DOCKETED	
Docket Number:	24-OIIP-03
Project Title:	Informational Proceeding on Non-Energy Benefits and Social Costs
TN #:	271110
Document Title:	Approaches to Integrate Non-energy Impacts in Supply Modeling - May 18, 2026 Workshop Details
Description:	N/A
Filer:	Blanca Munoz
Organization:	California Energy Commission
Submitter Role:	Commission Staff
Submission Date:	6/30/2026 1:52:09 PM
Docketed Date:	6/30/2026

California Energy Commission

STAFF REPORT

Approaches to Integrate Non-energy Impacts in Supply Modeling

May 18, 2026 Workshop Details

Month Year | CEC-200-2026-012

California Energy Commission

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ACKNOWLEDGEMENTS

The California Energy Commission (CEC) would like to acknowledge the original coalition of petitioners whose efforts and insights led to the decision to initiate the NEI informational proceeding and bring attention to this important issue. Additionally, the CEC would like to acknowledge the contributions of Physicians, Scientists, and Engineers for Healthy Energy Inc. (PSE) and HR&A Advisors (HR&A). Their contributions were instrumental to the development of this report.

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The report authors and their management extend their appreciation to the following commissioners for their leadership and support:

Vice Chair Siva Gunda

Commissioner Noemi Gallardo

The CEC appreciates the contributions from the following staff:

Hannah Craig
Anne Fisher
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PREFACE

This staff report was prepared by the California Energy Commission’s Energy Assessments Division as part of the Non-Energy Impacts Order Instituting an Informational Proceeding. The purpose of the proceeding is to explore how non-energy impacts can be more systematically considered and implemented into electricity resource planning and related analytical processes.

Electricity planning models play a central role in informing policy, investments, and regulatory decisions in the electricity sector, including in California. These models should be more comprehensive, adapting to incorporate broader societal and environmental effects that influence the electricity sector and beyond, not solely changes in technology and system operations. Non-energy impacts – such as public health, household energy costs, and workforce effects – concern all Californians and therefore are of upmost interest to policymakers, yet they remain difficult to incorporate within traditional modeling frameworks.

This report represents an initial step toward addressing that challenge. It documents staff’s assessment of potential approaches for integrating selected non-energy impacts into electricity supply modeling and related analyses. The methods described herein are exploratory and are intended to support learning, transparency, and iterative improvement rather than immediate implementation in formal planning or procurement decisions.

Public engagement is a central element of this effort given the broader impacts of energy resource policy and planning on Californians and the environment.

ABSTRACT

Traditional electricity supply modeling optimizes resource portfolios based on least cost. Non-energy impacts (e.g., public health effects, household energy costs, workforce outcomes) represent significant societal impacts associated with electricity generation and consumption, and are not reflected in traditional electricity supply modeling. The omission of these impacts can limit the ability of planning analyses to fully inform policy and investment decisions. This staff report presents a preliminary exploration of potential approaches to integrate non-energy impacts into electricity supply modeling frameworks.

Keywords: non-energy impacts, electricity supply modeling, externalities, resource planning, equity, public health, resilience, household energy costs, affordability, air quality, workforce

Jones, Jacqueline, Dhruv Bhatnagar. 2026. *Approaches to Integrate Non-energy Impacts in Supply Modeling – May 18, 2026 Workshop Details*. California Energy Commission. Publication Number: CEC-XXX-201X-XXX.

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EXECUTIVE SUMMARY

Electric system supply modeling is used to understand how an electricity system could evolve over time and to support planning to reliably and cost-effectively meet future electricity demand. Ensuring that California's electricity system provides safe, clean, equitable, and reliable energy requires planning tools that reflect the full range of impacts associated with electricity generation and consumption. While traditional electricity supply models are designed to minimize system costs and meet reliability requirements, they do not account for many non-energy impacts such as air quality and public health, household energy costs, water use, workforce needs, and energy resilience. Non-energy impacts represent societal impacts that influence communities' well-being and stability, opportunities for prosperity, and long-term system sustainability. Typically, they are evaluated outside of core planning models, considered only qualitatively, or not considered at all, even though they represent actual costs and benefits of producing and distribution electricity.

This staff report is a foundational part of the CEC Informational Proceeding on non-energy impacts. The report presents a suite of proposed non-energy impacts for assessment in resource planning and an initial framework for integrating selected non-energy impacts into electricity supply modeling in a transparent, methodologically rigorous, and policy-relevant manner. It describes the motivation for this effort, reviews existing planning practices and their limitations, and proposes multiple approaches for incorporating non-energy impacts into modeling workflows.

The report identifies five non-energy impacts categories for focused investigation:

- Ambient air quality and public health (emissions that cause localized impacts, separate from greenhouse gas emissions that contribute to broader climate impacts)
- Household energy costs
- Energy resilience
- Water use
- Economic and workforce impacts

These categories were selected based on their relevance to electricity generation and consumption, and their exclusion from traditional planning metrics. Land use is reserved for further study in a separate docket because CEC has ongoing work in this area.

For each category, staff outline candidate metrics, data requirements, geographic scales, and potential integration pathways.

Three primary approaches to integration are examined:

1) Post-hoc analysis of modeled resource portfolios.
2) Modification of supply-side costs using non-energy impact-based adders if monetization is feasible.
3) Application of constraints or targets that reflect policy or equity objectives without requiring monetization.

The report also brings forward:

4) The importance of distributional analysis, which recognizes that many non-energy impacts vary significantly by location, technology type, and population characteristics.
5) The potential for non-energy impacts to change as demand-side technology assumptions evolve or are adjusted.

This report is an interim technical document and does not prescribe specific policy outcomes or modeling decisions. Instead, it seeks public input on the proposed methods, assumptions, and priorities. Feedback received through the Non-energy Impacts Informational Proceeding will inform refinement of the analytical framework and may guide subsequent modeling efforts. Future phases of this work may apply selected non-energy impacts integration methods to illustrate resource scenarios and report comparative results to support more holistic electricity system planning in California.

CHAPTER 1: Background

Electricity resource planning is the process utilities, grid operators, and energy agencies use to ensure there will be reliable, affordable and safe electricity available in the future, while also supporting progress toward greenhouse gas reduction targets. It informs which power plants, storage systems, demand-side programs, and transmission investments should be made over time. It involves forecasting electricity demand and assessing available (existing and new) resource options. Electric system supply modeling is a critical input within the overall resource planning process. It typically uses two types of models, capacity expansion models to develop resource portfolios to meet future demand and production cost models to simulate the performance of these portfolios, hour by hour, under various scenarios.

The analytical frameworks used to guide statewide investment decisions were developed in the 1970s, when dispatchable, utility-scale, typically fossil fueled resources dominated the grid. As the resource mix has shifted toward variable renewables, energy storage, and distributed energy resources (DER) these frameworks have adapted, but the core architecture still reflects the system they were built to model. Resources with fundamentally different value propositions, including non-energy impacts (NEIs), are often not fully captured in how investment decisions are made. For this reason, historically, the goal has been to identify the least cost plan that meets the reliability requirements or other policy objectives like meeting GHG reduction targets. These analyses generally omit other societal costs and benefits or externalities that may result from electricity generation. Such externalities could include water consumption and thermal pollution affecting aquatic ecosystems, job creation and tax revenue, or transmission line or wind generation impacts on birds and wildlife.

