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Description:	The California Energy Code sets minimum efficiency standards for buildings, but statewide compliance rates remain unclear. Existing studies report varying and sometimes conflicting compliance rates, with some indicating high adherence and others showing low permitting and documentation rates, particularly in residential projects. This gap analysis identifies 20 barriers - including inconsistent definitions, poor permit data, and limited methods to measure unpermitted work - that hinder understanding of compliance. It defines process- vs. energy-based compliance, recommends focusing on process-based compliance initially, and proposes a two-pronged approach: short-term field studies (1–5 years) and long-term development of compliance metrics using existing infrastructure. The CEC seeks stakeholder input on building category priorities, feasible metrics, impacts of unpermitted work, and data challenges across 500+ jurisdictions.
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STAFF REPORT

California Energy Code Compliance Gap Analysis

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ABSTRACT

As the state’s primary energy policy and planning agency, the California Energy Commission (CEC) is responsible for the adoption and implementation of California’s Building Energy Efficiency Standards, including requirements in the Energy Code (Title 24, Part 6) and voluntary standards in CALGreen (Title 24, Part 11). The Energy Code is applicable to all residential and nonresidential newly constructed buildings, additions, and alterations throughout California. Voluntary energy efficiency standards in CALGreen serve as examples for local governments that choose to exceed the minimum requirements of the Energy Code. Together with appliance efficiency standards, CA’s Building Energy Efficiency Standards have saved Californians over \$200 billion dollars in energy costs.

The Energy Code consists of two equally important parts that work together to reduce wasteful, uneconomic, inefficient, or unnecessary energy use in California: the development of regulations and ensuring compliance with those regulations. Both are essential to the Energy Code’s goals of lowering energy costs, advancing energy efficiency, and achieving California’s bold climate action goals. Currently, the state lacks comprehensive data on Energy Code compliance rates, regional variations in compliance, and the root causes of noncompliance. This limits the CEC’s ability to fully understand the cost of noncompliance to the state, effectively implement state policy, and allocate supporting resources where they are needed most.

This report, referred to as a “gap analysis”, attempts to improve on those conditions by identifying challenges and proposing solutions to enhance the state’s intelligence related to Energy Code compliance. This gap analysis also establishes a technical foundation through defined compliance terms, a literature review, data analysis, gap identification, field study methodologies, and actionable recommendations.

Key findings of this report include the impact of unpermitted construction, existing methodological gaps, the need for clear definitions, and lessons learned from prior studies. To improve compliance, staff recommend the CEC conduct targeted field studies in the short term (1-3 years) and develop systematic ongoing tracking of key compliance metrics in the long term (3+ years). Field studies would require coordination with the more than 540 local jurisdictions in California. Data-driven methods – such as HVAC sales tracking, real estate data analysis, interval meter data analysis, and satellite imagery analysis – can provide valuable insights but should be viewed as supplemental to primary research methods like field studies, which are more critical. Engaging interested parties is also essential, as it enables the validation or refinement of assumptions made during the initial gap analysis.

Next steps include stakeholder engagement via public workshops and acquiring funding for field studies. Addressing these issues will enhance enforcement, improve compliance, and help to improve the overall efficacy of California’s building energy efficiency standards.

Keywords: Building Energy Efficiency Standards, Energy Code, compliance, enforcement

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EXECUTIVE SUMMARY

The California Energy Code (Title 24, Part 6) sets the minimum energy efficiency requirements for residential and nonresidential buildings in California, reducing long-term energy costs for homeowners, renters, and businesses. Compliance with the Energy Code is important for ensuring that Californians receive the benefits of energy-efficient buildings. Compliance with the Energy Code generally means that a building project adheres to the requirements and achieves the projected savings set by the Energy Code. *Compliance rate* refers to the ratio of code-compliant projects to the total number of projects in a specific region.

California does not currently have robust analysis on the Energy Code compliance rates for various building categories across the state. Interested parties, including designers, program Providers, advocacy groups, and labor unions have voiced concerns over low compliance rates due to perceived lack of enforcement, complexity in the compliance process, and other reasons. A few studies showing low permitting rates particularly in existing residential buildings raise further questions about compliance levels for unpermitted projects. Overall, a robust analysis will be critical to the CEC's ability to effectively understand the current market, identify causes of compliance challenges, and strategically address these challenges to improve Energy Code compliance and enforcement.

