

Renewable Energy Systems in the Transition of North America to Net Zero Emissions

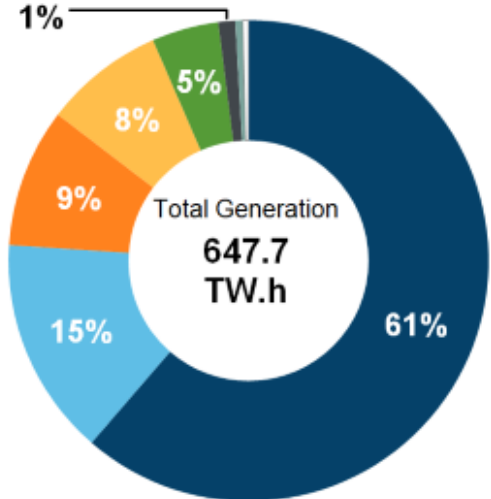
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U.S. National Renewable Energy Laboratory (NREL)



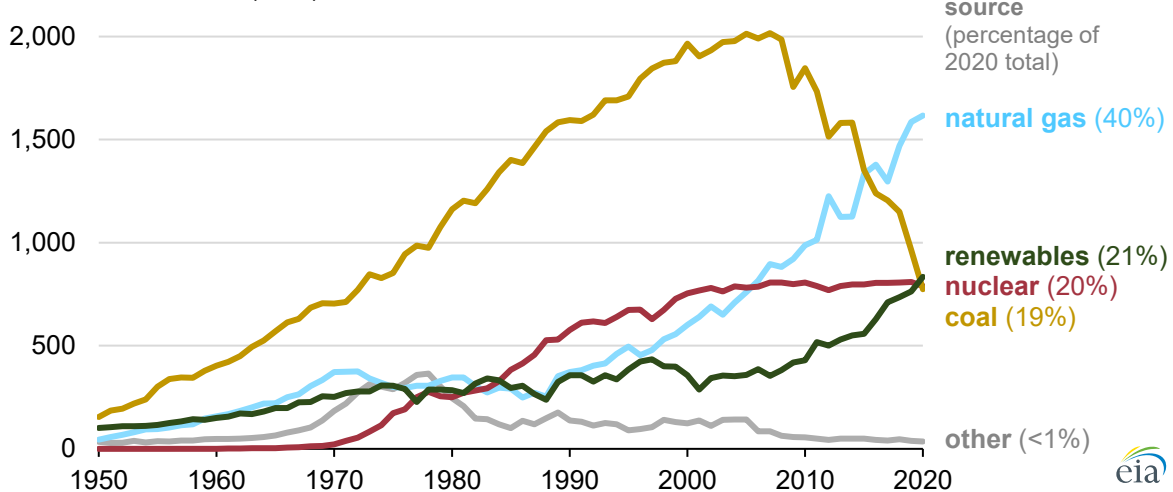
North American power system → renewables & gas

Canada electricity generation by fuel type (2018)



- Hydro / Tidal
- Uranium
- Natural Gas
- Coal & Coke
- Wind
- Biomass / Geothermal
- Solar (<1%)
- Petroleum (<1%)

Annual U.S. electricity generation from all sectors (1950–2020)
billion kilowatthours (kWh)

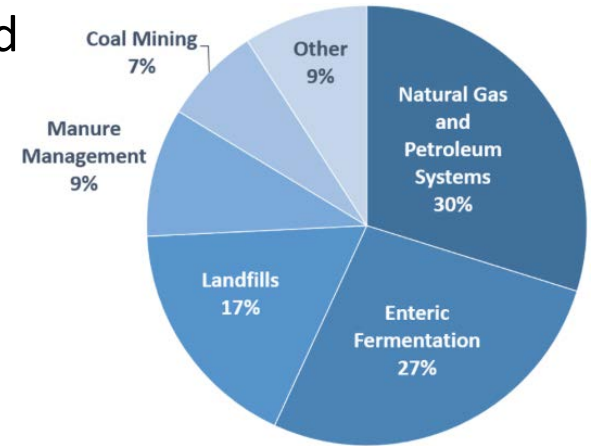


Current U.S. targets:
Decarbonized electricity by 2035
Decarbonized economy by 2050