NEIs represent the externalities associated with producing and delivering electricity that are not reflected in direct resource costs. Electricity supply modeling needs to be updated and evolve to explicitly incorporate NEIs. Integrating these factors into electricity supply modeling can provide a more complete picture of the broader societal implications of generation resource choices.

As the state's primary energy policy and planning agency, the CEC promotes a clean, reliable, affordable, safe, and equitable energy system.[1] Part of that role is to provide a comprehensive, statewide assessment of electric and gas energy resource planning[2] in line with the CEC's mission and values. The CEC's Justice, Access, Equity, Diversity, and Inclusion (JAEDI) initiative recognizes an ongoing commitment to embedding these five principles into our work to meet our mission of a 100% clean energy future for all Californians. That commitment spans all the agency's work - both internally (staff, policies) and externally (programs, community engagement), including resource planning. This report and the NEI

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[1] *See* Warren-Alquist State Energy Resources Conservation and Development Act, Public Resources Code sections 25000 et seq.

[2] Public Resources Code Section 25301.

informational proceeding seek to provide a more complete understanding of the broader societal implications of electric generation resource choices.

The Petition

On February 5, 2024, a coalition of petitioners[3] requested "the CEC adopt an order instituting a rulemaking proceeding to determine methodologies to integrate non-energy benefits and social costs into the CEC's resource planning and investment decision-making processes."[4] These benefits and costs are the NEIs discussed in this report.

Findings and Initiating Decision

The CEC found that "including NEIs in CEC resource planning analyses and decision-making provides a more holistic understanding of the impacts and benefits of investments and decisions."[5] The ultimate goal is to better inform decisions related to implementing clean electricity.

On March 13, 2024, the CEC partially granted[6] the Petitioners' request as follows:

- Granting the Petitioners' request to initiate a transparent process to determine methodologies to integrate NEIs into the CEC's resource planning, processes, and decision-making.
- Determining an informational proceeding to be the appropriate forum for the process, initiating the NEI Order Instituting an Informational Proceeding (OIIP) (Docket No. 24-OIIP-03).
- Denying the Petitioners' request that the CEC adopt an Order Instituting a Rulemaking.

The NEI OIIP

The CEC's NEI OIIP is a "transparent proceeding designed to investigate methods for integrating NEIs in electricity resource planning."[7] The ultimate goal is to improve decision making and energy resource planning. NEIs provide a more complete understanding and current lens of the broader societal implications of resource choices while ensuring reliability in meeting electricity demand advances the CEC's mission to achieve a 100% clean energy future for all Californians.

The NEI OIIP is an opportunity that encourages public engagement to:

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[3] Center for Biological Diversity, Central California Asthma Collaborative, California Environmental Justice Alliance, Asian Pacific Environmental Network, Greenlining Institute, Local Clean Energy Alliance, Sierra Club California, The Climate Center, Center on Race, Poverty and the Environment, Clean Coalition, 350 Bay Area, GRID Alternatives, The Protect Our Communities Foundation, the BEEP Coalition, the Local Government Sustainable Energy Coalition, and Environment California.

[4] Petition to Integrate Non-Energy Benefits and Social Costs into Resource Planning (Feb. 15, 2024), Docket No. 23-OIR-03, TN# 254486, https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=23-OIR-01.

[5] Order Granting in Part and Denying in Part Petition for Rulemaking on NEBs and Social Costs (Mar. 19, 2024), Docket No. 23-OIR-01, TN# 255179.

[6] Ibid.

[7] The OIIP and all other documents associated with the informational proceeding can be found in CEC Docket No. 24-OIIP-03, https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=24-OIIP-03.

- Review proposed approaches for integrating NEIs.
- Ensure flexibility and iterative feedback to refine the approaches.
- Inform development of methods to integrate NEIs in analysis and decision-making.

This staff report is the first in a series documenting the work of the NEI OIIP and seeking public input. It outlines proposed approaches for incorporating NEIs into resource planning, including an overview of traditional planning processes and the challenges of integrating NEIs into supply-side modeling. Subsequent chapters describe the specific NEIs selected for analysis and present the proposed methods for integrating and calculating these impacts.

CHAPTER 2:
Resource Planning Processes and NEIs

California's electric system planning faces a fundamental methodological challenge. As previously noted, analytical frameworks are being adapted but still don’t fully capture the different value propositions of NEIs in investment decisions.

This limitation has particularly adverse consequences at statewide scale. Planning models typically operate at the transmission or bulk-system level, which precludes detailed consideration of how the impacts of resource additions or retirements vary across communities. This leads to investment portfolios that optimize for the cost of electricity production in aggregate, without accounting for the distributional aspect of those choices or the full value of resources that serve purposes beyond energy delivery.

California's planning agencies have generally addressed these gaps by treating NEIs outside of the core modeling process, either as inputs that inform assumptions and predetermined builds, or as post-hoc evaluation of model results. Unfortunately, these approaches fail to fully capture the value of NEIs – as discussed above, the NEIs do not get integrated into the model. This is a limitation of the process, but as discussed further below, planning models were not designed to include NEIs. The 2021 SB 100 Report, for example, included social costs in a post-modeling evaluation step; similarly, California Air Resources Board’s (CARB) Scoping Plan includes post-hoc analysis of NEIs. In both cases, these analyses were designed to illustrate the implications of modeled scenarios rather than to shape the selection of resources within the reports.

Purpose of Supply Modeling

Electric system supply modeling, also known as capacity expansion modeling, is used to plan how an electricity system should evolve over time to reliably and cost-effectively meet future electricity demand. These models simulate decisions about which generation, transmission, and storage resources to build, retire, or operate at a regional level, under a wide range of economic, policy, and technological scenarios. Their purpose is to optimize investment and operational strategies that balance system reliability, cost minimization, and environmental objectives, while accounting for constraints such as fuel prices, renewable resource availability, emissions limits, and transmission capacity.

These models are heavily used across industry, governmental entities, and researchers as the principal electricity planning tools. These models were developed to address the growing complexity of electric power systems as they expanded and diversified. Early utility planning and operational analysis could rely on simple forecasts and heuristics, but as systems became larger and more interconnected, more sophisticated analytical tools were needed. Electric system supply models, such as capacity expansion and production cost models, provide a structured, data-driven framework for making long-term planning and operational decisions in the face of uncertainty, enabling policymakers, regulators, and utilities to assess trade-offs among cost, reliability, and sustainability.

Limitations of Traditional Supply Models

Despite the important value they offer in conducting comprehensive evaluation of electric system evolution, supply models have limitations. These limitations largely stem from the simplifying assumptions made to manage complexity and computational burden.

Capacity Expansion Models

Many capacity expansion models rely on coarse temporal and spatial resolution, representing system operations through a handful of representative time slices, such as typical summer or winter days, or aggregating large geographic areas into single zones. At a statewide scale, these simplifications can obscure important operational dynamics: the hourly variability of renewable generation, transmission congestion between regions, and localized reliability issues that aggregate modeling cannot resolve. Traditional models also tend to make simplified assumptions regarding future costs, demand, and technology maturity, which understate the real-world uncertainty that planners must navigate.

