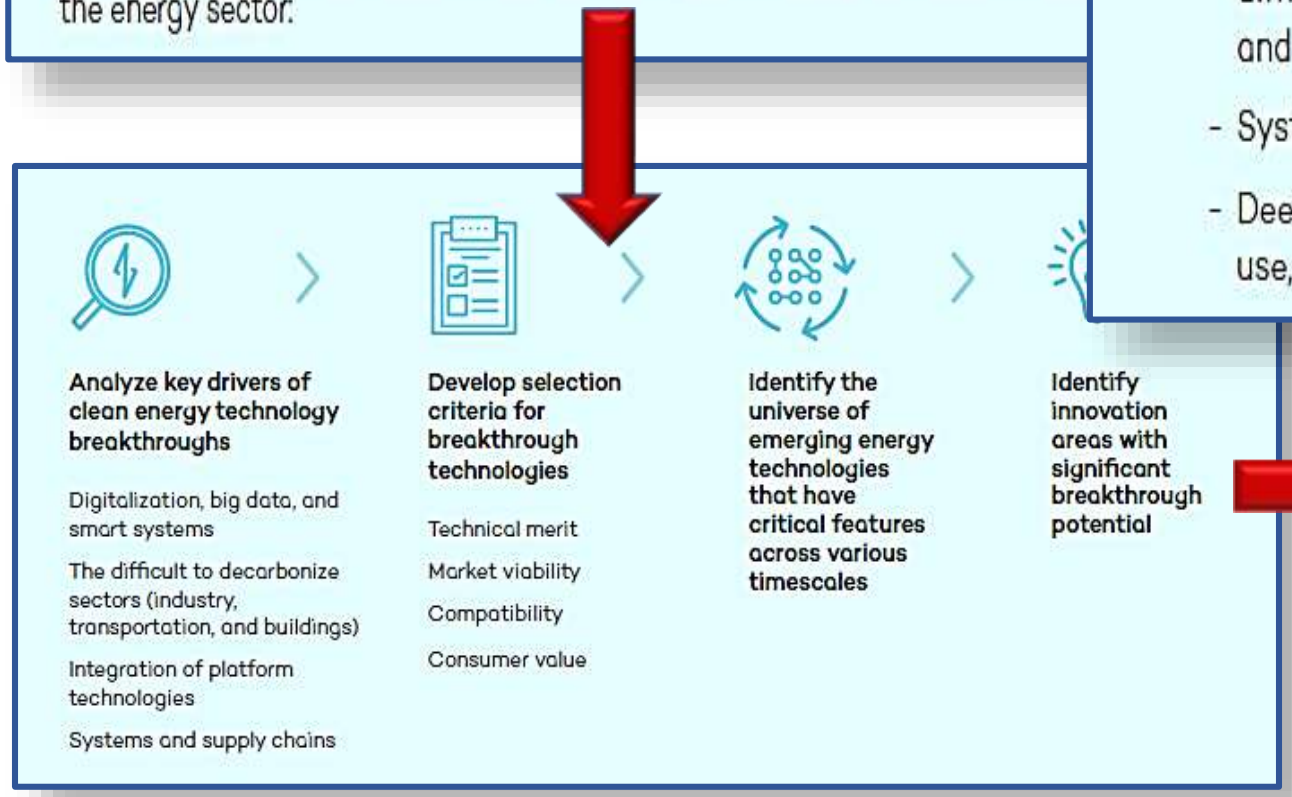
- …a multi-trillion dollar per year, highly capitalized, commodity business…
- …with exquisite supply chains,,,
- … and established customer bases…
- … providing essential services at all levels of society.

