Caltrans Division of Research, Innovation and System Information



PI-0372: Pathways to Powering Caltrans with Zero-Carbon Renewable Energy By: Connor P. Campbell

Requested by Sue Lee, Division of Sustainability

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Executive Summary

Background

The Preliminary investigation seeks to evaluate the different types of powered infrastructure in Caltrans' portfolio and develop guidance that will aid Caltrans in determining the best approach to procuring renewable energy for various assets. As such, this PI will focus on existing Caltrans guidance and resources in conjunction with current research on outstanding best practices and approaches that other organizations have taken in pursuit of a greener and more sustainable future. This document will consider the following elements:

- Prioritized list of joint state and utility actions for establishment of fully carbon free and renewable electricity sources
- Available real estate for self-generation and storage
- Return on investment of self-generation vs. cost of grid-based procurement.
- Front-of-meter aggregation capabilities.
- Ensuring the zero-carbon and eligible renewable resources meet the requirements of Public Utilities Code section 454.59.

• The methodology for each approach that Caltrans can utilize to procure or generate carbon free, renewable electricity.

• Financial viability of different approaches

Summary of Findings

Related Research and Resources

There are a number of existing sources that could inform a comprehensive, data-driven guide for the implementation of renewable energy programs at Caltrans. Chief among them is the Caltrans Sustainability Road Map published in 2022, mainly chapters 3 and 5 that focus on Caltrans energy resources and existing green operations of the organization. Another public agency resource that could inform future research include the "California Energy Commission 2020 Total System Electric Generation" website that outlines the breakdown of total energy generation for the entire state, though this is not Caltrans specific.

Several previous studies looked at Caltrans' impact on the climate in terms of GHG and carbon emissions such as the study "Life Cycle Assessment and Life Cycle Cost Analysis for Six Strategies for GHG Reduction in Caltrans Operations." This 2020 report thoroughly examines a selection of potential approaches and programs that could reduce the environmental impacts of Caltrans' operational functions. Additionally, the document discusses the pros and cons of each suggestion to provide a more balanced and realistic view of what could be done in this regard. Another study, performed by Caltrans and presented in a report to the California Legislature titled "Clean Renewable Energy Bonds Program 2020 Annual Report," presents an analysis and update on the Clean Renewable Energy Bonds program of 1995 which provides insights into public funding mechanisms for "financing the acquisition and installation of photovoltaic (solar) energy systems." The report presents the renewable investments made with bond funding and a cost benefit analysis of the program as a whole from its inception. This includes new analysis based on current conditions that discusses projected and actual savings from the transition to solar.

Other states in the US are also moving toward 100% renewable energy, though at different rates. For example both Oregon and Washington are already heavily reliant on hydroelectric generation for their power grid, with other renewables making up a substantial amount of remaining power demand and find themselves in line with California. In order for these states to free themselves for the constraints of fossil fuels, Washington is seeking to match the 100% renewable energy goal set by California and Oregon is aiming for 50% renewable energy over a similar timeframe. However other states, such as Texas, are still leaning heavily on carbon and GHG intensive production methods for the majority of their electricity generation such as coal, oil and natural gas plants.

Looking outside the United States, the report "Achieving a 100% Renewable Grid: Operating Electric Power Systems with Extremely High Levels of Variable Renewable Energy," published by the Institute for Electrical and Electronics Engineers, evaluates approaches taken in other countries that have claimed to achieve 100% renewable energy-based power grids. Many of the countries examined rely on hydroelectric dams to for the majority of their consistent power. Per the study, if most sites that can be used to generate hydroelectric power are already utilized then jurisdictions will need to turn to other, more variable sources of power such as solar and wind. Given that California is one of the largest states in the US and one of the largest economies in the world, analyzing how other countries of similar size have transitioned their energy systems might provide some insights on how we could more effectively move toward 100% renewable grid energy.