More recent approaches have begun to address this through stochastic demand forecasting, explicit evaluation of weather variability, and consideration of climate change impacts on both demand and renewable output, but meaningful gaps remain in representing the full range of conditions that could characterize California's electric system over a multi-decade planning horizon. Additionally, capacity expansion models have limits in their ability to represent emerging technologies and evolving market structures. Many were designed primarily for centralized, fossil-based systems and do not fully capture the behavior and value of variable renewables, DERs, energy storage, and demand-side flexibility. They also are unable to include both investment and operational detail in the same model due to computational constraints, limiting their ability to reflect interactions between short-term dispatch and long-term planning. Computational constraints have historically forced trade-offs between model detail and run time, which could result in oversimplified outcomes that miss critical system dynamics, particularly in modern grids transitioning toward high shares of renewables and decentralized resources.

Production Cost Models

Alongside capacity expansion models, which inform investment decisions, production cost models (PCMs) are used to simulate detailed (usually hourly over a year) power system operations. This can include the operations associated with future planned resources, such as planning outputs from capacity expansion models. PCMs can capture detailed dispatch, fuel use, renewable hourly variability, emissions, operational costs, and other metrics that the simplified dispatch in a capacity expansion model would not. They too, however, have limitations. PCMs are typically dispatch-focused and assume a fixed generation and transmission fleet as inputs, subject to the scenario being evaluated, limiting their ability to optimize across resource portfolios and rather reflect a predetermined system. Their results are highly dependent on assumptions imported from other models or planning processes.

In addition, PCMs often assume perfect unit availability (although implementing outage probabilities can help to an extent) and rational market behavior, which can understate operational risk and fail to capture real-world constraints such as forced outages, imperfect bidding strategies, or institutional barriers. Another limitation is the trade-off between operational detail and computational intensity. To manage this, modelers may simplify network representations, reduce simulation years, or limit treatment of uncertainty, potentially missing extreme events or rare but consequential conditions. Finally, while PCMs do well at modeling thermal dispatch, they have historically not been able to fully represent the value or detailed operational parameters of emerging resources such as residential solar PV and energy storage, demand response, and hybrid or inverter-based technologies, as well as non-economic drivers of system operation like resilience, affordability or environmental equity, or emergency response considerations.

Existing Approaches to Incorporate NEIs in Supply Modeling

Whether NEIs are integrated directly into model optimization or assessed through post-hoc analysis carries meaningful consequences for how results are interpreted. It is a methodological distinction that merits further investigation. In recent years, multiple studies have built NEIs into power sector modeling frameworks. Primarily, these works have centered around air pollution impacts from generators on public health. A review of 88 separate studies as of 2023[8] demonstrates the range of these studies. In general, many of the surveyed studies found that increased health, economic, equity, and resilience benefits could be realized when data on these considerations are more tightly integrated with modelling workflows. Additional studies focus exclusively on California. The recent California Public Utilities Commission (CPUC) *Staff Report on the Impact of a Societal Cost Test On Resource Procurement*[9] studied the impact, among others, of the inclusion of monetized health impacts from fossil gas generation into cost minimization, while a more recent study in California[10] explores methods that constrain mortalities and reduce environmental justice impacts. There are also studies in academic literature that include local air quality impacts as part of the electricity system optimization, alongside cost minimization.[11]

Integration of NEIs resulting from demand-side resources into supply-side modeling can provide a more holistic view of resource build options. Currently, modeling typically relies on a "most likely to occur" forecast based on economic and demographic inputs, technology cost, rate design and established program assumptions, as opposed to testing how those resources could support the electricity system. Electrification of end-uses, a central strategy to economy-wide decarbonization, is leading to rapid deployment of demand-side resources in California, creating additional opportunity for these resources to mitigate bulk scale resource needs. These range from energy storage in vehicles and buildings to smart devices that optimize customers' time of electricity usage.

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[8] Goforth, Teagan, Todd Levin, and Destinie Nock. 2023. *Incorporating Energy Justice and Equity into Power System Models: A Review of Current Practices and Paths Forward*. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=4591242

[9] Mantegna, Gabe, Jen Cardona, Mengyao Yuan, Arne Olson, Aaron Burdick, Alireza Eshraghi, and Joy Morgenstern. 2022. *Societal Cost Test Impact Evaluation: CPUC Staff Report on the Impact of a Societal Cost Test on Resource Procurement*. https://www.ethree.com/wp-content/uploads/2022/01/CPUC-SCT-Report-FINAL.pdf

[10] French, Jordan, Sarah Alverson, Pedro A. Sánchez-Pérez, Martin Staadecker, Patricia Hidalgo-Gonzalez, and Sergio Castellanos. 2025. "Challenges in Incorporating Environmental Justice Constraints for Capacity Expansion Modeling." *Environmental Science & Technology*. https://pubs.acs.org/doi/10.1021/acs.est.4c12991?ref=PDF

[11] Sergi, Brian J., Peter J. Adams, Nicholas Z. Muller, Allen L. Robinson, Steven J. Davis, Julian D. Marshall, and Inês L. Azevedo. "Optimizing Emissions Reductions from the U.S. Power Sector for Climate and Health Benefits." *Environmental Science & Technology* 54, no. 12 (June 16, 2020): 7513–7523. https://doi.org/10.1021/acs.est.9b06936.

Challenges with Integration of NEIs

Integrating NEIs into supply modeling presents multiple challenges. First, supply modeling occurs at a much coarser spatial scale (i.e., a balancing authority or regional level) than many NEI metrics are typically measured. While the specific location of the source is not a critical input for some impacts (e.g., climate), the geographical distribution of resources is a significant factor for many categories of impacts. Second, data to support NEI analysis are not immediately available at the scales of supply models which operate on high-level grid topologies, and so intermediate data cleaning and modeling is needed. For example, health impacts resulting from air pollutants emitted by generators require the performance of localized air quality modeling. Third, established methods for integration of NEIs into modeling workflows are lacking. Benefits such as the ability of distributed resources to provide backup power during outages tend to be ignored and are rarely represented in existing models and require further research to determine how they could be appropriately integrated. A central goal of this proceeding is to build on existing approaches and demonstrate pathways for overcoming these challenges.

More specifically, integrating demand side resources into supply side models is a longstanding challenge in power sector modeling. Demand side resources such as energy efficiency, load flexibility, and self-generation (e.g., behind-the-meter solar photovoltaics) impact supply side resource needs but have different NEIs than utility-scale resources. However, it is not clear how to fairly estimate costs and benefits for these resources, as they can both increase and offset investments in the existing power grid. This poses a major obstacle towards a full integration of demand and supply resources. Instead of being integrated into system-wide planning, demand-side resource programs use cost effectiveness tests. These tests assess program costs and benefits from different stakeholder perspectives (i.e., in California these include the Total Resource Cost, Program Administrator Cost, Ratepayer Impact Measure, and Participant Cost Test as part of CPUC's Standard Practice Manual). Tools such as the CPUC's Avoided Cost Calculator aim to capture the benefits of demand-side resources, focusing on the avoided costs related to energy generation and distribution, but they are not designed for integration into supply side modeling, rather to inform post-hoc analysis or other cost effectiveness tests. [12] More integrated modeling frameworks are needed for the simultaneous tracking of both demand-side and supply-side resource portfolios alongside their costs and associated NEIs.

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[12] CPUC. 2024. "DER Cost-Effectiveness". https://www.cpuc.ca.gov/dercosteffectiveness.

