Evolving Energy Realities: Adapting to What's Next

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August 15, 2019

Optionality, Flexibility & Innovation: Pathways for Deep Decarbonization in California
Sectoral Emissions in California, 2016

Industry: 23%
- Industry: 100.4 (23%)
- Rest of Economy: 329.0 (77%)

Transportation: 39%
- Transport: 169.3 (39%)
- Rest of Economy: 259.9 (61%)

Electricity: 16%
- Electricity: 68.6 (16%)
- Rest of Economy: 360.8 (84%)

Buildings: 9%
- Buildings: 39.4 (9.2%)
- Rest of Economy: 390.0 (90.8%)

Agriculture: 8%
- Agriculture: 33.8 (8%)
- Rest of Economy: 395.5 (92%)

Source: EFI using data from CARB

Industry: 23%
Transportation: 39%
Electricity: 16%
Buildings: 9%
Agriculture: 8%
Sectoral GHG Emissions Reductions Achieved by 2030 From Top Two Technology Pathways*

**Industry:** 23%
- Need 40 MMT reduction by 2030
- Top 2 pathways get halfway there

**Transportation:** 39%
- Need 68 MMT reduction by 2030
- Top 2 pathways get 44% of way there

**Electricity:** 16%
- Need 27 MMT reduction by 2030
- Top 2 pathways get 100% of target

**Buildings:** 9%
- Need 15 MMT reduction by 2030
- Top 2 pathways get 93% of way there

**Agriculture:** 8%
- Need 13 MMT reduction by 2030
- Top 2 pathway gets 35% of the target

*From 2016 emissions baseline, growth not assumed*
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
Seasonal Variation in Solar & Wind

Metered Solar Generation

- 1.5 TWh in January
- 3.2 TWh in June
- Delta: 1.7 TWh

Wind Generation

- 0.6 TWh in January
- 2.0 TWh in June
- Delta: 1.4 TWh

Wind/Solar Seasonal Delta Between January and June, 2016

- 3.1 TWh

Source: EFI, compiled using data from CAISO
Industry: Multiple Subsectors, Combustion and Non-Combustion Emissions Require a Range of Pathways

Industry Sector Energy Consumption by Fuel Type

- Natural Gas 55%
- Petroleum 29%
- Coal 2%
- Distillate Fuel Oil 5%
- Petroleum Coke 4%
- Asphalt & Road Oil 4%
- Motor Gasoline 2%
- Hydrocarbon Gas Liquids 1%
- Lubricants & Kerosene 1%
- Other Petroleum Products 11%

Potential Sequestration Sites for Industrial Facilities

- Cement Plants
- Gas Processing Plants
- Oil Refineries
- Oil & Gas Reservoirs
- Saline Formations
Industry is the sector that is most difficult to decarbonize. Innovation is needed in hydrogen, carbon capture, storage and utilization, and biogas.
Utilizing agricultural residues and manure as biogas feedstocks for RNG could provide up to 46.6 Bcf/year of carbon-neutral gas by 2030...Biogas capture also could provide emissions reductions and economic benefits to the Agriculture sector....Diverting methane into a useable product in the form of RNG can have a significant net impact on CO₂e levels—potentially reducing the Agriculture sector’s emissions 13 percent by 2030.
Meeting the Clean Energy Ministerial’s target of 30 million electric vehicle sales by 2030 would require 314 kt/yr. of cobalt, almost three times the 2017 level for all uses. At those rates, reserves would last 23 years.

Tesla’s global supply manager for battery metals, told a closed-door Washington conference of miners, regulators and lawmakers that the automaker sees a shortage of key EV minerals coming in the near future...Tesla will continue to focus more on nickel, part of a plan by Chief Executive Elon Musk to use less cobalt in battery cathodes.

Electrek, May, 2019

Source: USGS, 2019
Breakthrough Technology Portfolio, Post-2030

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Seasonal Storage

- Electrolyzer + H2 Storage (Power2Gas) + FC/Generator
- Seasonal Thermal
  - High Temp Thermal (CSP)
  - Building or Load shifting
  - Pumped Hydro
  - CAES
  - Flow Battery
- Lead Acid Battery
- Li-ion Battery
- Flywheels
- Supercapacitors
- SMES

- Regulation
- Load Following
- Energy Shifting

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Direct Air Capture, Large Scale Carbon Management

**CAPTURE**
- Dilute Sources
- Concentrated Sources

**UTILIZATION**
- Products or Fuels
- Enhanced Recovery

**STORAGE**
- Biological
- Geologic

Source: EFI Analysis, NREL