Finally, the research proposal states that the study will also perform a review of ways that Caltrans could consider obtaining renewable and carbon free energy. A preexisting project titled "Solar in the Right of Way" was produced by DRISI in 2020, which per the website is currently stalled after its highly promising phase 1 study. Revisiting the project could allow for substantial solar energy generation utilizing resources that Caltrans already owns (namely the right of way on state highways). Part of the project includes a request for "Available real estate for self-generation and storage," which would be a good place for future research to start evaluation on this matter as Caltrans already has a readily available source for land. Other states, such as Oregon, have already implemented similar solar programs and have seen success in these efforts so there is already precedent for a similar project in California to be successful.

Gaps in Findings

While there are various sources available that detail California's renewable-to-nonrenewable energy use, research in this area that specifically and directly targets Caltrans in the manner specified above does not seem to exist at the time of this literature review. Thus, this PI was unable to successfully find an answer to the question being posed.

Next Steps

Interested parties can look into the Solar in the Right of Way" project for an example of how Caltrans can better prepare its systems and power utilization to operate more sustainably. Additionally, reviewing the below sources could help the reader expand their knowledge base on this topic.

More information:

For more information, please consult the below sources, which have been organized into three categories. The first focuses on published documentation on what Caltrans has done and could possibly do in the future and includes examples of proposed projects that might merit further review. The

second and third sections covers how other organizations, both in California and the broader US and Global contexts, have tackled the issue of 100% renewable energy for their infrastructure.

Related Research and Resources

Existing Caltrans/California Renewable Resource Utilization and Plans

Caltrans Sustainability Road Map

URL: https://dot.ca.gov/-/media/dot-media/programs/esta/documents/sustainable-ops/dot-2022-2023sustainability-road-map-final-signed-a11y.pdf

The Caltrans sustainability roadmap is a cornerstone of the department's guidance for transitioning from a more traditionally minded organization to one that is on the cutting edge of responsible environmental sustainability. The document is broken down into the following five chapters, each with numerous subsections covering the respective topic in more depth:

Chapter 1: Climate Change Approach

• This chapter focuses on three topics: Infrastructure and Capital Outlay projects, Grants and Development of strategic and functional plans. This includes information on climate change risks to facilities as well as possible mitigating measures that have been and could be taken.

Chapter 2: Zero Emission Vehicles

- This Zero- Emission Vehicles (ZEV) Chapter discusses the progress Caltrans has made toward meeting the Governor's sustainability goals related to ZEVs. This chapter identifies successful accomplishments, ongoing efforts, outstanding challenges, and future efforts.
- Chapter 3: Energy
 - This chapter discusses the progress Caltrans has made toward meeting the state's sustainability goals related to energy. This report identifies successful accomplishments, ongoing efforts, and outstanding challenges. Chapter 4: Water Efficiency and Conservation
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 - This section outlines the existing water resources available to Caltrans and the infrastructure that utilizes these sources. Covered in detail are the plans for ensuring responsible water use and conservation of water in Caltrans facilities.
- Chapter 5: Green Operations
 - This chapter covers the various methods that Caltrans has pursued in order to develop more sustainable operations for infrastructure under their purview and provides statistics and metrics to outline the performance of these measures. The section covers numerous topics from building design to cleaning procedures.

These chapters are followed by several appendences that provide ancillary detail that provide additional context and resources for the reader. Of these items, chapters 3 and 5 should be of most interest to the panel.

California Energy Commission 2020 Total System Electric Generation:

URL: <u>https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/2021-total-system-electric-generation/2020</u>

This source from the California Energy Commission provides an overview of the sources of power for California as a whole. While not Caltrans specific, the source does provide insights into the breakdown

of grid power generation from the various sources in the state. The report also provides a written explanation in order to provide more context to what is being presented here.

Solar in the Right of Way

URL: <u>https://dot.ca.gov/-/media/dot-media/programs/research-innovation-system-information/documents/final-reports/ca20-3177-finalreport-a11y.pdf</u>

Solar in the Right of Way is a proposed project by Caltrans that would seek to utilize the existing space on the side of state owned freeway, the "right of way", in order to build utility-scale solar power generation facilities on the land that would allow Caltrans to generate substantial amounts of renewable energy in order to help the organization meet the goals set forth in S.B. 1020 by December 31, 2035. This is an excellent example of a meaningful and tangible project that the department could pursue that would aid in meeting the goals set forth by the executive and legislative branches. According to the website, the stage one feasibility research has been done and provided highly favorable results and the research team and customer might want to look further into this as a realistic viable option for future development.