CHAPTER 3:
Approaches for Model Integration

As previously noted, post-hoc analysis of NEIs is commonly used and may continue to be used where NEIs cannot currently be integrated in modeling. In the OIIP, CEC will evaluate multiple approaches for integrating NEIs into resource planning. The CEC is using its power sector model to test methods for incorporating NEI analysis directly into the modeling framework. In addition, the CEC will assess alternative approaches for NEIs whose metrics, at least at this time, cannot be reasonably represented within the resource planning model itself.

Table 1 below identifies multiple technical approaches for consideration, the advantages and disadvantages of each, along with some example analyses for the recommended approaches. Ultimately, the decision to utilize an approach will be dependent on the objective of the analysis, any regulatory framework driving that analysis, the availability of data to support specific NEI integration and technical capabilities of the models.

Table 1: Proposed Model Integration Approaches for NEIs

Approach	Description	Example	Advantages and Disadvantages
Post-hoc analysis of NEI impacts	After modeling is completed, this approach uses model outputs of changes in resource capacity and generation and separately evaluates potential NEI impacts to compare scenarios.	Assesses the social cost of carbon for the modeled electricity mix for California comparing the 60% renewable portfolio standard scenario with the 100% zero carbon electricity scenario.[13]	**Advantage(s):** Can be calculated independently based on scenario results and is the most straightforward to analyze. Allows for integration of more NEIs that do not yet have a modeling integration strategy. **Disadvantage(s):** With the modeling step already completed, the analysis is limited to the resource choices contained in the predetermined scenarios, thereby excluding other potential portfolios that might offer improved NEI performance.

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[13] Gill, Liz, Aleecia Gutierrez, and Terra Weeks. 2021. *2021 SB 100 Joint Agency Report, Achieving 100 Percent Clean Electricity in California: An Initial Assessment*. California Energy Commission. Publication Number: CEC-200-2021-001. https://www.energy.ca.gov/publications/2021/2021-sb-100-joint-agency-report-achieving-100-percent-clean-electricity

Approach	Description	Example	Advantages and Disadvantages
Supply cost modifier	Within the model, societal costs (positive or negative) associated with each NEI are added to the traditional financial costs for each technology.	Includes a monetized air quality adder ($/MWh) to capture negative health impacts resulting from air pollution emitted from specific types of generators.[14]	**Advantage(s):** Integrates the NEI into the existing cost-minimization model. **Disadvantage(s):** Relies on NEI monetization which is rarely straightforward and often controversial and uncertain.
Constraints to meet NEI targets	One or more constraints within the model can force modeled capacity and generation to meet NEI targets, similar to how GHGs targets are incorporated.	Constrains models to reduce the number of mortalities resulting from generator air pollution.[15]	**Advantage(s):** Works for all metrics. Does not require monetization. Realizes scenario portfolios and resulting cost impacts regardless of cost effectiveness **Disadvantage(s):** Requires identification of reasonable NEI targets which may be difficult or subjective

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[14] Mantegna, Gabe, Jen Cardona, Mengyao Yuan, Arne Olson, Aaron Burdick, Alireza Eshraghi, and Joy Morgenstern. 2022. *Societal Cost Test Impact Evaluation: CPUC Staff Report on the Impact of a Societal Cost Test on Resource Procurement*. https://www.ethree.com/wp-content/uploads/2022/01/CPUC-SCT-Report-FINAL.pdf

[15] French, Jordan, Sarah Alverson, Pedro A. Sánchez-Pérez, Martin Staadecker, Patricia Hidalgo-Gonzalez, and Sergio Castellanos. 2025. "Challenges in Incorporating Environmental Justice Constraints for Capacity Expansion Modeling." *Environmental Science & Technology*. https://pubs.acs.org/doi/10.1021/acs.est.4c12991?ref=PDF

Approach	Description	Example	Advantages and Disadvantages
Multiple objective optimization	Modeling frameworks exist to simultaneously optimize multiple separate objectives. This allows for cost minimization and NEI optimization within a model.	Optimize cost and reliability for more vulnerable populations simultaneously by identifying solutions that minimize negative tradeoffs between the two objectives.[16]	**Advantage(s):** Within one modeling workflow, users can identify solutions that account for multiple objectives simultaneously without monetization of NEIs by considering tradeoffs among objectives. **Disadvantage(s):** More sophisticated approach is challenging to adapt using existing modeling packages. Limited studies exist for power system models.
Integration of Demand Side Technologies	Demand side resources are added to resource portfolios as an input assumption. Modeling demand-side resources in supply models is complex as traditionally they are not dispatched by a system operator and, accordingly, their response and availability are uncertain relative to supply resources. Additionally, decisions of procurement and ownership are not centralized as with traditional procurement.	Comparison of scenarios with varying amounts of demand-side resources including vehicle electrification, building electrification, building efficiency, distributed solar and storage, and demand response.	**Advantage(s):** Captures potential impacts from DERs typically not accounted for in supply modeling. **Disadvantage(s):** Depending on their availability, additional time/resources needed to develop and analyze additional demand-side resource scenarios with survey estimates of their associated NEIs and costs where feasible.

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[16] Byles, Dahlia, Patrick Kuretich, and Salman Mohagheghi. 2024. "Generation and Transmission Expansion Planning: Nexus of Resilience, Sustainability, and Equity." *Processes*. https://www.mdpi.com/2227-9717/12/3/590

Approach	Description	Example	Advantages and Disadvantages
NEI distributional sensitivities	The magnitude of a given NEI is often strongly dependent on location of resources and who adopts them. Average values fail to capture the wide spread in these impacts. Downscaling or bottom-up modeling can identify ranges of potential NEIs given aggregate resources.	Aims to improve environmental justice disparities through consideration of generator specific health impact rates from air pollution.[17]	**Advantage(s):** Captures potential benefits from strategic integration of multiple programs and policies. Captures effects at scales smaller than typical model geographies. **Disadvantage(s):** Depending on resource availability, increased complexities resulting in additional model runs and analysis under various distributional strategies.

Source: California Energy Commission staff

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[17] French, Jordan, Sarah Alverson, Pedro A. Sánchez-Pérez, Martin Staadecker, Patricia Hidalgo-Gonzalez, and Sergio Castellanos. 2025. "Challenges in Incorporating Environmental Justice Constraints for Capacity Expansion Modeling." *Environmental Science & Technology*. https://pubs.acs.org/doi/10.1021/acs.est.4c12991?ref=PDF

CHAPTER 4: Landscape of NEIs

How electricity is generated and consumed affects many aspects of Californians' lives, and those impacts are rapidly evolving due to the change in attributes provided by increasing amounts of renewable and zero carbon resources. These impacts span a broad range of categories, including safety, environment, health and resilience. The CEC asked Physicians, Scientists, and Engineers for Healthy Energy (PSE)[18] and HR&A Advisors (HR&A)[19] to survey categories of NEIs and methods to quantify them. PSE and HR&A conducted a literature search and reviewed existing methods to represent NEIs used by CEC and other state agencies. From this work, they identified a catalog of many potential NEIs to investigate. These NEIs exhibit a broad range in the magnitude of their potential impact, state of readiness for use in resource planning, and feasibility for modeling integration. The CEC must use a structured approach to test key NEIs for initial model integration to ensure that the methodology is sound and will produce valid results. To identify and prioritize NEIs for further investigation, CEC used the following set of screening criteria. Each NEI should be:

1. **Directly associated with generation and consumption of electricity**. Upstream impacts including fuel production and manufacturing are not included in this analysis, unless the fuel is produced onsite where used (e.g., water use for some applications of hydrogen production). While these impacts can be significant, it is more challenging to predict how differences in resource adoption would lead to changes in these impacts due to their geographic scope. Moreover, second order effects that may occur as a result of these direct impacts, though important, are left for future work.
2. **Outside the scope of traditional planning, but relevant to state policy**. The aim of this work is to incorporate externalities that have previously been challenging to accommodate into decision-making frameworks. As such, additional modifications to climate impacts, traditional costs, or grid reliability metrics are not proposed. Feasible alternative technologies to improve the NEI must exist.
3. **Subject to significant change under feasible future alternatives**. If the magnitude of an NEI is unlikely to change under a wide range of feasible scenarios and technologies under consideration by the model, then it is deprioritized for consideration in this study. For example, ecological impacts associated with existing hydropower operations are not expected to change under the feasible future scenarios likely to be considered. Because hydropower use remains largely constant across these alternatives, this NEI could be deprioritized.

