Regulator/Policy-maker Perspective From Various Regions

Sixth Annual Expert Workshop: Challenges in Electricity Decarbonization
Mid-century Decarbonization in the Electricity Sector

October 17, 2019

ENERGY FUTURES INITIATIVE

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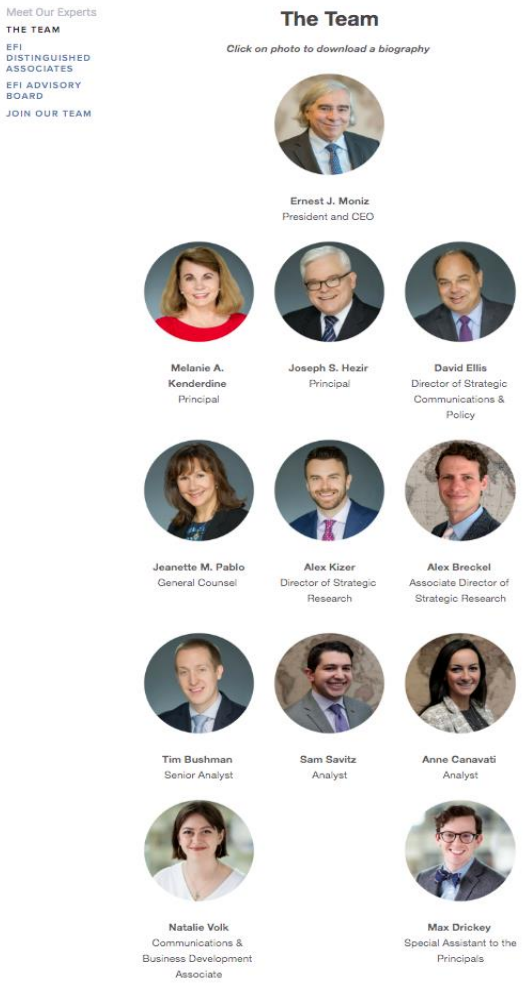
Energy Futures Initiative



Our Mission

EFI is dedicated to harnessing the power of innovation - both in technology and policy - to create clean energy jobs, grow economies, enhance national and global energy security, and address the imperatives of climate change.

To fulfill this mission, EFI conducts and analyzes research, preserving independent control of the methodology, content, and conclusions of its project and publication and making the results public thought its website and other means.

Energy Futures Initiative

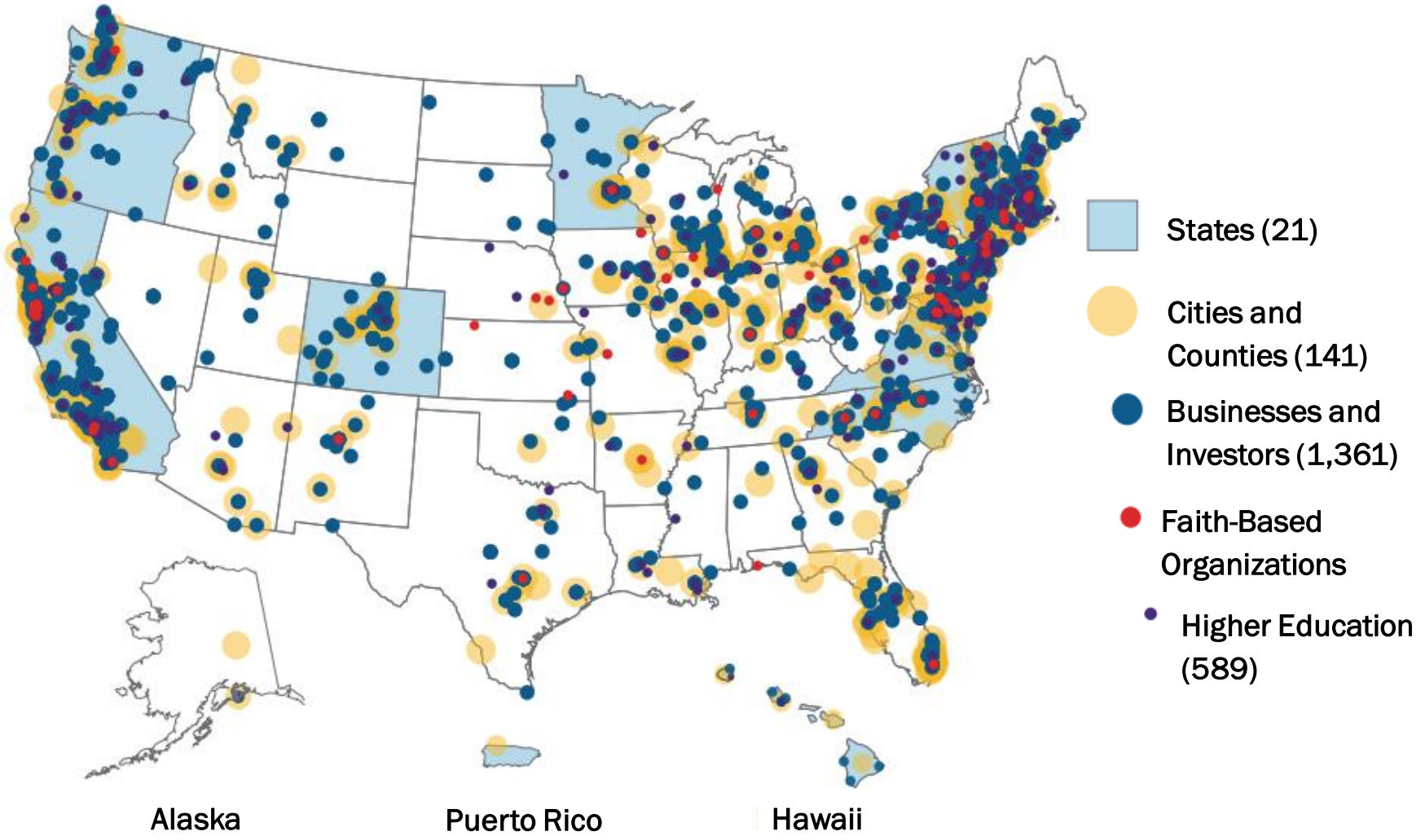
1. The U.S. Nuclear Energy Enterprise: A Key National Security Enabler (August 2017)
2. Leveraging the DOE Loan Programs: Using $39 Billion in Existing Authority to Help Modernize the Nation's Energy Infrastructure (March 2018)
3. The 2018 and 2019 U.S. Energy and Employment Reports (March 2019 & June 2018) – National Association of State Energy Officials*
4. Promising Blockchain Applications for Energy: Separating the Signal from the Noise (July 2018)
5. Advancing Large Scale Carbon Management: Expansion of the 45Q Tax Credit (May 2018)
6. Investing in Natural Gas for Africans: Doing Good and Doing Well (November 2018)
7. Advancing the Landscape of Clean Energy Innovation (February 2019) – IHS Markit*
8. More Funding Needed for Carbon Removal Technologies (April 2019) – Bipartisan Policy Center*
9. Optionality, Flexibility & Innovation: Pathways for Deep Decarbonization in California (May 2019)
10. The Green Real Deal: A Framework for Achieving a Deeply Decarbonized Economy (August 2019)
11. Clearing the Air: A Federal RD&D Initiative and Management Plan for Carbon Dioxide Removal Technologies (September 2019)