This leads to a system with considerable inertia, aversion to risk, extensive regulation, and complex politics

Key Questions

Focusing the Energy Innovation Portfolio on Breakthrough Potential

- Federal and private clean energy innovation investment are complementary.
- Key platform technologies hold great potential to unlock significant clean energy innovation.
- A four-step process is used to identify breakthrough technologies that have potential to aid government, industry, and thought leaders in efforts to transfor the energy sector:



- Critical innovation areas identified are:
  - Storage and battery technologies
  - Advanced nuclear reactors
  - Technology applications of industry and buildings as sectors that are difficult to decarbonize: hydrogen; advanced manufacturing technologies; and building energy technologies
  - Systems: electric grid modernization and smart cities
  - Deep decarbonization/large-scale carbon management: carbon capture, use, and storage at scale; sunlight to fuels; biological sequestration

Policies & Programs

LCOE for Renewables/Gas, LCOS Renewables with Battery Storage ($/MWh)

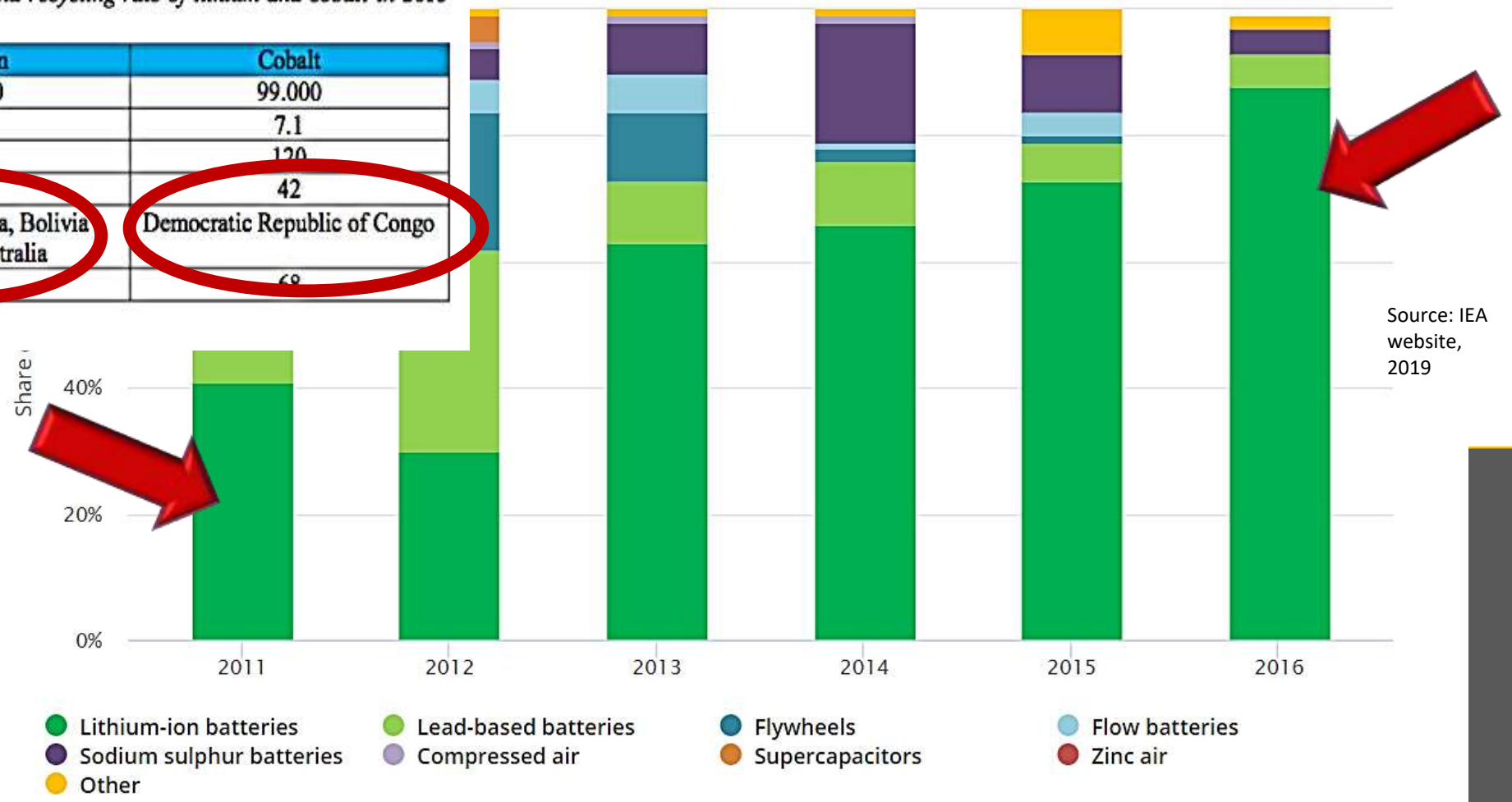
Leveliz

Table 1. Production, reserves, share of battery use and recycling rate of lithium and cobalt in 2015 (Jaskula, 2016) (CDI, 2016) (UNEP, 2011).

	Lithium	Cobalt
Annual production (Ton/a)	32.500	99.000
Useful reserves (million tons)	14	7.1
Global resources (million tons)	34	120
Share of battery use (%)	35	42
Main reserves	Chile, Argentina, Bolivia China, Australia	Democratic Republic of Congo
Recycling rate (%)	<1	68

Gas peaker

U



Source: IEA website, 2019

Source: Lazard, Levelized Cost of Storage Analysis, Version 4.0, 2018

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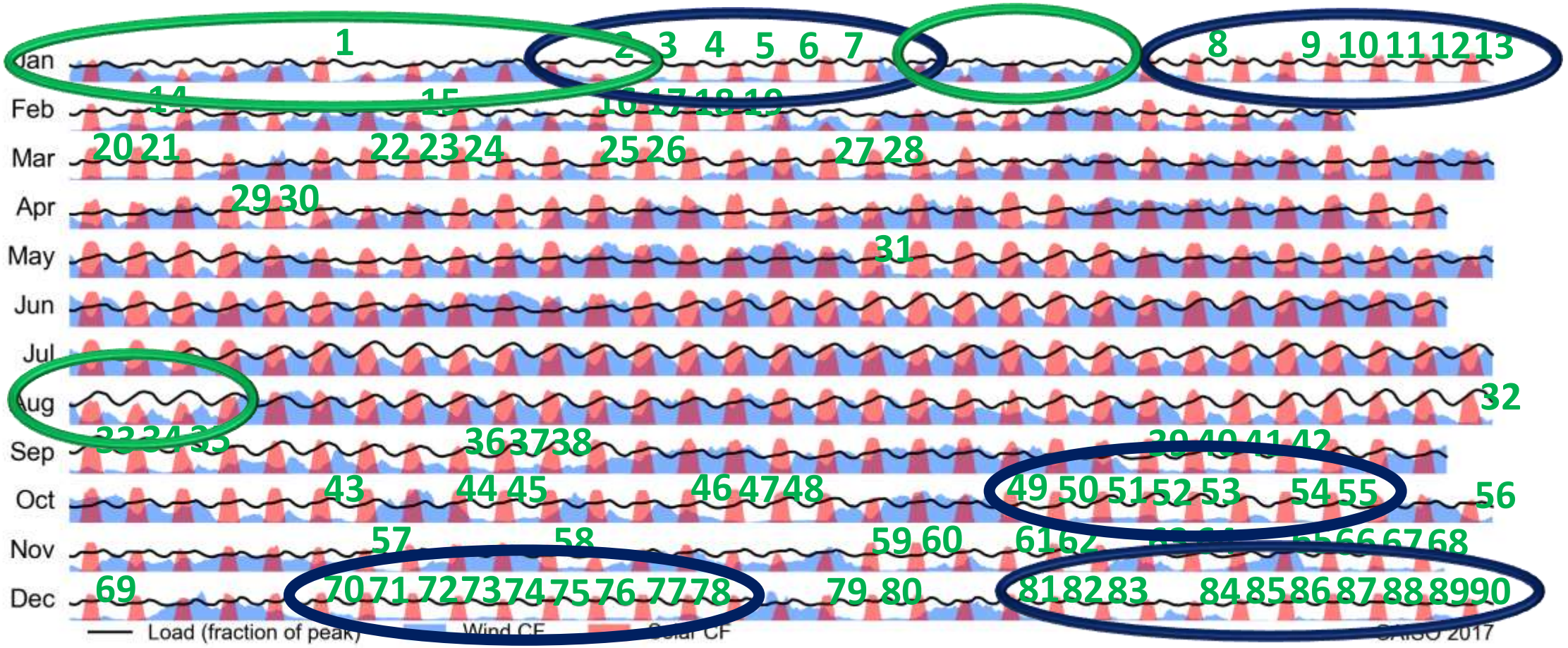
Significant Challenges for Utility Scale Battery Storage