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[18] PSE Healthy Energy is an independent scientific research institute that specializes in bringing science to energy policy. With a mission is to generate energy and climate solutions that protect public health and the environment, they combine cutting-edge research with science communications and advice to advance evidence-based strategies that address real-world challenges.

[19] HR&A brings five decades of experience helping clients transform vision into action by analyzing challenges, developing strategies, and implementing solutions that expand opportunity and improve quality of life. Their expertise centers on creating economic frameworks grounded in rigorous quantitative analysis to guide strategic decisions that revitalize regions and turn them into job-creating, community-strengthening assets.

4. **Feasible to analyze based on existing literature and data**. NEIs that lack literature and data, but that are potentially highly impactful should be prioritized for future data collection and methods development.

NEI Categories Selected for Investigation

As described above, through a detailed literature search, and public outreach, the relevant domains of NEIs were narrowed based on the criteria above resulting in the following list.

- **Ambient Air Quality and Health**: Health outcomes due to changes in air quality from generation and demand-side emissions.
- **Household Energy Cost**: Annual costs California households pay to run homes and vehicles with special consideration of low-income households.
- **Energy Resilience**: Ability of systems to withstand, adapt to, and recover from inevitable disruption in centralized energy systems.
- **Water**: Impacts on bodies of water and access to water.
- **Economics and Workforce**: Employment opportunities and economic activity (e.g., manufacturing components, increased local spending).

For each NEI domain, PSE reviewed the literature to identify potential methods for quantifying NEI response to resource changes. PSE identified approaches for model integration that each NEI is best suited for (e.g., post-hoc, cost modifier) and their potential to be integrated into a capacity expansion model framework based on the available data to support the analysis. For many impacts, more than one approach for assigning numeric values is proposed. Multiple approaches were considered since the context of a certain analysis may be better suited to one representation as compared to another. The following sections provide high-level descriptions of specific options for quantifying leading metrics within each domain followed by an explanation of how they can be integrated into the modeling workflow.

Ambient Air Quality and Health

Electricity generation and consumption can influence outdoor air quality. Traditional power plants that rely on fossil fuels release pollutants such as particulate matter, sulfur dioxide, nitrogen oxides, and volatile organic compounds during combustion. By transitioning to cleaner electricity sources and implementing advanced emission controls, California has significantly reduced these pollutants and has an opportunity to further reduce pollutants through the transition to a low-carbon electricity system.

Another opportunity to reduce emissions is through electrification of heating systems powered by fossil fuels or wood in residential and commercial buildings. CARB’s 2022 Scoping Plan - Building Decarbonization Appendix F, found that transitioning to electric appliances statewide would yield significant public health benefits by reducing secondary nitrate $PM_{2.5}$ (from NOx) and primary $PM_{2.5}$.[20]

The transportation sector is the single largest contributor to air pollution in California. The electrification of transportation provides a significant opportunity to improve air quality by eliminating the release of nitrogen oxides and particulate matter from fossil-fueled vehicles.

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[20] CARB. 2022. *2022 Scoping Plan – Appendix F: Building Decarbonization*. https://ww2.arb.ca.gov/sites/default/files/2022-11/2022-sp-appendix-f-building-decarbonization.pdf

Together, the effects of reduced emissions from clean electricity generation, building electrification, and transportation can create air quality and health benefits for all communities. For example, studies have shown that a 10 ug/m^3 reduction in PM$_{2.5}$ concentration is associated with a 3-12% decrease in all-cause mortality.[21,22,23] Incorporating the quantified societal cost impacts of changes to public health outcomes enables a more comprehensive, informed, and balanced evaluation of resource choices. CEC identified two approaches to be tested to incorporate ambient air quality and health[24] into the modeling workflow:

- *Supply Cost Modifier Integrated into the Model:* The analysis could include estimates of both health endpoint rates (e.g., mortalities/MWh) and monetized health damages (e.g., $/MWh) associated with generation from fossil-gas generators. For buildings and transportation electrification, similar estimates, but on a per unit fuel used basis (mortalities/fuel used and $/fuel used), could be selected.
- *Health Impact Constraint Integrated into the Model:* A separate modeling approach involves the same health endpoint rates discussed above but could be used instead to constrain the capacity expansion model to a maximum allowable health impact. Scenarios resulting from this approach could then inform the cost-optimal blend of resources to realize this health-related goal, without having to monetize those impacts. For example, a scenario may be modeled without health impacts first. The cumulative mortalities resulting from this scenario could be calculated post hoc. These cumulative mortalities may then be used to inform a constraint for subsequent scenarios that reduce the number of mortalities and report the shift in resources to realize these reductions.

Energy Resilience

Energy resilience is the ability of systems (buildings, businesses, households, and communities) to withstand, adapt to, and recover from inevitable disruption in centralized energy systems. While California's power grid spans the state, energy resilience happens locally, with people and organizations preparing for and responding to outages that can occur at the circuit or sub-circuit level in response to local or regional events and climatic conditions. Energy resilience can be bolstered with energy resources, including DERs, that are close to and interconnected with loads.[25] Electricity reliability analysis and modeling for policy decision-

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[21] Wu, X., D. Braun, J. Schwartz, M.A. Kioumourtzoglou, and F. Dominici. 2020. "Evaluating the impact of long-term exposure to fine particulate matter on mortality among the elderly." *Science Advances*. https://www.science.org/doi/10.1126/sciadv.aba5692

[22] Di, Qian, M.S., Yan Wang, M.S., Antonella Zanobetti, Ph.D., Yun Wang, Ph.D., Petros Koutrakis, Ph.D., Christine Choirat, Ph.D., Francesca Dominici, Ph.D., and Joel D. Schwartz, Ph.D. 2017. "Air Pollution and Mortality in the Medicare Population." *The New England Journal of Medicine*. https://www.nejm.org/doi/pdf/10.1056/NEJMoa1702747

[23] Krewski, Daniel, Michael Jerrett, Richard T Burnett, Renjun Ma, Edward Hughes, Yuanli Shi, Michelle C Turner, et al. 2009. "Extended Follow-Up and Spatial Analysis of the American Cancer Society Study Linking Particulate Air Pollution and Mortality." Health Effects Institute. https://www.healtheffects.org/publication/extended-follow-and-spatial-analysis-american-cancer-society-study-linking-particulate

[24] Additional methodological details are in Appendix A - Table 2.