*Partners

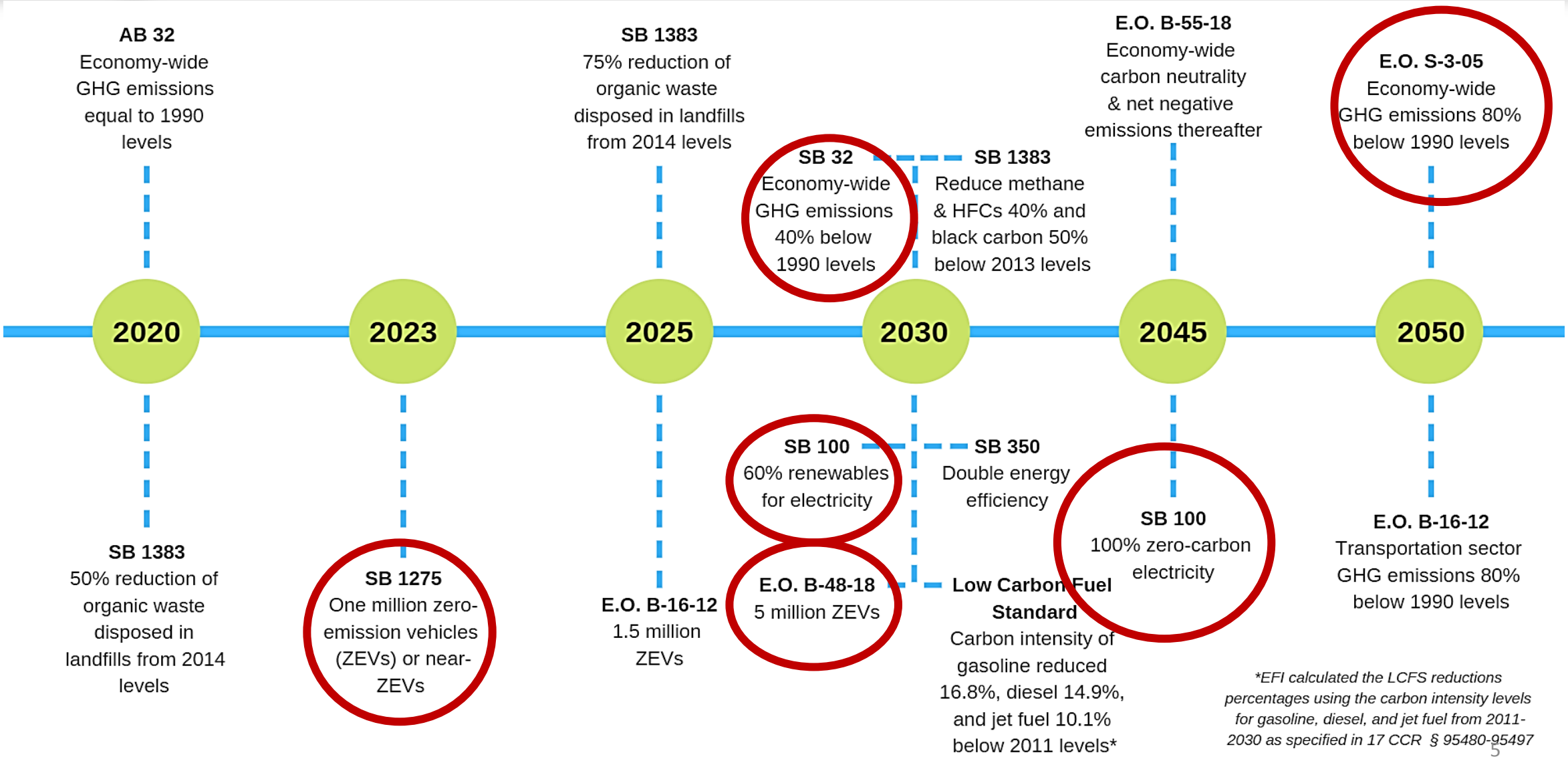
Sub-national Players Committed to Paris Accord

80x50 GHG Emission Analysis and Policy Studies:

Massachusetts
New York City
New Jersey
Delaware
Colorado
Nevada



Timeline of Key California Policies for GHG Reductions



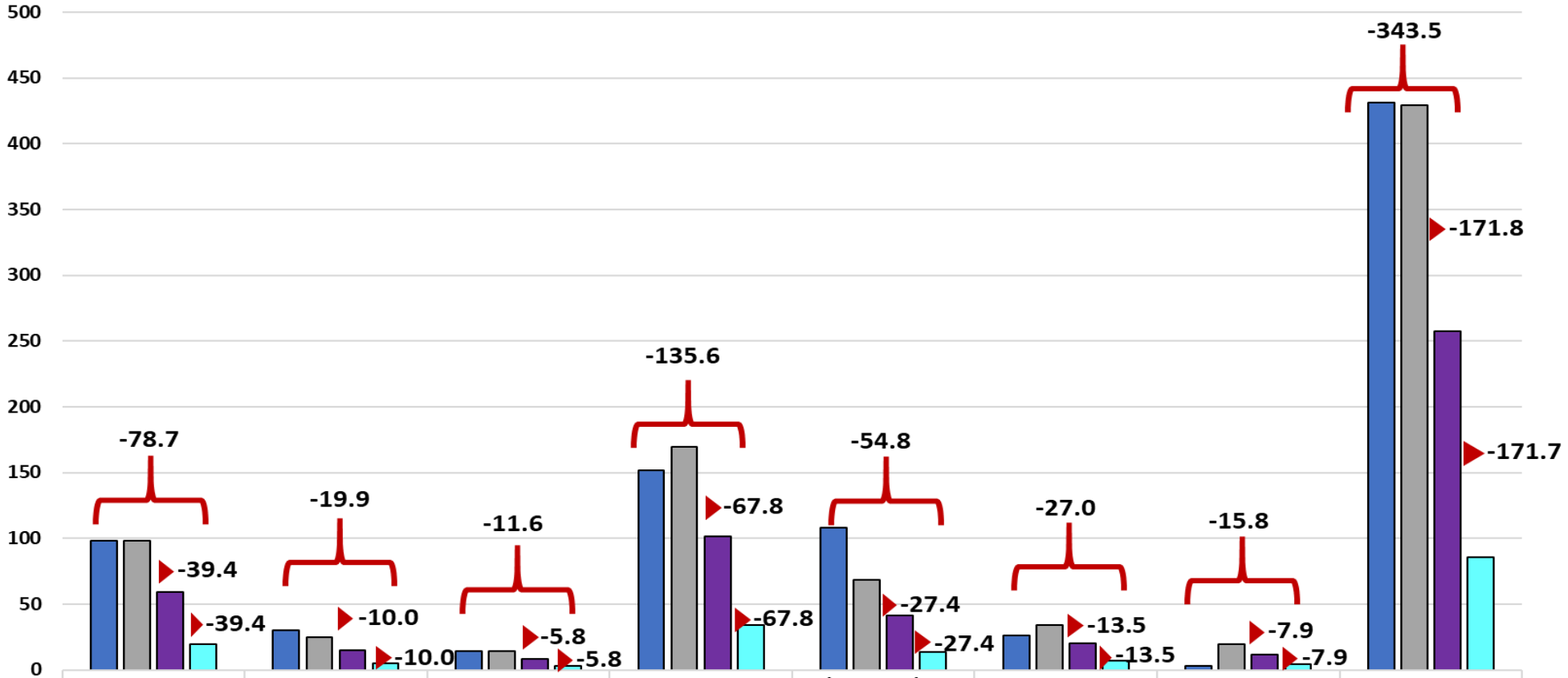
**EFI calculated the LCFS reductions percentages using the carbon intensity levels for gasoline, diesel, and jet fuel from 2011-2030 as specified in 17 CCR § 95480-95497*