Life Cycle Assessment and Life Cycle Cost Analysis for Six Strategies for GHG Reduction in Caltrans Operations

URL: https://escholarship.org/uc/item/0mx245rd

From the abstract: "The focus of this study and technical memorandum is to examine several strategic options that Caltrans could adopt to lower its GHG emissions in operating the California (CA) state highway network and other transportation assets so it can help meet the state's GHG reduction goals. Although many GHG reduction strategies appear to be attractive, simple, and effective, most also have limitations, trade-offs, and unintended consequences that cannot be identified without a preliminary identification and examination of the full system they operate in and their full life cycle. To achieve the most rapid and cost-effective changes possible, the costs, times to implement, and difficulty of implementation should also be considered when the alternative strategies are being prioritized."

Quantitative Performance Measures for the Caltrans System Investment Strategy

URL: https://rosap.ntl.bts.gov/view/dot/79205

From the article: "This research aims to develop a robust set of quantitative performance metrics, measures, and methodologies to assess project alignment with the Climate Action Plan for Transportation Infrastructure (CAPTI). The outcome of this research will allow for a data- and performance- driven approach to project nomination and evaluation"

Clean Renewable Energy Bonds Program 2020 Annual Report

URL: <u>https://dot.ca.gov/-/media/dot-media/programs/legislative-affairs/documents/clean-renewable-energy-bonds-program-2020-annual-reportfinal-remediated.pdf</u>

This document provides both houses of the legislature an update on the Clean Renewable Energy Bonds Program of 1995 that is still in operation today.

From the document:

"The Clean Renewable Energy Bonds 2020 Annual Report includes the following information:

• The status of each facility on which Caltrans has installed photovoltaic energy systems as part of the Clean Renewable Energy Bonds Program (Exhibit 1).

• An accounting of the costs for each photovoltaic energy system installed or acquired by Caltrans (Exhibit 1).

• A description of the energy savings Caltrans has achieved by acquiring or installing photovoltaic energy systems (Exhibit 3).

• A review and analysis of the expected cost savings at the time of issuance of the bonds (Exhibit 2) versus actual to-date annual savings (Exhibit 3)."

This source might be useful when evaluating the funding opportunities and options for installing and mainlining the renewable power infrastructure.

California Grid Readiness: Stakeholder and Public Awareness

URL: https://intra.ece.ucr.edu/~hamed/CGR2024.pdf

From the abstract: "Electrification is rapidly growing in California in many sectors, particularly transportation and buildings. This shift is fundamentally changing both the amount and patterns of electricity consumption on California's power transmission and distribution networks. Due to the impacts of climate change, California is also facing more frequent extreme events, such as wildfires and heat waves. They, too, are creating more stress on the grid, affecting its resilience and reliability. Therefore, it is crucial to ensure that California's electric grid is prepared to face this new reality. Several reports on this subject already exist from utilities, government, and academia, each typically focusing only on specific aspects or specific stakeholder viewpoints. This white paper, however, aims to bridge these various studies, providing a high-level but broad view of the diverse issues, concerns, projections, suggestions, and solutions that have been raised so far.

This white paper focuses on key concepts and broad subjects in this domain. To prepare this white paper, a wide range of studies were reviewed to address both short-term and long-term challenges, the latter of which is often discussed in academic literature."

Other States in the US

Oregon Power Profile

URL: https://www.eia.gov/state/analysis.php?sid=OR

From the article: "Energy use per capita in Oregon is less than in more than two-thirds of the states. In 2021, the transportation sector accounted for about three-tenths of the state's total energy consumption. The industrial sector, Oregon's second-largest energy consumer, used about one-fourth. Although Oregon's agriculture, food processing, and forestry activities, including the manufacture of forest products, are energy-intensive, most of the state's gross domestic product (GDP) comes from non-energy-intensive service-providing businesses. The residential sector accounted for one-fourth of the state's total energy consumption, and the commercial sector used nearly one-fifth. In part because most of Oregon's population centers are in mild climate zones in the Willamette Valley and along the Pacific Coast west of the Cascades, the state's residential sector energy use per capita ranked 39th in the nation in 2021."