[25] Zitelman, Kiera. 2024. "Advancing Electric System Resilience with Distributed Energy Resources: A Review of State Policies". NLR. https://docs.nrel.gov/docs/fy24osti/90137.pdf

making is performed at the transmission level and typically does not directly include consideration of outage impacts at the household, building, business, and community levels.

Characterizing the equitable distribution of energy resilience requires incorporating both grid resilience and reliability considerations, as well as the DERs serving as backup energy for critical services. In addition, gas, propane and other non-electrical sources provide energy services during grid outages; the resilience value from these sources also should be included as part of resilience and energy transition NEIs. Critical services can differ by community, both in terms of hazard exposure and individual and local community vulnerabilities.

Four energy resilience metrics are proposed to capture resilience impacts based on distributional sensitivities. Each of these metrics will be calculated at very granular spatial and demographic levels, and then aggregated by geographic regions, demographics and other significant characteristics (e.g., high fire-threat areas, priority beneficiaries[26], etc). The metrics proposed for consideration are:[27]

1. *Unmitigated Home Energy Outage Costs*, which monetizes outage impacts to represent the economic costs.
2. *Household Resilient Energy Cost Burden*, which transforms these costs into a percentage of household income.
3. *Resilient Energy Affordability Gap*, which calculates the dollar value spent by households on the combination of energy, resilient energy, and outage impacts and mitigations that exceed an affordability threshold (six percent of gross income, 8.5-10 percent of net income after essential expenses).
4. *Households with Backup Power*, which calculates the number and percentage of households with access to backup power.

Proposed model integration approaches:

- *Resilience Constraint Integrated into the Model:* The driving input variable for resilience is DER capacity.[28] As such, varying levels of DER based on CEC modeling will be used as constraints to force the capacity expansion model to increase resilience.
- *Post-hoc Analysis with Distributional Sensitivities After the Modeling:* Calculation of the multiple household resilience metrics will also be performed using outputs from various scenarios of the capacity expansion modeling scenarios. Post-hoc analysis explores sensitivities of residential DER distributions across households through downscaling of projected DER resource builds. These sensitivities include DER distributions that allocate DER to address power outage impacts.

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[26] CEC JAEDI Framework. 2022. https://www.energy.ca.gov/sites/default/files/2023-11/CEC-JAEDI-Framework_ada.pdf CEC-100-2022-001-CMF-APA

[27] Additional methodological details are in Appendix A – Table 3.

[28] Gilani, Mohamad, Ahad Kazemi, Mostafa Ghasemi. 2019. "Distribution System Resilience Enhancement by Microgrid Formation Considering Distributed Energy Resources". Science Direct. https://www.sciencedirect.com/science/article/abs/pii/S0360544219321371?utm

Household Energy Cost

Energy costs remain a persistent burden for households across California, with the greatest strain on households below the poverty threshold.[29] As such, the costs that households pay to operate a safe home and maintain access to reliable transportation represent a broader societal concern.

Existing supply models do not sufficiently represent the range of possibilities to improve household energy costs. Supply models seek only to reduce supply costs, which are a component of rates, for a given assumption of demand-side technologies. However, energy costs for households can be impacted by adoption of demand-side technologies including self-generation and storage, efficiency, fuel switching, and electrification. These changes in turn impact resource planning. Quantifying these cost impacts is further complicated by accounting for differences in access to these demand-side resources based on household income.[30]

Proposed model integration approach:

- *Post-hoc with Distributional Sensitivity Analysis After the Modeling:* This approach includes calculation of five standard household energy cost metrics for all households, including those that are both above and below the poverty thresholds used for utility bill assistance eligibility. These metrics include separate estimates of energy costs for home and for personal transportation as they are driven by separate forecasts of building and transportation consumption changes. The percentage these costs represent of both household gross income and disposable income are also calculated. Moreover, estimates of the dollar value spent by all households that exceed a certain income threshold will be calculated. To do so, estimates of the effect of demand-side technologies on energy consumption at home and for transportation will be calculated and merged with rate projections and rate impacts from different supply-side resource scenarios.

Water

Generation technologies such as fossil gas turbines and geothermal rely on water to generate electricity. The change in water due to electricity generation is measured through water withdrawal and consumption. Withdrawals quantify the water used, generally for cooling, that is returned to its source, while consumption quantifies water that is not returned to its source, typically through evaporation. Electrolysis for clean hydrogen production, which is used for generation, results in water loss due to evaporation. While water use for hydrogen production is an upstream impact, it is included for consideration when the hydrogen is generated locally and serves the role in planning as an energy storage technology.

Water use is proportional to specific types of generation so it could be incorporated into the model via a constraint (e.g., gallons/MWh) in the same manner as mortalities from reduced air quality from generation if there is a specific reduction target. However, due to efficiency improvements and once-through cooling regulations, water impacts from the power sector have decreased significantly in recent decades and now make up a very small proportion of

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[29] Scheier, Eric, Noah Kittner. 2022. "A Measurement Strategy to Address Disparities Across Household Energy Burdens", Nature Communications, Journal, 13, 288, https://www.nature.com/articles/s41467-021-27673-y?utm.

[30] Additional methodological details are in Appendix A - Table 4.

statewide water usage. This NEI, therefore, does not represent a significant impact and is limited to a post-hoc consideration.[31]

Water is also impacted by resources such as pumped water storage and hydroelectric power. However, the range of potential change of these resources is relatively small and their impact on water availability is difficult to estimate, so we do not include these considerations in this current study.

Proposed model integration approach:

- *Post-hoc Analysis After the Modeling:* Monitoring shifts in water use for electricity generation can help identify pathways for management. This involves the multiplication of generation by the rates of water consumption and withdrawal for each generation type in each region.

Workforce

Clean electricity deployment generates direct and indirect employment opportunities and economic activity. Understanding workforce impacts at a regional and technology level allows planners to align decarbonization strategies with job creation and economic development objectives.[32]

Proposed model integration approach:

- *Post-hoc Analysis After the Modeling:* Both utility-scale energy resources and DERs generate employment and economic activity through construction and installation, operations, and ongoing maintenance. Applying standardized job-intensity coefficients (job-years per megawatt), job quality coefficients (employee compensations per megawatt), and economic-intensity coefficients (economic output per megawatt) can reveal the impact of various pathways on the number of jobs, job quality, and economic activity based on their proposed resource mix. This approach of translating megawatts (MW) to jobs and related variables has been validated through other studies.[33] The purpose of National Laboratory of the Rockies' (NLR) Jobs and Economic Development Impact (JEDI) models,[34] which have previously been applied to NLR's Regional Energy Deployment System, is to calculate jobs impacts.[35]

Utility-scale coefficients can be derived from NLR's JEDI and Rhodium Group datasets to estimate employment and economic characteristics associated with each major generation technology for direct, onsite impacts, and indirect, supply-chain impacts. Importantly, these

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[31] Additional methodological details are in Appendix A - Table 5.

[32] Additional methodological details are in Appendix A - Table 6.