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



Source: CAISO data, EFI analysis

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

Expanded 45Q Tax Credit for Carbon Capture, Utilization and Storage (CCUS), AOTA

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Estimated and Measured First-of-a-Kind Costs for CCS Applied to Different Plants

Tax Credit Value Available for Different Sources and Uses of CO_2

Type of CO_2 Storage/Use	Minimum Size of Eligible Carbon Capture Plant by Type ($ktCO_2/yr$): Power Plant	Other Industrial Facility	Direct Air Capture	Relevant Level of Tax Credit in a Given Operational Year ($USD/$tCO_2$): 2018	2019	2020	2021	2022	2023	2024	2025	2026	Beyond 2026
Dedicated Geological Storage	500	100	100	28	31	34	36	39	42	45	47	50	Indexed to Inflation
Storage via EOR	500	100	100	17	19	22	24	26	28	31	33	35	
Other Utilization Processes[1]	25	25	25	17[2]	19	22	24	26	28	31	33	35	

[1] Each CO_2 source cannot be greater than 500 $ktCO_2/yr$

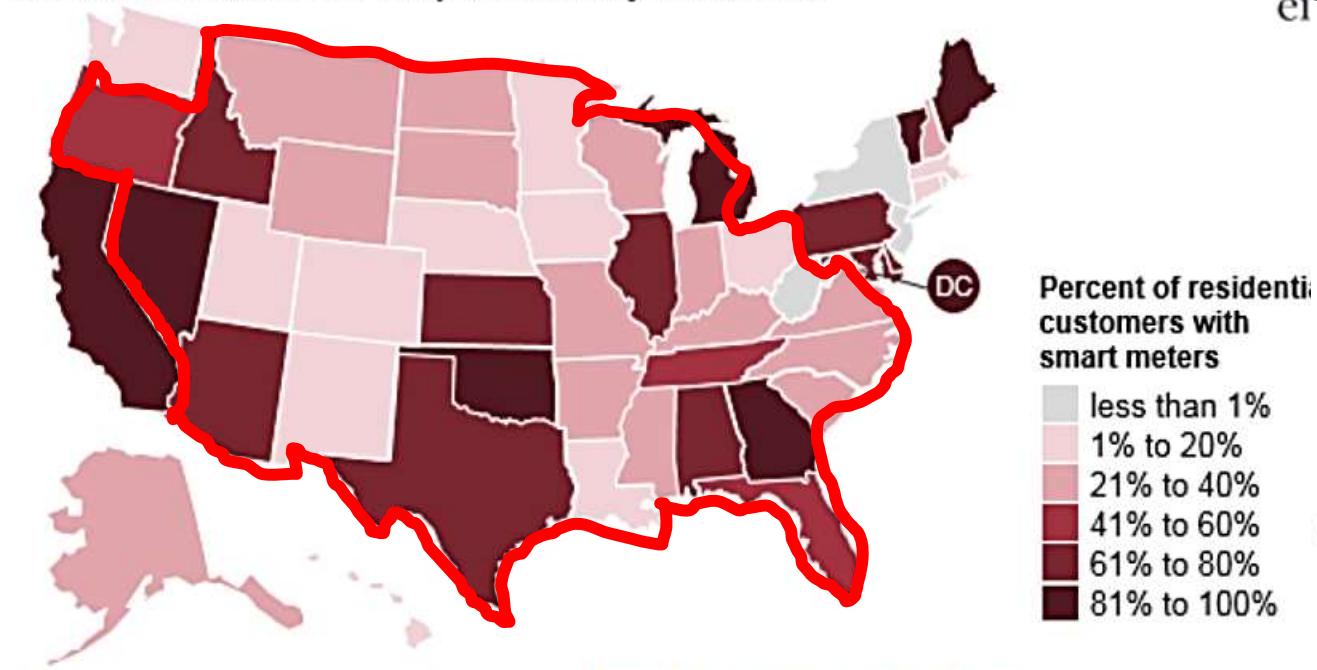
[2] Any credit will only apply to the portion of the converted CO_2 that can be shown to reduce overall emissions