Oregon Solar Highway Program

URL: https://www.oregon.gov/odot/programs/pages/solar-highway.aspx

From the abstract: "On December 19, 2008, the nation's first solar highway project started feeding clean, renewable energy into the electricity grid, and the first Oregon Solar Highway project has been operating seamlessly ever since. The 104 kilowatt (dc) ground-mounted solar array, made up of 594 solar panels, is situated at the interchange of Interstate 5 and Interstate 205 south of Portland, Oregon, and offsets over one-third of the energy needed for freeway illumination at the site."

Oregon Renewable Portfolio Standard

URL: <u>https://www.oregon.gov/energy/energy-oregon/pages/renewable-portfolio-</u> <u>standard.aspx</u>

From the article: "Starting in 2011, SB 838 required "large" utilities like PacifiCorp and Portland General Electric Company to obtain at least 5 percent of their electricity from qualifying renewable resources. The percentage obligation increases over time and was initially set to reach 25 percent by 2025. In March 2016, the passage of Oregon Senate Bill 1547 increased the RPS requirement for "large" investor-owned utilities to at least 27 percent in 2025 and ultimately at least 50 percent by 2040. SB 1547 did not change the requirement for "large" consumer-owned utilities like the Eugene Water & Electric Board to obtain at least 25 percent of their electricity from qualifying renewable resources by 2025. "Small" utilities must obtain at least 5 percent of their electricity from qualifying renewable resources starting in 2025."

The website also provides sources that can be used to track the progress the state of Oregon is making toward its renewable goals.

Washington Power Profile

URL: https://www.eia.gov/state/analysis.php?sid=WA

From the article : "In 2023, hydroelectric power accounted for 60% of Washington's total electricity net generation from both utility-scale (1 megawatt or larger) and small-scale (less than 1 megawatt) facilities.23 Washington typically contributes between one-fourth and one-third of all conventional hydroelectric generation in the nation annually. Nine of the state's 10 largest power plants by capacity and 7 of the 10 by actual generation are hydroelectric facilities.

Natural gas, nonhydroelectric renewable resources (mostly wind), nuclear energy, and coal provide almost all the rest of Washington's in-state electricity generation. Natural gas is the second-largest instate source of net generation, and it fueled about 18% of the state's total electricity generation in 2023. Renewable resources other than hydroelectric power accounted for about 10% of state generation. Wind represented almost four-fifths of that share. Biomass and solar energy supplied the rest of the renewable generation. Nuclear energy provided about 8% of Washington's total in-state generation, all of it from the Columbia Generating Station, which is the state's only operating nuclear power plant."

Washington State Clean Energy Transformation Act (CETA)

From the article: "On May 7, 2019, Governor Jay Inslee signed the Clean Energy Transformation Act (CETA) (SB 5116, 2019) into law, which commits Washington to an electricity supply free of greenhouse gas emissions by 2045. Clean electricity will allow Washington residents and businesses to power their

buildings and homes, vehicles and appliances with carbon-free resources, such as wind and solar. Reducing fossil-fuel use will improve the health of communities, grow the economy, create familysustaining jobs, and enable the state to achieve its long-term climate goals."

Iowa Power Profile

URL: https://www.eia.gov/state/analysis.php?sid=IA

From the article: "Iowa ranks among the top 10 states in total energy consumption per capita, mainly because of its small population and large industrial sector, which includes agriculture. The industrial sector leads Iowa's end-use energy consumption, accounting for slightly more than half of the state total. Iowa is among the 10 states with the most total industrial sector energy use.

Renewables also provide much of Iowa's electricity. In 2023, about three-fifths of the state's total electricity net generation came from renewable resources, almost all of it from wind.25 The state was the second-largest wind power producer, after Texas. Wind energy powered 59% of Iowa's net generation in 2023. [However] [n]atural gas-fired power plants contributed 15% of Iowa's in-state generation in 2023, with total generation from natural gas at a record high."

Arkansas Power Profile

URL: https://www.eia.gov/state/analysis.php?sid=AR

From the article: "In 2023, natural gas remained the leading fuel used to generate electricity in Arkansas and accounted for 39% of the state's total electricity net generation. Natural gas-fired generation exceeded the state's coal-fired generation in 2020 for the first time. Coal accounted for 27% of the state's generation in 2023.