[33] Larson, Eric, Chris Greig, Jesse Jenkins, Erin Mayfield, Andrew Pascale, Chuan Zhang, Joshua Drossman, et al. 2021. "Net-Zero America: Potential Pathways, Infrastructure, and Impacts," Princeton University. https://www.dropbox.com/scl/fi/ol7ivcso5t2k3wux2r5bk/Princeton-NZA-FINAL-REPORT-29Oct2021.pdf?rlkey=zmhc0gryurzlyfo0faac036v6&e=1&dl=0

[34] National Laboratory of the Rockies, "Jobs and Economic Development Impact (JEDI) Models." https://www.nrel.gov/analysis/jedi/index.html.

[35] M. Brown et al. 2020. "Regional Energy Deployment System (ReEDS) Model Documentation: Version 2019" NRL. https://www.nrel.gov/docs/fy20osti/74111.pdf

coefficients differentiate between one-time, non-recurring jobs associated with construction and ongoing, permanent jobs that span the operational life of the project.

Unlike utility-scale technologies, no comprehensive dataset on statewide workforce impacts exists for DERs, and therefore quantifying similar coefficients is required for this work. To establish similar coefficients for DERs, the workforce analysis for DERs must first investigate existing data sources to track DER deployment activity in California to estimate employment and economic impacts which can then be converted into job and economic coefficients. These datasets include but are not limited to:

- The CEC's Distributed Generation Statistics database and net energy metering interconnection data can provide solar installation volumes by sector.
- Energy storage deployment data from CPUC's Self-Generation Incentive Program database, which tracks residential and commercial battery installations.
- Weatherization activity sourced from the California Department of Community Services and Development's Low-Income Weatherization Program reports, which document homes weatherized and corresponding investment levels.
- Interstate Renewable Energy Council's (IREC) National Solar Jobs Census 2024,[36] which provides segmentation of solar installation jobs by market segments for utility and non-utility scales.
- Freeing Energy's reports, which serve as national benchmarks for job-creation per MW for small vs utility scale solar.[37]

To validate results, review of new datasets may also be necessary, such as through clean energy employment surveys and/or interviews with DER providers in California's solar installation, energy efficiency, and energy storage sectors. Once the jobs and economic coefficients are established for DERs, they may be used in conjunction with utility-scale estimates.[38,39]

This analysis can provide a consistent and transparent framework for estimating statewide and regional workforce effects from modeled generation buildout. It can also support evaluation of employment scale and distribution under different buildout trajectories.

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[36] Interstate Renewable Energy Council. 2025. *National Solar Jobs Census 2024*. https://irecusa.org/programs/solar-jobs-census/

[37] Freeing Energy. 2026. The Number of Jobs Created per MW of Solar Installed. https://www.freeingenergy.com/facts/jobs-solar-installation-residential-utility-g207/

[38] Wei, Max, Shana Patadia, and Daniel M. Kammen. 2010. "Putting renewables and energy efficiency to work: How many jobs can the clean energy industry generate in the US?" *Energy Policy*, *38*(2), 919–931. https://doi.org/10.1016/j.enpol.2009.10.044

[39] Sovacool, Benjamin K., Darrick Evensen, Thomas A. Kwan, and Vincent Petit. 2023. "Building a green future: Examining the job creation potential of electricity, heating, and storage in low-carbon buildings." *The Electricity Journal*, *36*(5), 107274. https://doi.org/10.1016/j.tej.2023.107274

CHAPTER 5: Next Steps

Analysis Plan

After reviewing public feedback, the identified integration and quantification methods will be re-evaluated to incorporate revisions as appropriate. The CEC will test individual approaches for the metrics, as modified through the comment process. Analytical results and an assessment of the approaches tested will be included in a future staff report.

ACRONYMS AND ABBREVIATIONS

CEC – California Energy Commission

CEIDARS – California Emissions Inventory Data Analysis and Reporting System

CPUC – California Public Utilities Commission

DER – distributed energy resources

GHG – greenhouse gas

HR&A – HR&A Advisors

JAEDI – Justice Access Equity Diversity & Inclusion

JEDI – Jobs and Economic Development Impact

MW – megawatt

MWh – megawatt hour

NEI – non-energy impact

OIIP – Order Instituting an Informational Proceeding

PCM – production cost model

PSE – Physicians, Scientists, and Engineers for Healthy Energy Inc.

APPENDIX A:
Additional Method Details By NEI Category

Ambient Air Quality and Health

Health impacts will be calculated using metrics described in Table 2. More details around the methodologies for the different sources are below.

Table 2: Ambient Air Quality & Health Metrics

Metric	Unit	Description	Geographic Scale
Health Impacts	- mortalities/fuel used (transportation and buildings) - mortalities/MWh (natural gas generators)	Converts air quality changes from electrification into mortality rates per unit generated or consumed.	- State (transportation and buildings) - State, county, and individual facility (natural gas generators)
Monetized Health Impacts	- $/fuel used (transportation and buildings) - $/MWh (natural gas generators)	Uses the value of a statistical life to convert mortalities associated with air quality changes due to electrification into dollars per unit of generated or consumed.	- State (transportation and buildings) - State, county, and individual facility (natural gas generators)

Source: California Energy Commission staff

Fossil Gas Power Plants

For power plants, the health impact analyses of emissions from existing facilities will be used to estimate regional health impact rates. CEC analysis typically assumes no new fossil gas power plants will be built. Studying existing facilities individually is important since where they are situated can result in drastically different levels of health impacts. For example, plants far removed from populated areas will have lower negative health impacts. However, these data will need to be aggregated for many power sector modeling studies as they do not consider the dispatch of individual facilities. As such, reliance on generator regional averages retains some, but not all, of the generator specific differences in health impacts.

We use the following procedure to calculate estimates of generator health impacts rates. First, emissions for all fossil gas generators will be obtained from the California Emissions Inventory Data Analysis and Reporting System (CEIDARS). For facilities not included in CEIDARS, emissions will be estimated using standardized factors based on electricity generated and fuel type. These emissions will then be used to drive simulations for each facility using the Interventional Model for Air Pollution (InMAP) tool. InMAP calculates mortalities based on annual simulated PM2.5 concentrations, population, and established relationships between PM2.5 concentration and health. These mortality calculations will be converted into a monetized health metric using the value of a statistical life. This value will be normalized by the electricity generated at the facility, providing a normalized metric per facility ($/MWh). These values can then be directly incorporated into electricity planning modeling. Finally, these results will be aggregated at sub-state levels (e.g., PLEXOS zones, air basins, or counties) to perform post-hoc analyses of the scenarios. These estimates are produced at the facility level, allowing for flexibility in how they are spatially aggregated in post-hoc analyses. This approach balances computational efficiency with the higher spatial granularity of InMAP, allowing for additional scenario analysis without the need for new simulations.

These results will also be compared to statewide results from the referenced report[40] for fossil-gas generators. Air quality modeling previously done using the Community Multiscale Air Quality model coupled with the Environmental Benefits Mapping and Analysis Program tool calculated the changes in air quality and associated health impacts due to the complete removal of fossil gas generators.

Buildings and Transportation

Quantification of health and monetized impacts will rely on a previous study[41] that used air quality modeling to determine the state-averaged impacts of building and transportation electrification. As with the fossil-gas generators, the referenced report used robust air quality modeling to separately calculate the changes in outdoor air quality due to the complete removal of buildings and transportation (i.e., the electrification of each resource). The statewide estimated metric ($/fuel used) from this study will be used for post-hoc analysis of electricity supply and demand scenarios. Specifically, reductions in fuel consumption derived from projected CEC transportation and building modeling scenarios that capture fuel switching will be multiplied by these rates to estimate the aggregate health impacts.