This gap analysis seeks to set a foundation for conducting a comprehensive Energy Code compliance rates analysis in California and identifies priorities of future work. This gap analysis is divided into six chapters:

- **Chapter 1:** Provides **background** on compliance definitions and describes the existing compliance ecosystem, and key interested parties.
- **Chapter 2:** Offers a **literature review** which summarizes work on energy code compliance in different countries, within the United States, and within California.
- **Chapter 3:** Discusses analysis relating to permit data and other **data** resources.
- **Chapter 4:** Inventories the **gaps** and discusses a gap framework and analysis.
- **Chapter 5:** Discusses a **menu of approaches** for compliance rate field studies and data-driven studies.
- **Chapter 6:** Provides staff's **recommendations** on the next steps.

Key Findings

California Studies

Relevant studies relating to compliance rates have been conducted primarily to evaluate energy efficiency programs overseen by the California Public Utilities Commission (CPUC) and administered through the investor-owned-utilities (IOUs). These studies generate "compliance rates", later redefined and reworded to "Energy Savings Factor",

for the Energy Code through field surveys and modeling tools. The findings estimate energy savings directly attributable to the California IOU Codes and Standards (C&S) Building Code Advocacy program. This program specifically aims to save energy on behalf of ratepayers in IOU service areas. These IOU C&S Building Code Advocacy Program evaluations have generally shown high “compliance” / “Energy Saving Factor” rates (more than 90 percent) in recent years, drawing concern that the results do not represent the state of overall building compliance in California. The primary objective of these studies has been to assess the program-caused savings specifically attributable to the IOU C&S Building Code Advocacy program, which is materially different from evaluating statewide adherence to the Energy Code.

Alternatively, Regional Energy Networks (RENs) are program administrators authorized by the CPUC to deliver programs to local communities and have also conducted research on permitting and Energy Code compliance in their respective regions. Results from Bay Area REN (BayREN) showed that only 16 percent of projects in the Bay Area included complete compliance documentation, indicating lack of understanding and adherence to compliance process. Studies conducted by other RENs focused on field survey and qualitative analysis of compliance gaps. Altogether, the current body of research in California presents conflicting findings regarding Energy Code compliance and fails to provide a clear assessment across the state.

Compliance Definitions Matter

There can be many variations to compliance definitions. To establish a framework for understanding compliance dimensions, staff propose two fundamental definitions: process-based compliance and energy-based compliance. Process-based compliance differs from energy-based compliance in its focus and requirements. *Process-based compliance* describes projects that obtain necessary permits, go through the full permitting and inspection processes, and maintain accurate documentation throughout design to completion. It does not require that the project achieves energy savings as intended by the Energy Code. *Energy-based compliance*, in contrast, focuses on outcomes. It means that the completed project performs at or above the energy efficiency level intended by the Energy Code. Unlike process-based compliance, it does not require that all procedural steps are completed.

In this gap analysis, *full compliance* is defined as a project that satisfies both process-based and energy-based compliance criteria. Ultimately, California should work to improve full compliance; both process-based and energy-based compliance. However, it’s important to establish that the state, authorities having jurisdiction, and other energy professionals play a much larger role in process-based compliance, while energy-based compliance focuses on the performance of the as-built product and whether it meets the intentions established by the Energy Code. Energy-based compliance is significantly more challenging to investigate and collect data on due to the numerous provisions within the Energy Code and the granular data required at different construction phases, resulting in highly resource-intensive efforts—particularly

when attempting to analyze hundreds or thousands of buildings to obtain representative samples for targeted building stock. Therefore, staff recommends focusing the research efforts on process-based compliance and limiting the scope of energy-based compliance evaluation.

Additionally, the terms compliance evaluation and compliance checks serve different purposes. *Compliance evaluation* involves using statistical analysis to assess regional compliance rates, while *compliance checks* focus on determining whether individual projects meet specific compliance requirements. Historically, statewide studies in California have primarily leveraged compliance evaluations to assess the energy savings of as-built projects to attribute those savings to energy efficiency programs. This approach often overlooks other root causes of noncompliance. A study that incorporates both compliance evaluation and compliance checks—examining both regional trends and project-level outcomes—would provide a more comprehensive understanding of compliance than previous studies.