Emissions-Reduction Baseline

MMT CO2e reductions needed by 2030 from 2016 actual

MMT CO2e reductions needed by 2050 from 2040 target

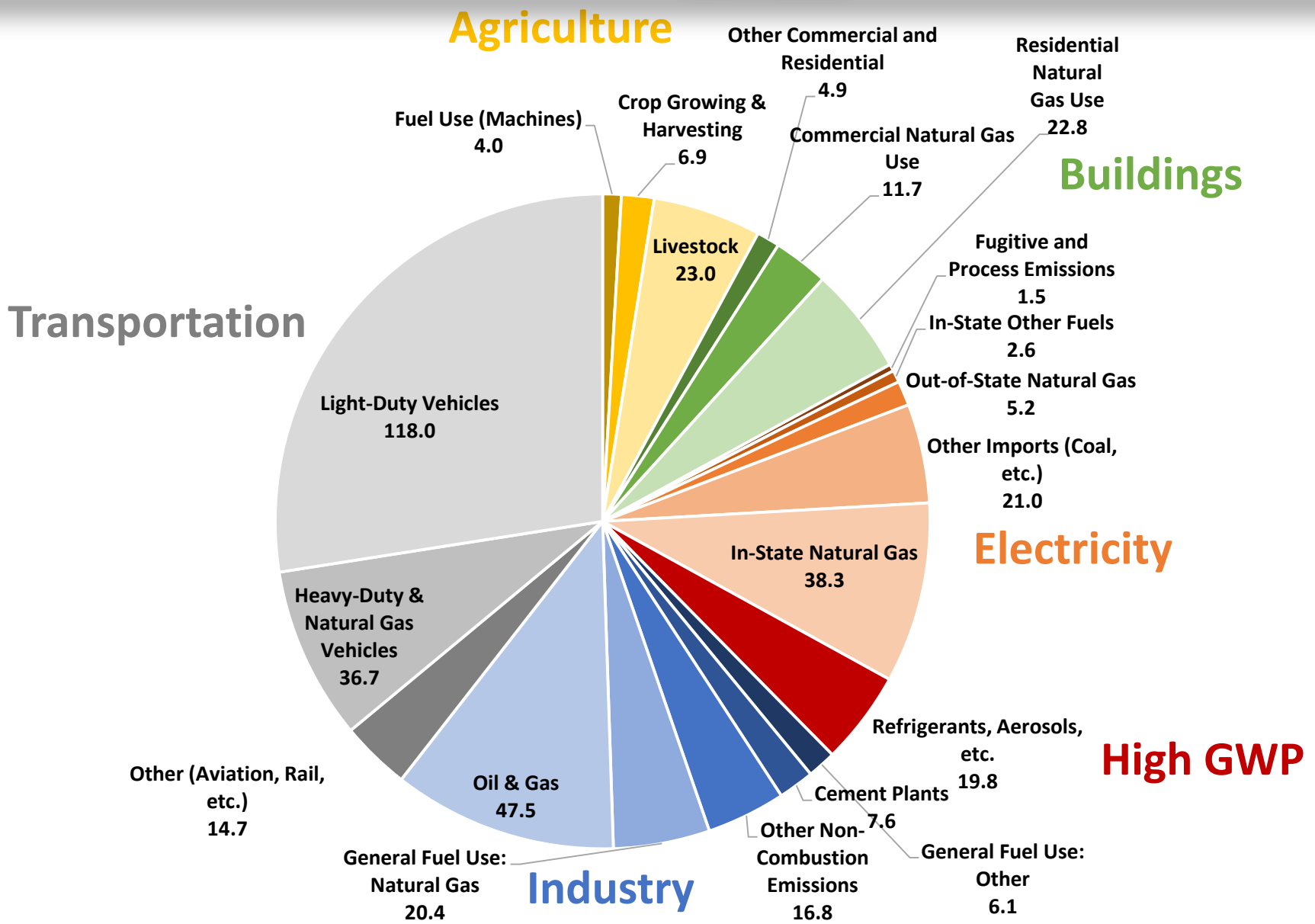
Total MMT CO2e reductions needed by 2050 from 2016 actual



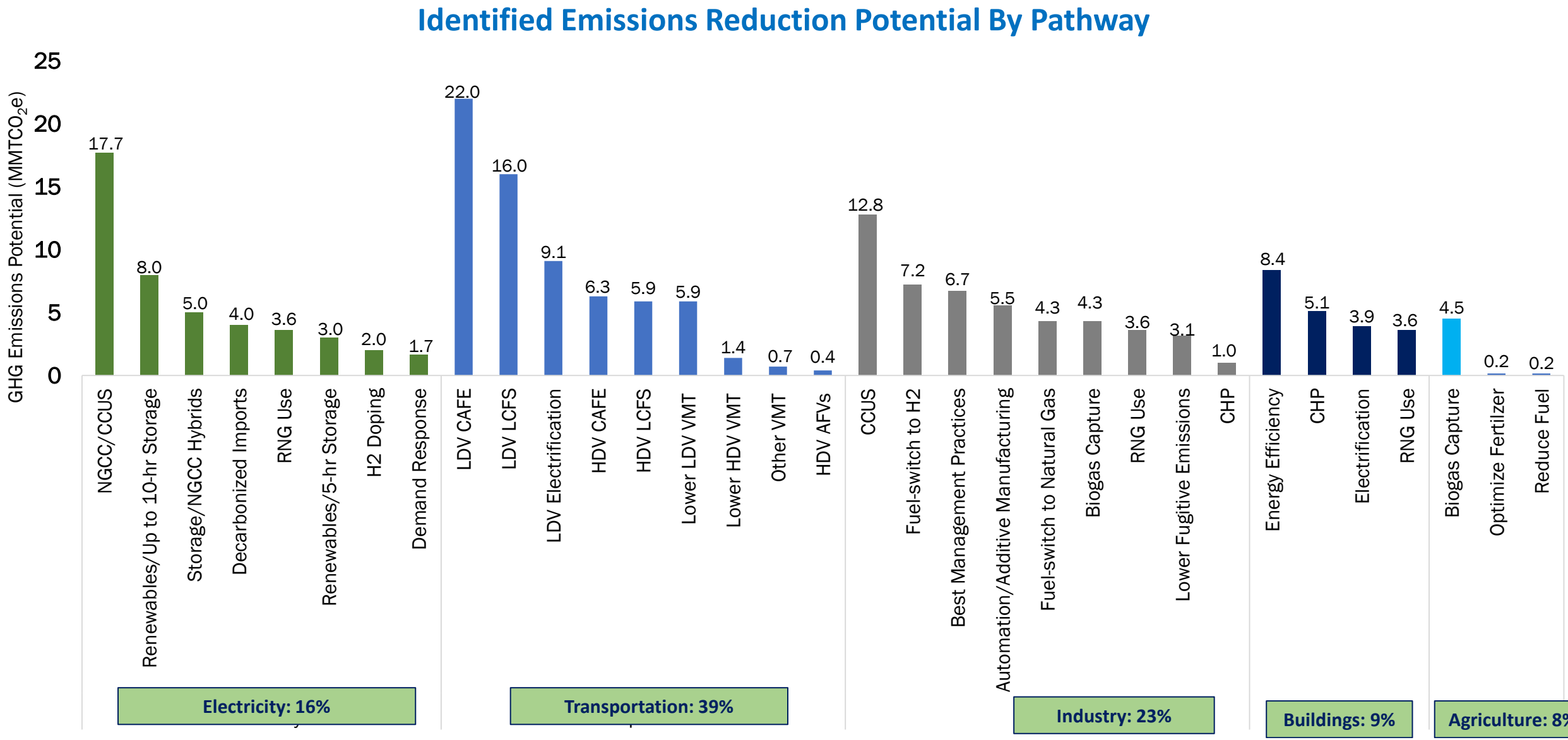
	Industry	Residential	Commercial	Transportation	Electricity (inc. imports)	Agriculture	High GWP	TOTAL
1990 Actual	98	30	14	152	108	26	3	431
2016 Actual	98.4	24.9	14.4	169.38	68.58	33.84	19.78	429.28
40% Reduction from 2016 Actual	59	14.9	8.6	101.6	41.1	20.3	11.9	257.6
80% reduction from 2016 Actual	19.7	5	2.9	33.9	13.7	6.8	4	85.9

