

Affordable Deep Decarbonization in California

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An affordable zero-carbon electricity system is critical to overall deep decarbonization success.

Electricity is expected to have an outsized role in deep decarbonization.

Because electricity is technically easier and relatively less costly to decarbonize, economy-wide studies rely upon expanded generation of carbon-free electricity to meet greater shares of energy demand for heating, industry, and transportation.

In several scenarios, modelers see an average of 50% of total energy demand in the U.S. being satisfied by electricity by 2050. In 2017 in California, ~23% of energy was consumed in the form of electricity.

If we fail to decarbonize this sector in an affordable way then it is a risk to the entire deep decarbonization efforts.



Relying largely on variable renewables + batteries has challenges: <u>seasonal variability</u>

Smoothed Daily Load & Renewable Energy Generation, Mixed Renewable Scenario (MW)



Scenario definition: 2018 wind and solar generation scale to each meet 50% of total 2018 CAISO load



It could cost \$3 Trillion (= CA GDP) to use batteries to store & use all the surplus.

Daily Renewable Energy Generation Surpluses and Deficits, Mixed Renewable Scenario





Zero-carbon <u>firm energy</u> lowers system costs of zero-carbon electricity system.



Zero-carbon firm energy also reduces the system's physical footprint.









We need a zero-carbon energy system, not just zero-carbon electricity.

Electricity sector has reduced emissions, but other sectors are harder.



Figure 20a. 2017 GHG Emissions by Economic Sector. This figure shows the relative size of 2017 emissions by economic sector.



Figure 3. Trends in California GHG Emissions. This figure shows changes in emissions by Scoping Plan sector between 2000 and 2017. Emissions are organized by the categories in the AB 32 Scoping Plan.



To mitigate industrial emissions (24%) we need more than electrification.

For some industries such as cement and steel, a large part of Co2 emissions come from process emissions, not energy use.

Almost half of the energy needed by industry is high temperature heat (>400C) which is not readily economically supplied by electricity.



To mitigate transportation emissions (41%) we need more than electrification.

A third of transportation emissions from from heavy duty vehicles, shipping, aviation and rail. Electrifying these sectors will be extremely challenging (battery technology)





We need to embrace multiple options & pathways to reduce risk of missing climate goals.

We need other solutions and approaches.

- Zero-carbon liquid or gaseous fuels that can be used for transport, high temperature industrial heat, and building heat and to generate firm, non-weather-dependent electricity.
- Direct sources of zero-carbon high temperature heat such as supercritical geothermal energy and high temperature nuclear energy
- Industrial processes that do not inherently produce carbon emissions
- Carbon capture and storage for otherwise unavoidable industrial carbon emissions

A Zero Carbon Energy System



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In conclusion...

- We need to develop all options: cheap seasonal storage options, grid expansion, lower cost wind solar and demand side flexibility and other low and zero carbon options
- It is possible to see technological breakthroughs that will make relying more on one family of technologies cheaper, but the risk is vastly reduced if there are policies supporting multiple zero-carbon technologies.



Things I haven't addressed but are important...

- 1. Reducing super pollutants such as methane emissions from oil & gas sectors
- 2. Emissions from land use sector
- 3. Carbon removal strategies including direct air capture





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