Clean Energy and Post-COVID Workforce

Yale Center for Business and the Environment
Melanie Kenderdine
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Construction & Manufacturing Jobs Created per $million of Capital Investment

Existing grids: 5
New grids: 10
New hydro: 15
New nuclear: Jobs per million dollars
Wind power: 5
Solar PV: 10

Unabated coal-fired power: 5
Unabated gas-fired power: 10
Hydrogen production: 15
CCUS: Jobs per million dollars
Reducing methane emissions: 5

Urban transport infrastructure: 10
High-speed rail: 15
Building efficiency retrofit:
Efficient new buildings: Jobs per million dollars
Industry efficiency: 15

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

<table>
<thead>
<tr>
<th>Ranking of Top 10 States, Highest to Lowest</th>
<th>Total Unemployment Claims (03/16-06/06)</th>
<th>Claims as % of Workforce</th>
<th>Natural Gas and Oil Fuels Jobs Actual as % of Workforce</th>
<th>Efficiency Jobs Actual as % of Workforce</th>
<th>Efficiency Jobs Actual</th>
<th>Gas/Oil Generation Actual as % of Workforce</th>
<th>Gas/Oil Generation Actual</th>
<th>Solar Generation Jobs Actual as % of Workforce</th>
<th>Solar Generation Jobs Actual</th>
<th>Wind Generation Jobs Actual as % of Workforce</th>
<th>Wind Generation Jobs Actual</th>
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<tr>
<td>1</td>
<td>CA</td>
<td>GA (47.8%)</td>
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<td>IL</td>
<td>OK (31.1%)</td>
<td>KS (31.1%)</td>
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</table>

**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

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

National Sequestration Opportunities

Source: EFI analysis, compiled using data from the EPA and NETL
Example of a “Hydrogen Hub”: Ports of LA and Long Beach, Hydrogen Technology Readiness Levels

- **Combined Cycle Power Plant**
- **H₂ Storage**
- **Onshore Sequestration**

**Hydrogen Use in Transportation**
- Fuel Cell Light Duty Road Vehicles
- Fuel Cell Heavy Duty Road Vehicles
- Fuel Cell Ships
- Ammonia-fueled Ships

**Hydrogen Use in Industry**
- Fossil-based Ammonia with Carbon Capture
- Fossil-based Methanol with Carbon Capture
- Electrolysis for Methanol & Ammonia
- High Levels of Blending into Commercial Iron Processes

**Hydrogen Use in Buildings**
- Hydrogen Boilers
- Fuel Cells
- Hydrogen-driven Heat Pumps
- High-temperature fuel cells
- Hydrogen-fired Gas Turbines
- Co-firing Ammonia in Coal Power Plants

**Hydrogen Use in Power Generation**
- Combined Cycle Power Plant
- Fuel Cell Light Duty Road Vehicles
- Fuel Cell Heavy Duty Road Vehicles
- Fuel Cell Ships
- Ammonia-fueled Ships

**Hydrogen Use in Fuels Transformation**
- Fossil-based Hydrogen with CCUS in Oil Refining
- Methane Splitting
- Electrolysis

**Hydrogen Use in Infrastructure**
- Pipelines
- Tanks
- Ammonia Tanker
- Refueling Stations
- Storage in Salt Caverns

**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

Electricity Generation from Selected Fuels, billion kilowatt hours

Renewable Electricity Generation, including end use, billion kilowatt hours

Source: Energy Information Administration, AEO 2020
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.

Carbonbrief.org

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

The oil industry is one of the few truly global industries. Along its supply chain, oil passes through different legal frameworks as it moves from one country to another. The oil and gas global supply chain includes activities such as domestic and international transportation, ordering and inventory visibility and control, materials handling, import/export facilitation and information technology.

Lithium Production/Reserves (metric tons)
Source: USGS, 2019

Cobalt Production/Reserves (metric tons)

Nickel (metric tons)


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

It would be reasonable to expect that all low carbon energy systems are more likely than not to be more metal intensive than high carbon systems. In fact, all literature examining material and metals implications for supplying clean technologies agree strongly that building these technologies will result in considerably more material-intensive demand than would traditional fossil fuel mechanisms. Simply put, a green technology future is materially intensive and, if not properly managed, could bely the efforts and policies of supplying countries to meet their objectives of meeting climate and related Sustainable Development Goals. It also carries potentially significant impacts for local ecosystems, water systems, and communities.

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

US should –

- Increase its diplomatic and investment focus on Western Hemisphere and Africa
- Protect supply chains for minerals/metal needed for wind, solar and batteries
- Support new domestic environmentally-responsible mining activities for key minerals/metal
- 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