2016 CA GHG Emissions by Sector, Subsector & Source

(MMTCo2e)

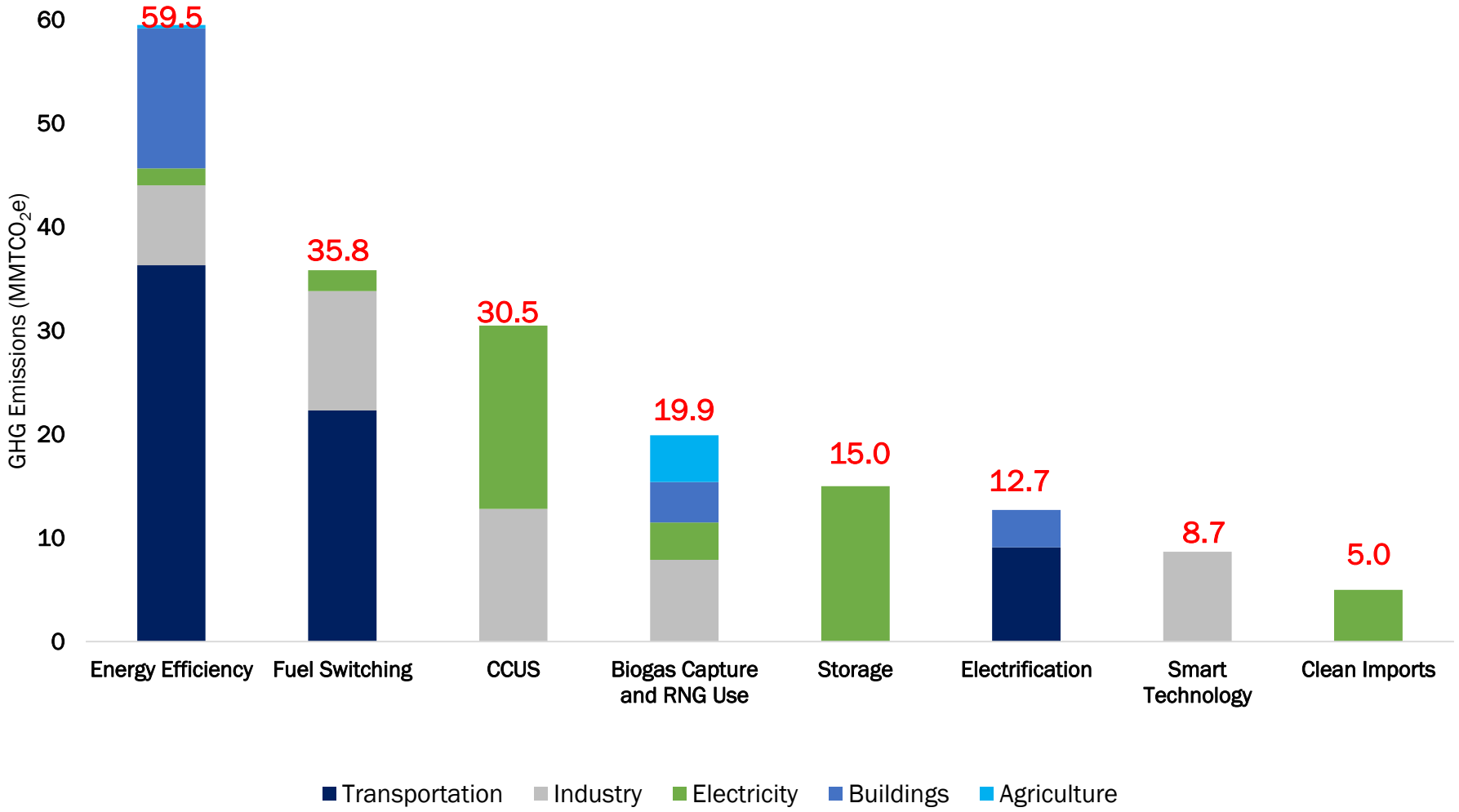


California: 33 Pathways were identified as options for meeting 40% emissions reduction by 2030



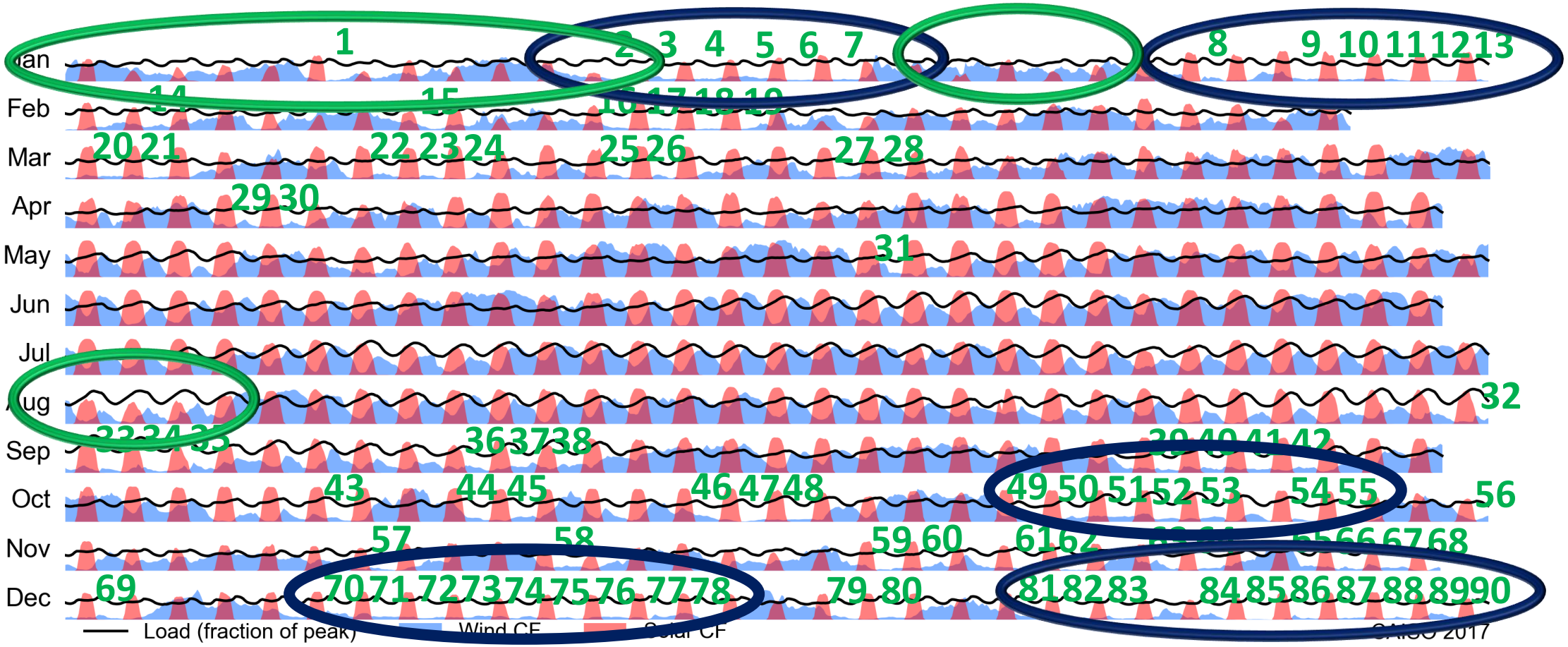
California: 33 Pathways were identified as options for meeting 40% emissions reduction by 2030