Sources: <https://www.cer-rec.gc.ca/en/data-analysis/energy-markets/provincial-territorial-energy-profiles/provincial-territorial-energy-profiles-canada.html>;
<https://www.eia.gov/todayinenergy/detail.php?id=48896> ;
<https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/>

New U.S. national methane regulations coming

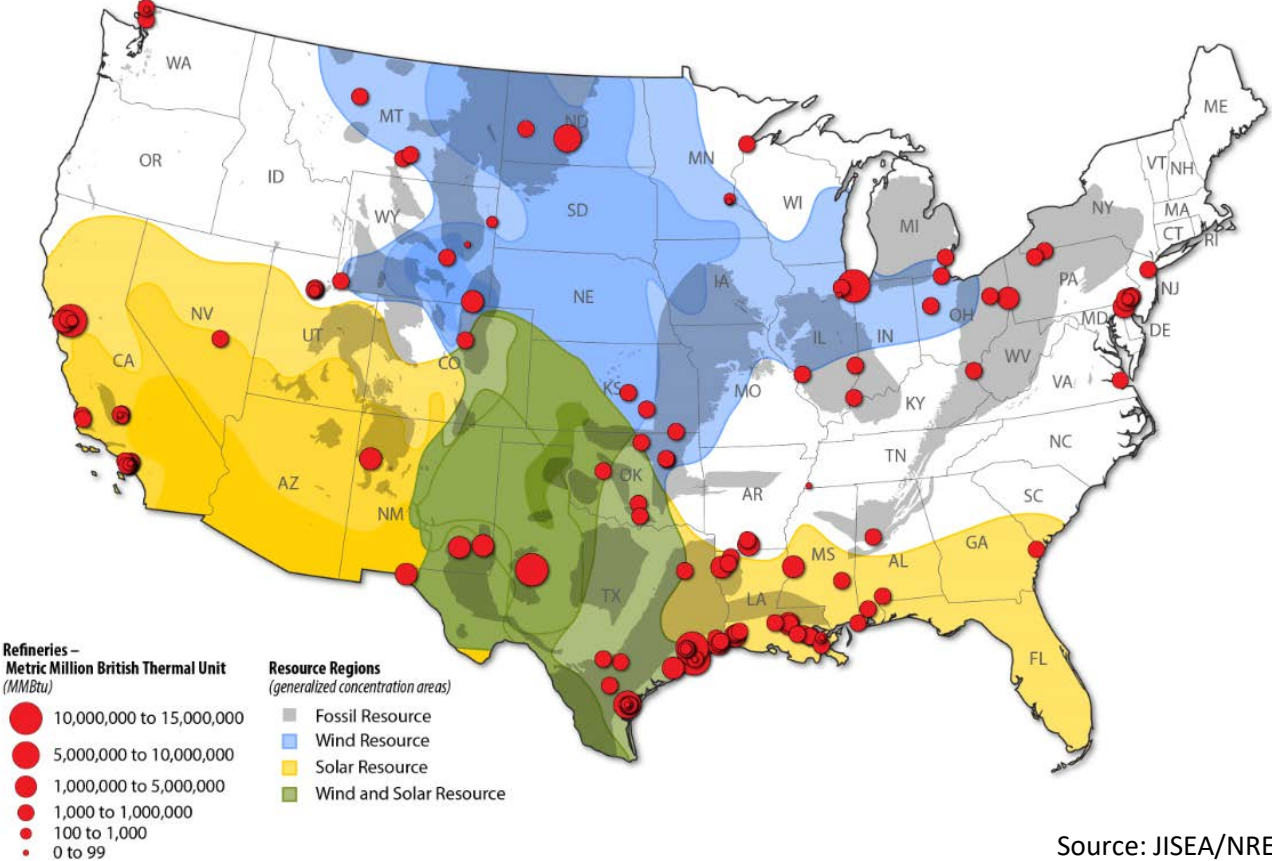
- U.S. Environmental Protection Agency (EPA) is finalizing new rules to govern new *and existing* sources of oil and gas methane leaks
- 2015 rules for new methane emissions challenged by previous Administration, but reinstated in 2021
- Clean Air Task Force estimates new rules could reduce methane emissions by 22-65% depending on details
- Controversy over stripper well regulation and small producers
- Most oil & gas companies recognize methane regulations are important for “social license to operate”