Natural gas fuels 5 of the 10 largest power plants by capacity in Arkansas, including the 2,000-megawatt Union Power Station, which is the largest power plant in the state. Coal fuels 4 of Arkansas's 10 largest power plants by capacity. The second-largest power plant is the state's one nuclear power plant—with two reactors—that provided about 24% of in-state net generation in 2023. The 1,822-megawatt nuclear power plant is located on Lake Dardanelle about 60 miles northwest of Little Rock. Almost all the rest of the state's electricity net generation came from renewables, mainly hydroelectric power, solar power, and biomass-fueled generating facilities."

Texas Power Profile

URL: https://www.eia.gov/state/analysis.php?sid=TX

From the article: "Texas leads the nation in energy production, providing about one-fourth of the country's domestically produced primary energy. Texas is the largest energy-consuming state, accounting for about one-seventh of the nation's total energy use, and it is sixth among the states in per capita energy consumption.

Texas produces more electricity than any other state, generating more than twice as much power as second-place Florida. In 2023, Texas accounted for 13% of the nation's total electricity net generation. Natural gas-fired power plants supplied more than half of the electricity generated in Texas. Natural gas fuels more electricity generation in Texas than in any other state and accounts for 15% of all U.S. natural gas-fired generation. Wind is the second-largest source of in-state generation in Texas."

Global Efforts

US Energy Information Administration Profile Analysis (California)

URL: https://www.eia.gov/state/analysis.php?sid=CA

The document provides a good overview of the energy sources used by Californians across the state. The document breaks down these sources into an overall energy profile as well as sections for renewable energy, petroleum, natural gas as well as an evaluation of energy sources located on tribal lands. While not Caltrans specific it could prove informative due to the large amount of sources listed in its bibliography.

Achieving a 100% Renewable Grid: Operating Electric Power Systems with Extremely High Levels of Variable Renewable Energy

https://ieeexplore.ieee.org/abstract/document/7866938

From the abstract: "What does it mean to achieve a 100% renewable grid? Several countries already meet or come close to achieving this goal. Iceland, for example, supplies 100% of its electricity needs with either geothermal or hydropower. Other countries that have electric grids with high fractions of renewables based on hydropower include Norway (97%), Costa Rica (93%), Brazil (76%), and Canada (62%). Hydropower plants have been used for decades to create a relatively inexpensive, renewable form of energy, but these systems are limited by natural rainfall and geographic topology. Around the world, most good sites for large hydropower resources have already been developed. So how do other areas achieve 100% renewable grids? Variable renewable energy (VRE), such as wind and solar photovoltaic (PV) systems, will be a major contributor, and with the reduction in costs for these technologies during the last five years, large-scale deployments are happening around the world."

While it is not US or California specific, this could provide the research team with some insights on how other places have handled the transition that could prove insightful for Caltrans' purpose.

Best Practice in Government Use and Development of Long-Term Energy Transition Scenarios https://www.mdpi.com/1996-1073/15/6/2180

From the Abstract: "Long-term energy scenarios (LTES) have been serving as an important planning tool by a wide range of institutions. This article focuses on how LTES have been used (and also devised in some cases) in the government sector, and specifically how the new challenges and opportunities brought by the aspiration for the clean energy transition change the way that governments use LTES. The information tends to remain tacit, and a gap exists in understanding the way to enhance LTES use and development at the government level. To address this gap, we draw on the experience from national institutions that are leading the improvement in official energy scenario planning to articulate a set of overarching best practices to (i) strengthen LTES development, (ii) effectively use LTES for strategic energy planning and (iii) enhance institutional capacity for LTES-based energy planning, all in the context of new challenges associated with the clean energy transition. We present implementation experience collected through the International Renewable Agency's LTES Network activities to exemplify these best practices. We highlight that in the context of the broad and complex challenges of a clean energy transition driven by ambitious climate targets, the LTES-based energy planning methodologies

need to evolve, reflecting the changing landscapes, and that more effective and extensive use of LTES in government needs to be further encouraged."