Identified Emissions Reduction Potential By Sector



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

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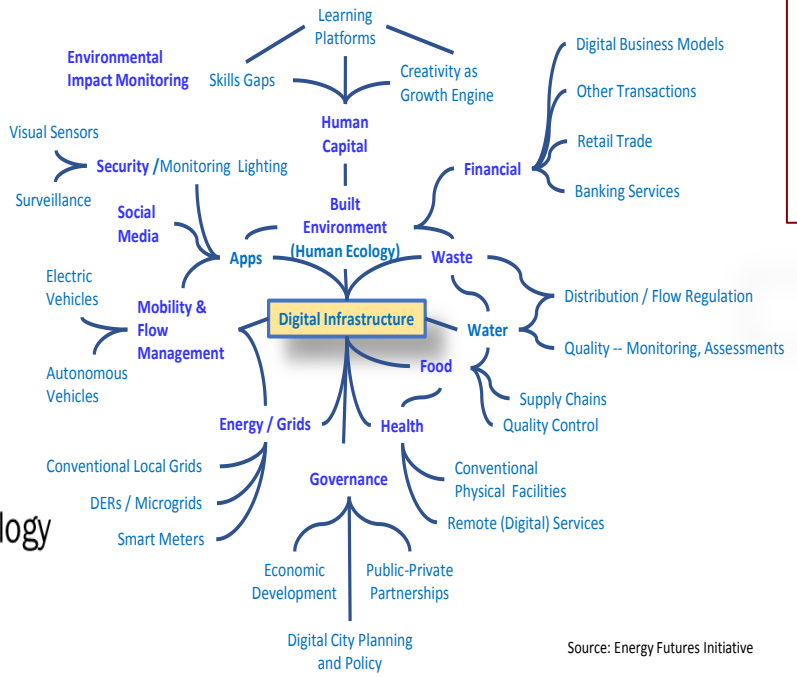
Cross-Cuts for Near- and Long-Term Decarbonization

Major Technology Cross Cuts	Electricity	Transportation	Industry	Buildings	Agriculture
Large Scale Carbon Management	Creates emissions reduction buffer for extremely hard to decarbonize processes		Reduces carbon from atmosphere and oceans, from diffuse and concentrated sources	Creates potential market for carbon-based products in Buildings (materials), Transport (fuels), and Agriculture (greenhouses)	
Hydrogen	Grid Balancing; End Use for Excess Renewables	Clean fuel for all vehicle classes	Meet high-grade heat requirements; used as clean feedstock	Blended with natural gas for all end use needs	Fuel for farming systems
Leveraging Carbon Infrastructure/ Expertise	Co-fire cleaner fuels (RNG, biofuels, H2) with natural gas	Existing networks can carry and store clean fuel alternatives	Refineries and terminals can blend, store, and consume clean alternatives	Existing distribution pipes can carry natural gas doped with H2, RNG	Can access markets with biomass-based products
Smart/Platform Technologies	Smart sensors and controls improve efficiency and resilience	Autonomous vehicles, on-road and -vehicle sensors improve safety and lower fuel use	Automation and additive manufacturing decrease fuel use and other costs	Improved building management can cut cost and connectivity improves livability	Data analytics can improve yields, lower costs

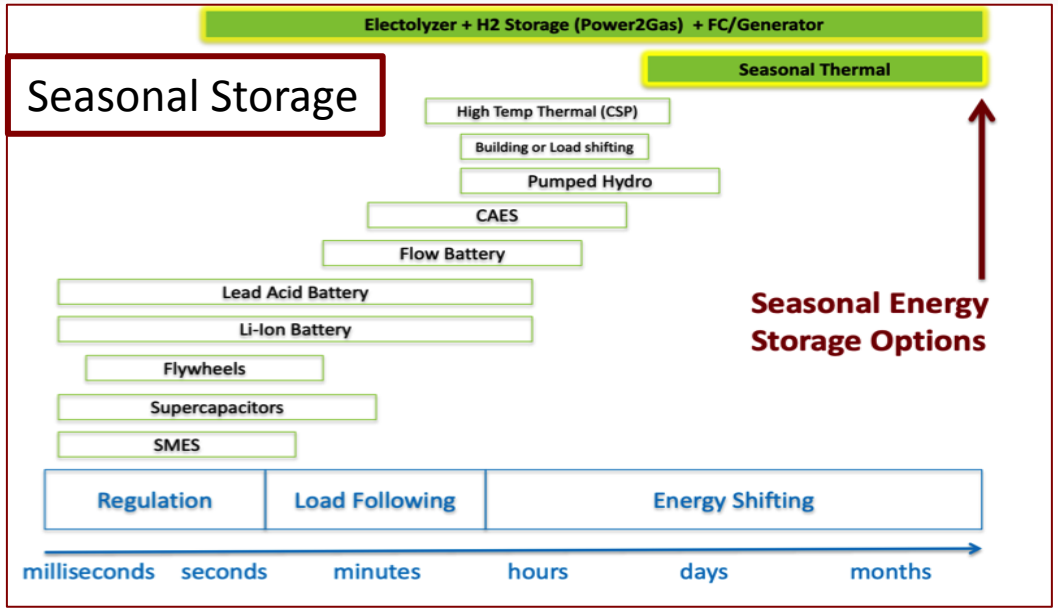
CA Breakthrough Technology Portfolio, Post-2030

- Smart Cities
- Hydrogen from Electrolysis
- Seasonal Storage
- Clean Cement
- Li-ion Battery Recycling
- Floating Offshore Wind
- Advanced Nuclear
- Building Performance Technology
- Bioenergy
- Advanced Photovoltaics
- Direct Air Capture