U.S. Methane Emissions by Source

Source: U.S. EPA, “Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019”

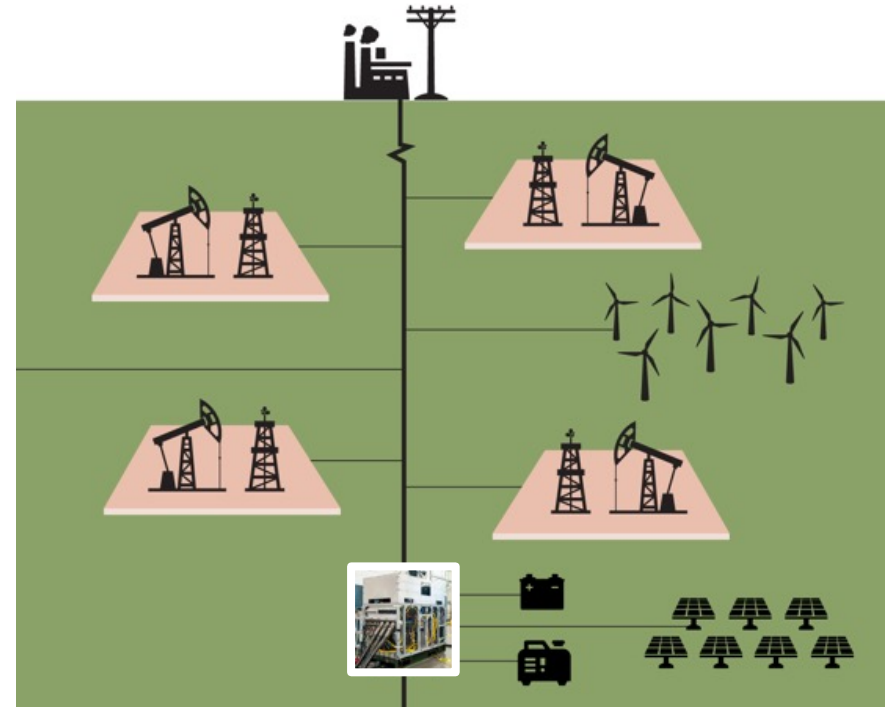
Oil & gas resources/infrastructure align with solar & wind