Impact of Unpermitted Projects

Particularly for residential building categories, there are two key recent studies that provide quantification of the unregulated or unpermitted market. In 2017 Det Norske Veritas (DNV), an internationally accredited registrar and classification society formerly known as DNV GL, conducted a study that found only 8 to 29 percent of heating and air conditioner (HVAC) changeouts obtain a permit in California. In 2014, the Stanford Regulation, Evaluation, and Governance Lab (RegLab), an impact lab that focuses on using data science and AI to improve government programs and policies, concluded that about 25 percent of newly constructed detached accessory dwelling units obtain a permit in the City of San Jose. These are low permitting rates. Low permitting rates imply the lack of process-based compliance and potential negative impacts to energy-based compliance. Moreover, the unregulated market also affects quality workforce, and worker programs and undermines the benefits set by the building codes. Due to the unknown number and impact of unpermitted projects, there are significant data gaps that make it difficult to fully understand the extent of noncompliance and the cost of noncompliance to the state.

Field Study Challenges

While there are national protocols developed by the U.S. Department of Energy (U.S. DOE) on field studies, compliance evaluations vary based on the context of the population being studied, the compliance ecosystem in place, the state's regulations, and the research questions. A literature review shows a higher number of residential field studies than nonresidential and multifamily likely because of the level of complexity of evaluation and difficulties in data collection. The costs for rigorous field studies are high and depend on the sampling design, including the number of strata and total number of samples.

Gap Analysis

This report identifies 20 gaps that impede a full understanding of compliance rates in California. Staff categorized gaps by types, including categories such as data gap, practical-application, literature gap, policy alignment gap, and temporal gap. To better facilitate interested parties' input and to prioritize the most critical gaps for future efforts, CEC staff developed a gap framework based on four criteria: alignment, transparency, market coverage, and feasibility. The total scores are weighted according to each criterion and then ranked. Similar scored gaps will show equal ranks.

Some gaps, such as "higher quality permit data is required" and "increased coordination needed with CPUC C&S program evaluations in looking at energy savings impact from compliance", can be mitigated within the project team's controls. More complex issues—such as prioritizing building categories, evaluating the impact of unpermitted projects, and developing whole-building energy-based compliance metrics—would benefit from input and discussion with subject matter experts, consultants, and local jurisdictions to identify the most impactful and feasible solutions. Gaps that can benefit from further discussion with interested parties are shown in **bold text** below.

Table 1: List of Final Ranked Gaps

Rank	Gap Name
1	Variability in compliance definitions
2	No single methodology to quantify compliance rates
2	Prioritize existing single-family residential buildings
2	Need for higher quality permit data
5	Poor data quality in the compliance process
6	Manual data collection from AHJs
6	Voluntary participation for field data collection
8	Field studies only provide a snapshot of compliance in time
8	Diverse building categories necessitate multiple analytical methods
8	Prioritize newly constructed multifamily over existing
8	Prioritize newly constructed nonresidential buildings over existing
12	Increase coordination with CPUC's C&S program evaluations
12	Challenges and costs of whole-building compliance assessments
12	Unclear level of energy compliance in unpermitted projects
12	Lack of supporting data for nonresidential building categories
12	Limited availability of HVAC sales tracking data
12	Sampling challenges lead to uncertainty
18	Lower priority for covered process
19	High scope and costs for nonresidential and multifamily categories
19	Limited compliance investigation coverage in rural service areas

Recommendations & Next Steps

To improve understanding of Energy Code compliance in California, CEC staff recommends a two-pronged approach: conducting field studies in the short term (1–5 years) and leveraging existing compliance infrastructure for systematic metric development in the long run (5+ years).