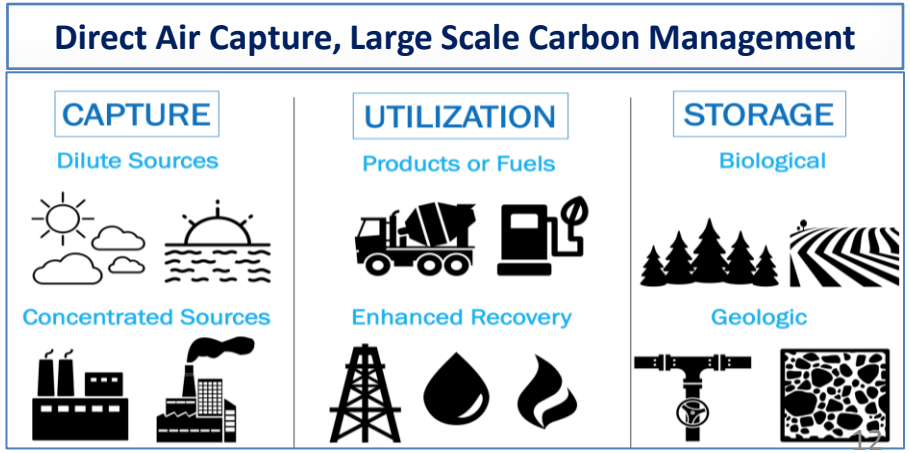
Figure X. Digital Infrastructure is Essential for Smart Cities



Source: Energy Futures Initiative



Source: EFI Analysis, NREL



Energy Innovation Initiatives

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VATTENFALL

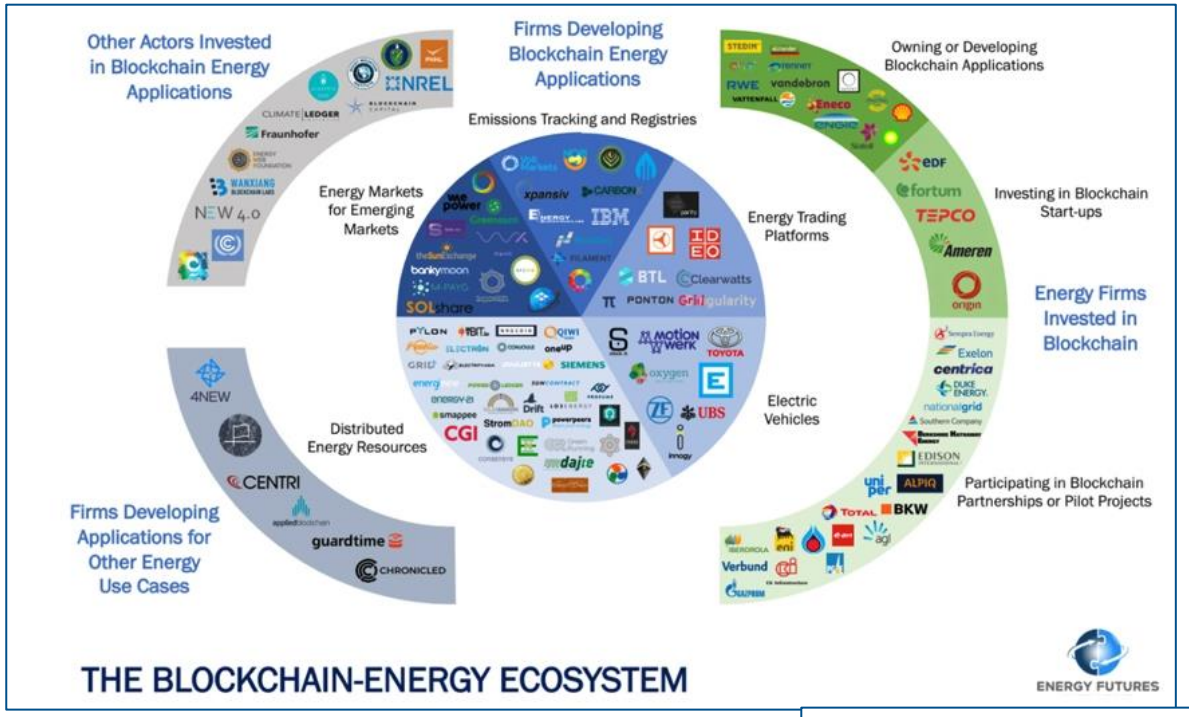
Carbon Engineering

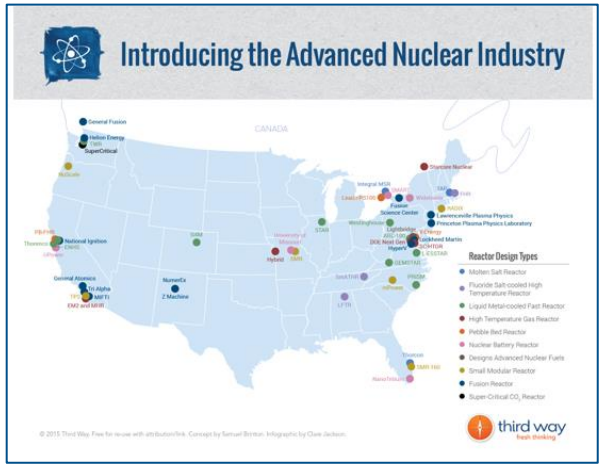
HYDROGENICS
SHIFT POWER | ENERGIZE YOUR WORLD

NETPOWER

Global Thermostat

CLIMEWORKS
Capturing CO_2 from air





Equinor—the world's leading floating offshore wind developer

Zhangjiakou HyPower New Energy Technology Co, a hydrogen energy technologies developer and related service provider in Zhangjiakou, invested about 10 million yuan ($1.5 million) on the city's first hydrogen refueling station for its 74 hydrogen fuel cell buses.

A hydrogen fueling station already built in Tokyo's Shiba Park. The metropolitan government plans to have 35 such stations in operation by 2020. And by 2025 it aims to have 80 hydrogen stations in operation and 100,000 fuel cell cars on the roads.

Significant Analytical Findings

- Today's available technologies are insufficient to reach deep decarbonization across all sectors in the long term. Decarbonization policy must support innovation on dual tracks: incremental improvements in existing technologies to meet 2030 targets, and technology innovations with breakthrough potential needed to meet midcentury goals.

- Climate solutions can result in uneven impacts and could be costly for those who are least able to afford them - absent proactive policy efforts.