Source: JISEA/NREL

Example: Electrification of the wellpad via microgrids

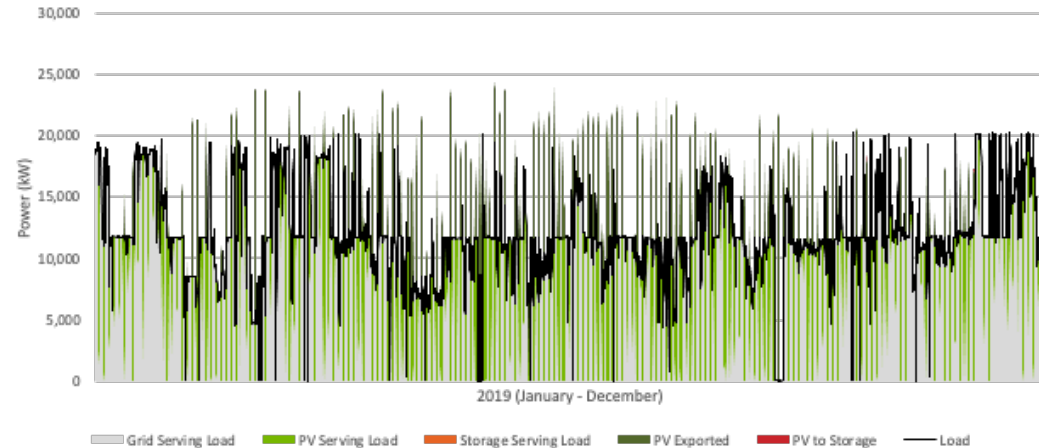
- Electrification of all equipment at wellpad connected via microgrid
- Power could consist of:
 - Field/Flare Gas fired generator
 - Solar PV/wind systems
 - Fuel cells
 - Energy Storage
 - Hydrogen
 - Batteries
 - Grid power (or offgrid)
- Benefits:
 - Resiliency during outages
 - Optimize for least cost
 - Reduce emissions
- Leverage work on remote communities and islands



Source: <https://www.nrel.gov/docs/fy19osti/72842.pdf>

Example: Clean power for gas pipeline compressor stations

- Smaller size renewable energy technologies are cost-effective; larger systems (generating 50% of the site's load) offset significant amounts of CO₂, but at an added cost
- Cost of emissions reduction (\$/tCO₂e) could improve the economics of onsite renewable energy
- Challenges from low industrial costs of grid electricity purchases
- Pipelines will still be needed for renewable natural gas, synthetic fuels, captured CO₂, hydrogen blends



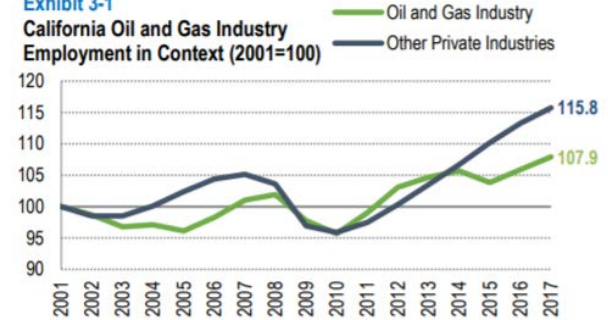
Source: <https://www.nrel.gov/docs/fy21osti/80540.pdf>

Regional Context: California oil and gas operations

- AB 32 (2006) – Carbon cap and trade
- SB 1281 (2014) – O&G water reporting to mitigate drought
- SB 100 (2018) – 60% RE by 2035
- Stringent air quality regulations
- Job growth and tax income
- Innovative solutions
 - Carbon capture and storage
 - Solar powered steam generation
 - Water treatment for agriculture

Exhibit 3-1

California Oil and Gas Industry
Employment in Context (2001=100)