Energy Resilience

Table 3: Resilience Metrics

Metric	Units	Description	Geographic Scale
Unmitigated Home Energy Outage Costs	$	Costs of power outages experienced by households, without outage mitigations.	CEC forecast zone and balancing authority; Built from underlying census tract scale modeling

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[40] Mantegna, Gabe, Aaron Burdick, Snuller Price, Arne Olson, Dr. Michael Mac Kinnon, and Dr. Scott Samuelsen. 2021. *Quantifying the Air Quality Impacts of Decarbonization and Distributed Energy Programs in California*. https://www.ethree.com/wp-content/uploads/2022/01/CPUC-Air-Quality-Report-FINAL.pdf

[41] Ibid

Metric	Units	Description	Geographic Scale
Household Resilient Energy Cost Burden	%	Proportion of income spent on resilient energy at home, including the cost of mitigations and interventions (from flashlights to whole-home backup systems to obtaining services at resilience hubs or outside the outage region) and the remaining unmitigated outage costs.	CEC forecast zone and balancing authority; disaggregated by regional income quantiles (e.g. 10th, 50th and 90th percentiles)
Resilient Energy Affordability Gap	$	Total spending on resilient energy at home, beyond an energy cost burden threshold consistent with energy affordability analysis (see more detail below), plus the remaining outage impacts, plus spending by others (communities, towns, cities, counties, etc.) to mitigate outage impacts on their constituents.	CEC forecast zone and balancing authority; Built from underlying census tract scale modeling
Households with backup power, by vulnerability tier status	#, %	Number of households and percentage of households with resilient backup power (total, and by demographic indicating vulnerability status and priority; e.g. income, medical device dependency, outage exposure).	CEC forecast zone and balancing authority; Built from underlying census tract scale modeling

Source: California Energy Commission staff

Existing affordability metrics include:

- **Energy cost burden** that accounts for the percentage of household income spent on energy bills.
- **CPUC's energy affordability ratio** that accounts for the fraction of household income spent on energy bills after housing and other utility costs; and
- **CEC's Energy Equity Indicators** that incorporate transportation costs and other cost-of-living expenses, adjusted by household size.

The first two metrics are widely used in regulatory and academic settings and are well-suited for making comparisons between geographic areas or populations to determine differences in energy affordability. The JAEDI framework incorporates CEC's equity and affordability considerations. None of these consider the costs incurred through experiencing power outages and the costs of investing in methods to mitigate those costs. As noted in affordability metrics discussions, these metrics have limitations when it comes to evaluating broader societal impacts rather than individual household impacts.

As with affordability analysis, the resilient energy affordability gap can capture the magnitude of social impact by quantifying the potential financial impact of technologies and linking them directly to policy outcomes, including the need for resilience assistance or the costs and benefits of publicly supported resilience countermeasures. They rely on the same thresholds to define the point beyond which societal costs begin to accrue, and these thresholds rely on well-established existing policies such as the threshold to qualify for California Alternate Rates for Energy (C.A.R.E) and Family Electric Rate Assistance (F.E.R.A.) program.

Statistics can be calculated at the census tract and then reaggregated to key geographies such as counties, forecast zones, and utility service areas as well as key subsets such as single-family versus multifamily housing, presence in disadvantaged communities, or energy source used for heating.

Household Energy Cost

To estimate these impacts, demand side changes will be accounted for by estimating changes in household energy consumption patterns that consider important local attributes such as climate and housing type. These estimates rely on demand side modeling data regarding fuel substitution, electric vehicle adoption, and distributed energy adoption along with rate projections for electricity and all fossil fuels and aligned projections of population growth from the California Department of Finance. Additional supply costs from capacity expansion models compared to a reference scenario will be allocated proportionally by demand to account for their impact on projected rates. The CEC proposes calculating metrics, summarized in Table 4 below, for each scenario.

Table 4: Household Energy Cost Metrics

Metric Name	Units	Description	Geographic Scale
Home Energy Spending	$	Total annual spending on energy at home for households segmented by poverty brackets (e.g. less than Federal Poverty Level, between 1 and 2 times the Federal Poverty Level, below 80% of the area median income, etc.)	CEC forecast zone and balancing authority; Built from underlying census tract scale modeling
Personal Transportation Energy Spending	$	Total annual spending on energy for transportation for households within the same income brackets for home energy spending listed above.	CEC Forecast Zone and balancing authority
Home Energy Cost Burden	%	Proportion of income spent on energy at home. Two options: • Proportion of gross income • Proportion of disposable income after other housing and utility costs, in line with CEC's Energy Equity Indicators metrics.	CEC forecast zone and balancing authority; Built from underlying census tract scale modeling

Metric Name	Units	Description	Geographic Scale
Transportation Energy Cost Burden	%	Proportion of income spent on energy for vehicles. Two options: • Proportion of gross income • Proportion of disposable income after housing costs, similar to CPUC affordability ratio.	CEC Forecast Zone and balancing authority
Energy Affordability Gap	$	The sum of all spending on energy at home beyond the percentage of income thresholds.	CEC forecast zone and balancing authority; Built from underlying census tract scale modeling

Source: California Energy Commission staff

Energy costs also impact commercial and industrial customers. However, for this proceeding additional NEI metrics for these customers are not proposed. Methods and literature for quantifying societal impacts from commercial and industrial customers bill changes are much more limited than household impacts due in part to the wide diversity of these customers.

Water

Generation weighted averages of water consumption and withdrawal for thermoelectric generation will be estimated from EIA's Thermoelectric cooling water data.[42] Consumption and withdrawal water usage rates for other resources will be determined for additional resources. Additional details regarding water metrics are shown in Table 5.

Table 5: Water Metrics

Metric	Unit	Description	Geographic Scale
Water Consumption	Gallons/MWh	Usage of water that is not returned to its source. May also include water used for hydrogen production that is consumed in generators.	Averages by generator type at Planning Area scale
Water Withdrawal	Gallons/MWh	Water that is used and returned to its source, typically at a higher temperature causing ecological impacts.	Averages by generator type at Planning Area scale

Source: California Energy Commission staff

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[42] EIA. 2025. Thermoelectric cooling water data. https://www.eia.gov/electricity/data/water/

Workforce

Additional details regarding workforce metrics are shown in Table 6 below.

Table 6: Workforce and Jobs Metrics

Metric Name	Units	Description
Construction Jobs Created	Job-years	Total direct construction jobs by technology and region.
Operations Jobs Sustained	Annual jobs	Long-term employment supported through operations and maintenance activities.
Labor Intensity by Technology	Job-years / MW	Employment coefficient per MW of installed capacity.
Regional Workforce Distribution	% share	Share of total jobs by modeled region, reflecting localized impacts.
Employee Compensation	$ / year	Estimated total labor income associated with construction and operations employment under each scenario.
Job Quality		Employee compensation (as a proxy for job quality) coefficient.
Total Economic Output	$ / year	The overall value of goods and services generated through direct, indirect, and induced effects of construction and operations activity under each scenario.
Economic Intensity by Technology	Economic Output/ MW	Economic Coefficient per MW of installed capacity.

Source: California Energy Commission staff

All coefficients are derived for California statewide impacts that can be applied to smaller geographies to estimate regional effects