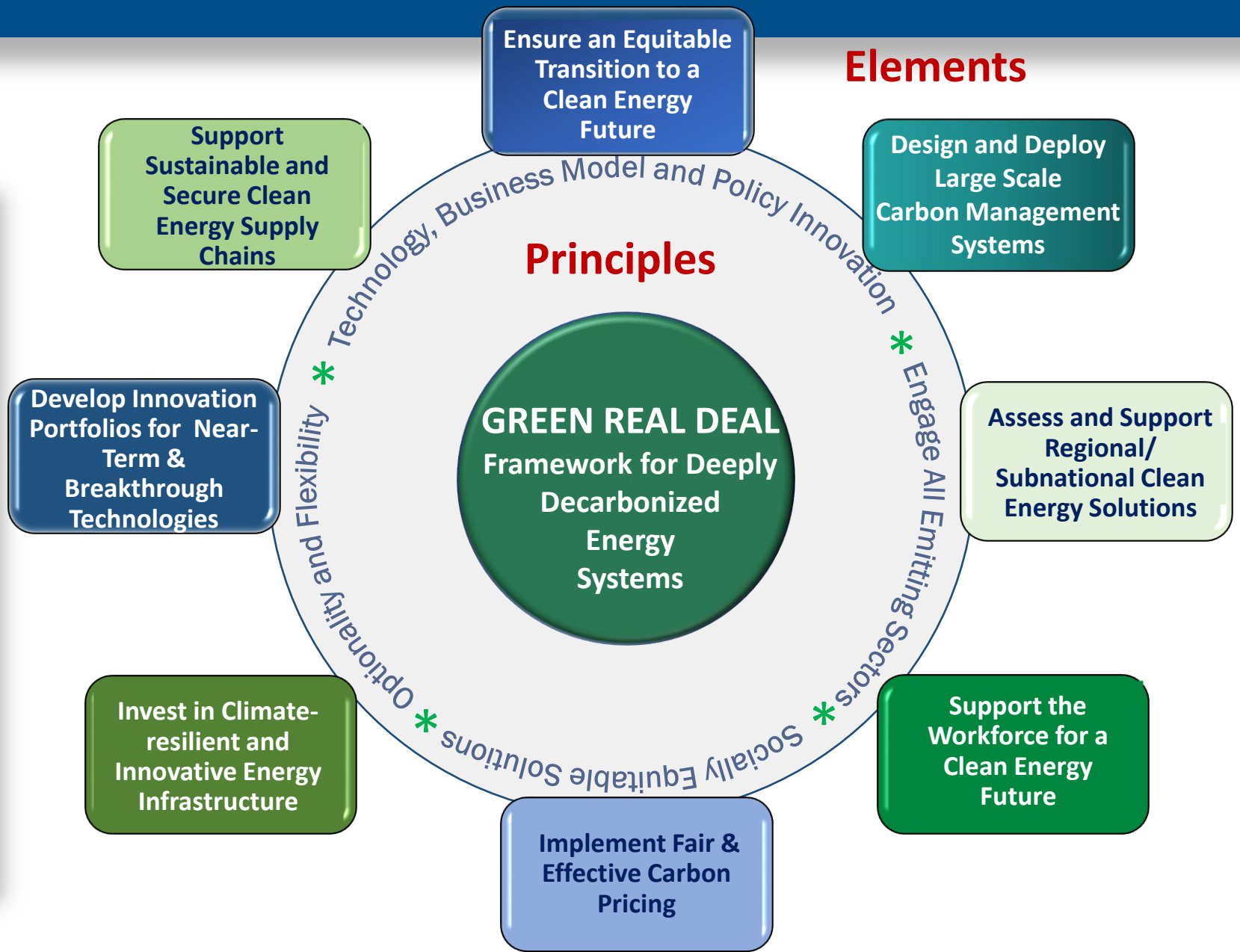
- Public acceptance issues may slow progress when acceleration is needed.

- Climate impacts are regional, mitigation costs will vary by region, and regional solutions are essential. Energy sector infrastructures also vary dramatically by region; impacts of climate change on discrete systems, and cross-cutting, and interregional systems—must also be considered when developing technologies, policies and business models for mitigating climate change.

Mission, Principles and Elements of a Green Real Deal DRAFT

Mission of GRD

Provide a framework for accelerating deep decarbonization of energy systems by mid-century in ways that
minimize costs, maximize economic opportunities and promote social equity.



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

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; and
- de-carbonization of the electricity sector due to flat demand and changing fuel mix

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

Source: Advancing the Landscape of Clean Energy Innovation, EFI, IHS Markit, February, 2019

Extra Credit

New Players in the Energy Space

Smart Platform Technologies

Patent Activity for Select Electricity Technologies: Japan - EU - US

Supply Chain Realities

New Players in the Energy Space

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New players need technology, policy and analytical support

Building Energy Mgmnt.

FirstFuel Software .* Kwantera *Pulse Energy Retroficiency * WegoWise

Oracle BuildingsIQ * C3 Energy * Daintree Networks Ecova * Energy Savvy

Global Drones in Energy

AeroVironment, Inc. (US), * Aerovel Corporation (USA) * Lockheed Martin (US),

Northrop Grumman Corporation (US) * Proxy Technologies Inc. * VDOS Global LLC(U.S.).

Energy Data Analytics

Auto Grid * Energy Impact Partners * Southern * National Grid * Xcel * Foundation Capital * Voyager Capital * Envision Ventures

E.ON * Venture Partners * EMeter * Oracle * Siemens * Palantir * BP *IBM

Smart Cities/Grid

BAE Systems * IBM * IOActive * Lockheed Martin * AlertEnterprise * AlienVault * Black and Veatch

Cisco Systems * Intel (McAfee) * Entergy Services * HP * N-Dimension Solutions * Sophos * Sourcefire * Symantec

Energy/Cyber-Security

Siemens * GE * Symantec * Managed Service Providers * Fathom5

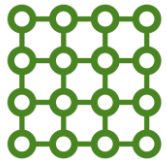
Cisco * FireEye * RSA * General Dynamics

Source: Advancing the Landscape of Clean Energy Innovation, 2019

US Trends/Issues

Smart Platform Technologies

Smart technologies that use data, connectivity, and analytics to improve the performance of both new and legacy systems.



Smart Grid

- Energy savings (efficient transmission, lower peak)
- Integration of clean energy and DER
- Improved security and resilience

Home Energy Management Systems

- Data and control over energy use
- Automatic adaptation to real-time conditions

5G Networks

- Faster connections with less energy use
- Built-in cybersecurity

Artificial Intelligence

- Managing increasingly complex markets and networks
- Mitigating risk from manmade and natural threats
- Improving transportation efficiency, cost, and safety

Additive Manufacturing

- Customizable products for industry, transport, etc.
- Leveraging new materials to improve efficiency and performance

Blockchain

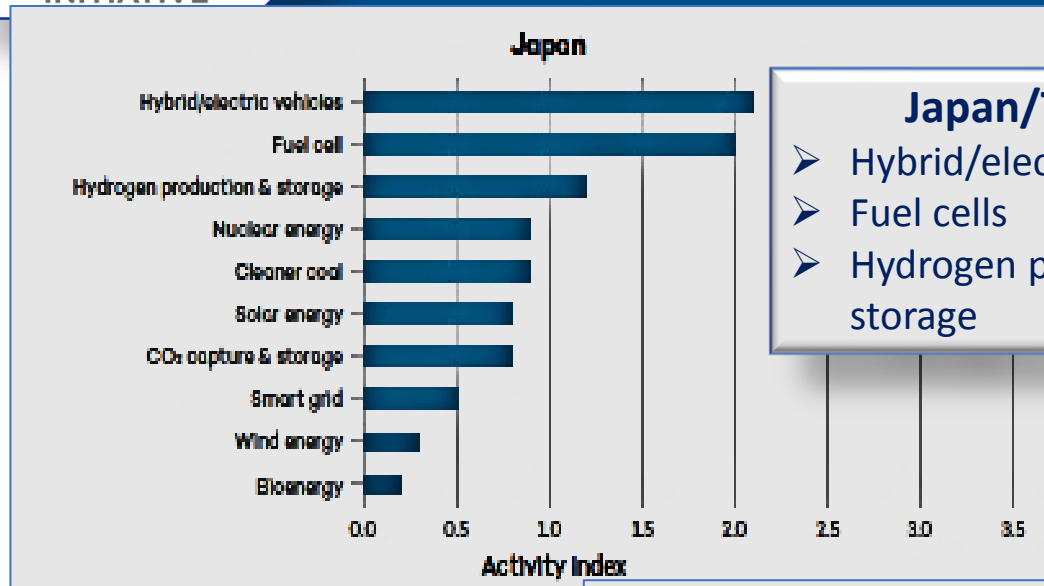
- Managing transactions quickly and securely for new markets: EVs, DER, unconnected areas
- New tools for supply chains, attribute trading

High-Performance Computing

- Producing and fabricating new materials
- Modeling and simulation to increase efficiency and productivity