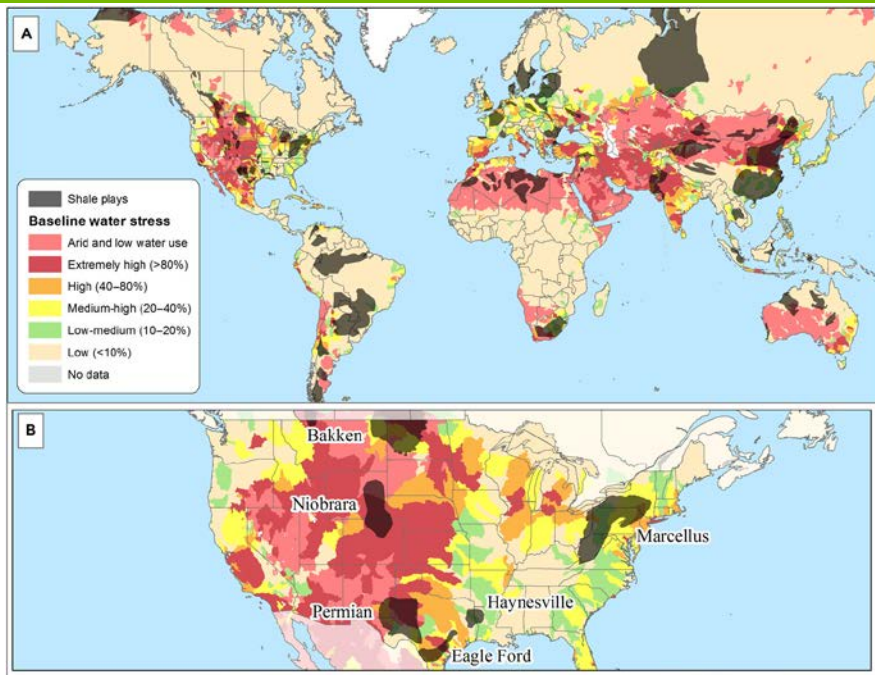


Source: CA EDD; Estimates by LAEDC



Source: (top) <https://laedc.org/2019/08/27/oil-and-gas-industry-in-california-2019-report/>, (bottom) https://www.bakersfield.com/financial-trouble-design-changes-delay-major-solar-project-in-west-kern-oilfield/article_6f692be4-e3bb-11e9-92a5-771e6c569123.html

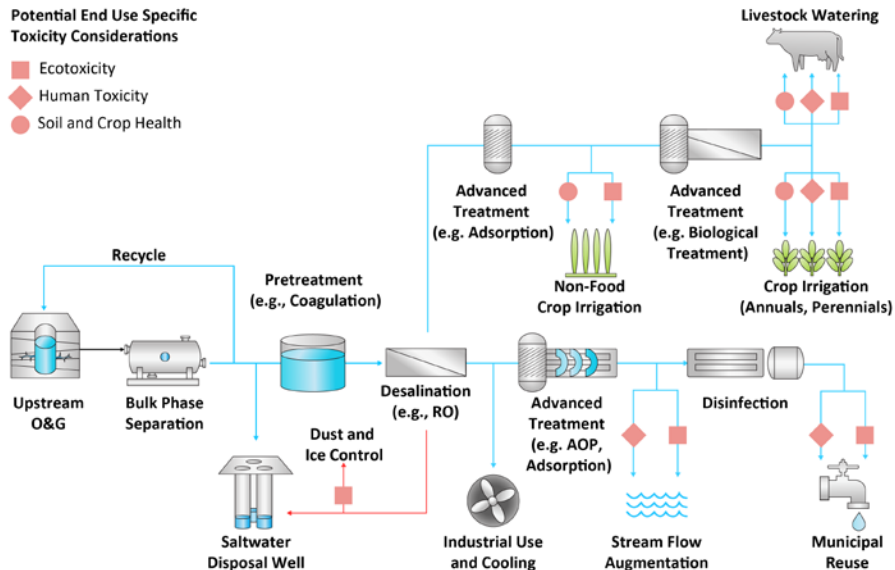
Energy water nexus and oil & gas



National Alliance for Water Innovation Priorities

Potential End Use Specific Toxicity Considerations

- Ecotoxicity
- Human Toxicity
- Soil and Crop Health



- Regional concerns for increased water use – hydraulic fracturing
- Potential for produced water treatment for beneficial reuse

Source: (left) <https://pubs.usgs.gov/circ/1441/circ1441.pdf?dLdf=false>, (right) Cooper et al. Forthcoming - *Oil and Gas Produced Water Reuse: Opportunities, Treatment Needs, and Challenges*



Thank you!

NREL/PR-6A50-81181

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This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by the Joint Institute for Strategic Energy Analysis and its sponsors. The views expressed herein do not necessarily represent the views of the DOE, the U.S. Government, or sponsors.

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