Industry is the sector that is most difficult to decarbonize. Innovation is needed in hydrogen, carbon capture, storage and utilization, and biogas.

US Natural Gas/Technology

Grid Modernization/Smart Communities

Residential smart meter adoption rates by state, 2016



Source: U.S. Energy Information Adm

Electric Coops Without Access to 25/3 Mbps Broadband

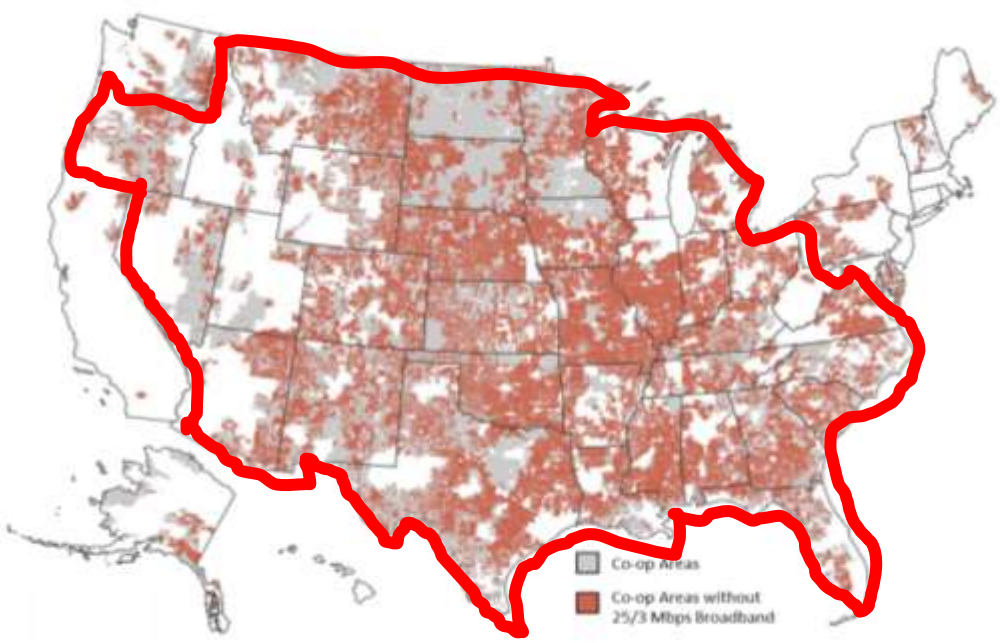


Figure 4: Forgone Value for Consumer-Members at Different Adoption Rates

Broadband Adoption Rate	Annual Economic Benefits	Discounted Present Value of Benefits over 20 Years
100%	$12.3 Billion	$139.3 Billion
75%	$9.2 Billion	$104.4 Billion
49%	**$6.0 Billion**	**$68.2 Billion**
34%	$4.2 Billion	$47.3 Billion