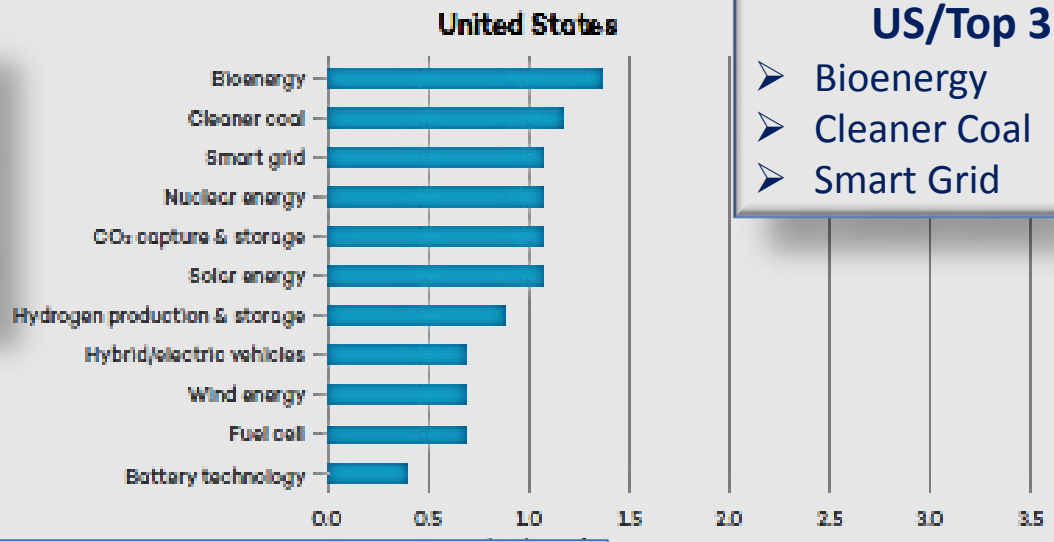
Tech companies are becoming players in the energy sector:

Japan/US/EU Patent Activity Index for Select Electricity Technologies



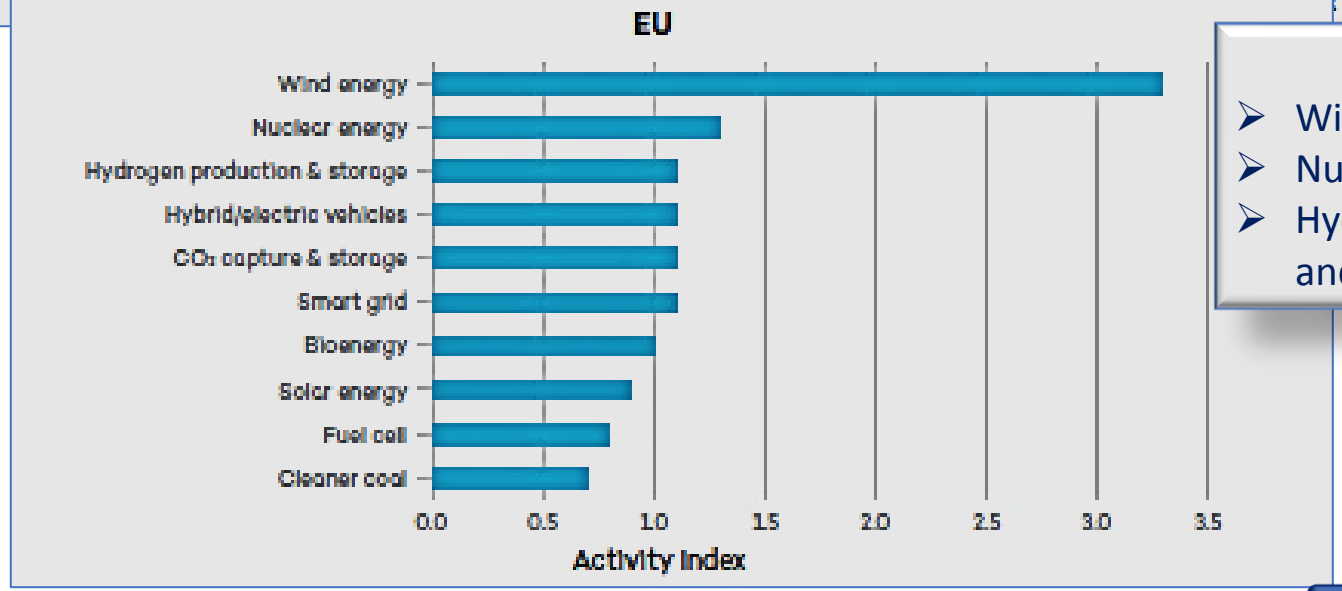
Japan/Top 3

- Hybrid/electric vehicles
- Fuel cells
- Hydrogen production & storage



US/Top 3

- Bioenergy
- Cleaner Coal
- Smart Grid



EU/Top 3

- Wind energy
- Nuclear energy
- Hydrogen production and storage

A patent activity index is the ratio of a country's share of a technology area to its share of all patents. A patent activity index greater (less) than 1.0 indicates that the country is relatively more (less) active in the technology area.

Source: NSF Website, accessed Mat 26, 2018

Select Metals, Minerals and Processes, #1 & Top Five

North America Top 5 in –

Aluminum Smelter Capacity (Canada)
Aluminum Refinery Production (US)
Bauxite (Jamaica)
Cadmium (Canada, Mexico)
Cobalt (Cuba)
Copper (Mexico, US)
Indium (Canada)
Iron Ore (US)
Lead (Mexico)
Raw Steel (US)
Molybdenum (US, Canada)
Rare Earths (US)
Nickel (Cuba)
Platinum (US, Canada)
Silicon Production (US)
Zinc (Mexico, US)

No number One's

South America Top 5/#1 in –

Aluminum Refinery Production (Brazil)
Bauxite (Brazil)
Cobalt (Cuba)
Copper (Chile)
Indium (Canada)
Iron Ore (Brazil)
Reserves/Iron Content (Brazil)
Lead (Peru)
Lithium (Chile, Argentina)
Manganese(Brazil)
Silver (Peru)
Molybdenum (Peru)
Rare Earths (Brazil)
Platinum (Canada)
Zinc (Peru)

3 Number One's

Source: The Growing Role of Minerals and Metals for a Low Carbon Future, World Bank Group/EGPS, June 2017

Select Metals, Minerals and Processes, #1/Top Five for Asia/Australia

Asia Top 5/#1 in --

Aluminum Smelter Capacity (China India)
Aluminum Refinery Production (China, India)
Bauxite (Vietnam)
Cadmium (China, Japan)
Chromium (Kazakhstan, India)
Cobalt (Philippines)
Indium (China, Japan, R. of Korea)
Pig Iron (China, Japan, India)
Raw Steel (China, India)
Crude Iron Ore (China)
Reserves/Iron Content (China, India)
Lead (China)
Lithium (China)
Manganese (India)
Nickel (Indonesia)
Molybdenum (China)
Silicon Production (China)
Rare Earths (China, India)
Silver (China)
Titanium (China, India)
Zinc (China)

11 Number One's

Source: The Growing Role of Minerals and Metals for a Low Carbon Future, World Bank Group/ECSPS, June 2017

Australia/New Caledonia Top 5/#1 in –

Aluminum Smelter Capacity
Aluminum Refinery Production
Bauxite
Cobalt
Copper
Crude Iron Ore
Reserves/Iron Content
Lead
Lithium
Manganese
Nickel (Australia, New Caledonia)
Rare Earths
Silver
Titanium
Zinc

5 Number One's