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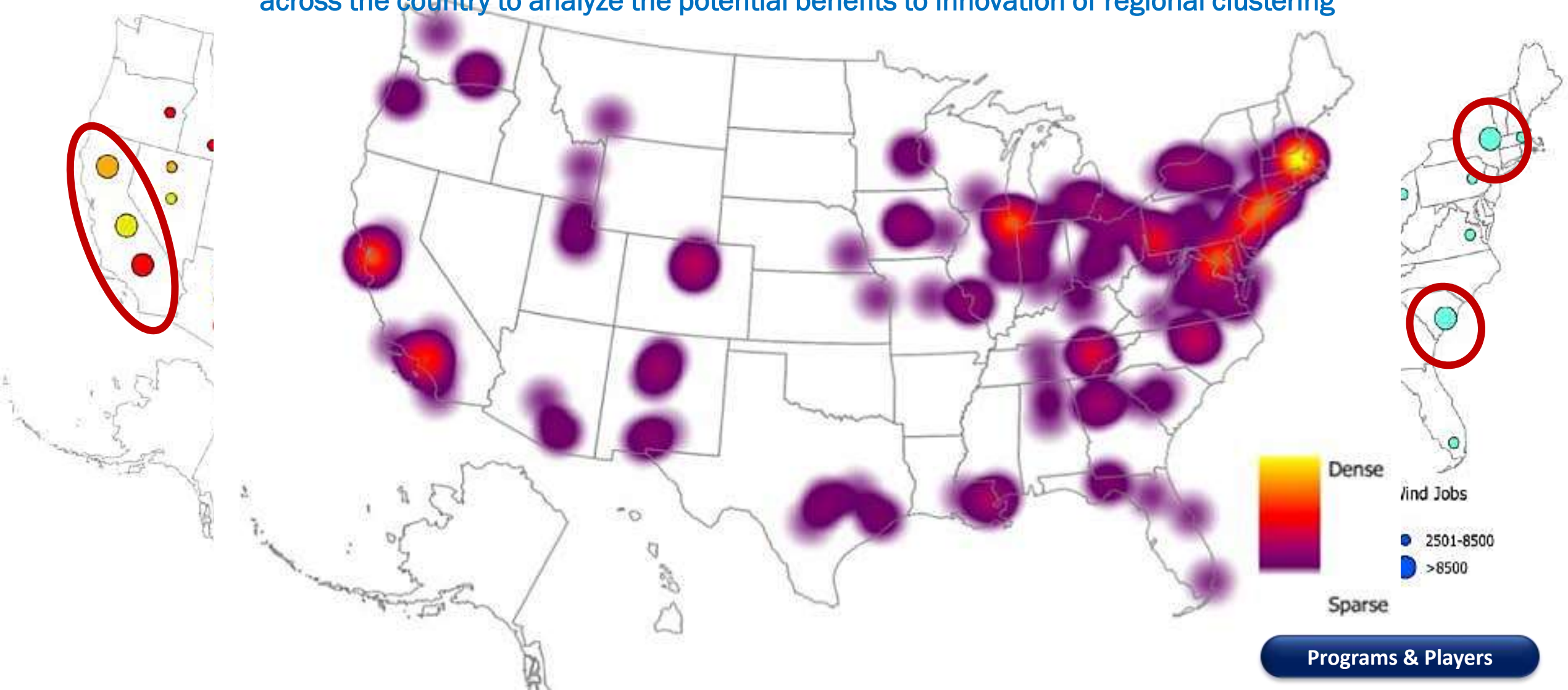
Regional Trends and Clean Energy Innovation Indicators

EFI's Regional Clean Energy Innovation Index combines locational data for energy RD&D resources across the country to analyze the potential benefits to innovation of regional clustering



Programs & Players