The current residential data registry system required by the CEC provides valuable information, including building characteristics and field verification results, forming a strong foundation for tracking compliance with specific measures. However, to develop a more complete picture, additional data—such as project plans, supplemental documents, and inspection checklists—are needed. These are typically maintained by California’s 540+ local jurisdictions, presenting an opportunity to strengthen collaboration across the state. Therefore, in the short to medium term, CEC staff recommends prioritizing the design and execution of tailored field studies. These field studies will play a critical role in verifying real-world conditions and performance, offering valuable insights into compliance across California’s diverse building stock. While these studies will require significant coordination and resources—reflecting the scale of California’s economy—they also present an important opportunity for broad local engagement and targeted analysis by building category (e.g., existing residential, new nonresidential, multifamily).

For the long-term (5+ years), CEC staff recommends leveraging the CEC’s existing investments in compliance infrastructure and on-going initiatives to track market trends. Rather than building a new, dedicated compliance tracking system, the project team recommends focusing on systematically developing compliance metrics using existing tools. While current data-driven methods have primarily focused on evaluating how much unpermitted work is occurring, they do not capture compliance directly. Unpermitted projects may still achieve varying levels of energy-based compliance, highlighting the need for more field-survey type of data to understand their impact on both building occupants and broader energy consumption trends. Emerging data sources—such as satellite imagery, assessor records, and interval meter data—offer promising opportunities for collaboration with research institutions and technical experts. The use of permit data and related construction data can inform the sampling approach and serve as valuable tools in closing key information gaps.

To guide and refine these efforts, the CEC can engage interested parties through public workshops, surveys, tailored engagements, and/or focus groups. This includes gathering feedback and answers to the following questions:

1) Prioritization of building categories – Which building category is most important for understanding compliance rates? Does Prioritization Option 2 as recommended in Chapter 6 align with interested parties?

1. Existing Single Family Residential

2. Newly Constructed Nonresidential
3. Covered Process
4. Existing Nonresidential
5. Newly Constructed Multifamily
6. Existing Multifamily
7. Newly Constructed Residential

2) Clear achievable objectives for process-based compliance and energy-based compliance – What are the feasible data that can be collected to answer key research questions and provide the most value? To what extent is our compliance evaluation focused on adherence to the full text of the Energy Code versus a targeted set of key impact measures?

3) Impacts of unpermitted projects – How important is it to evaluate the impact of unpermitted projects in the field survey? What is the scale of resources needed to identify and investigate unpermitted projects?

4) Understanding the variability in local jurisdictions workflow, capacity, and supporting infrastructure – With more than 500 local jurisdictions that oversee land uses, growth patterns, and local policy priorities, what are important considerations to sampling needs and challenges? What are the main barriers that local jurisdictions face in collecting and sharing permit data? How can burden be minimized during the data collection process?

CHAPTER 1:

Understanding the Current Landscape

In this chapter, California Energy Commission (CEC) staff delve into the energy codes compliance research landscape, aiming to provide a comprehensive overview of the current domain. Through a meticulous examination of various data sources and the latest research, staff consolidated the existing knowledge and identified critical gaps. By synthesizing insights from multiple perspectives, this chapter sets the groundwork for a deeper understanding of energy code compliance challenges through research and observations, followed up by a systematic inventory of gaps to be presented in subsequent sections.

1.1 Benefits and Overview of the Gap Analysis

California's Energy Code (*California Code of Regulations, Title 24 Part 6*)¹ plays a crucial role in the state's climate action plan and decarbonization efforts. Recent updates are estimated to provide more than \$8.8 billion in statewide benefits from the 2022 Energy Code alone over its lifetime.² To realize these calculated savings, all construction activities must meet and comply with the Energy Code to each letter of the code. In practice, compliance levels likely vary across project scopes, building categories, geographical areas, and other considerations. Therefore, the CEC seeks to understand compliance trends quantitatively through compliance rates and through conducting qualitative analysis thereafter.

At a high level, *compliance rate* refers to the ratio of code compliant projects to the total number of projects. Quantifying compliance rates across California serves several critical functions. It enables identification of non-compliance patterns. This data is essential to identifying new energy efficiency measures for code adoption and can help to confirm or challenge the prevalent assumptions of high compliance rates in energy forecasting and investment analyses.

Research from the Institute for Market Transformation (IMT) shows that every dollar invested in code compliance and enforcement yields a sixfold return in energy savings.³

1 International Code Council (ICC). 2025. [2022 California Energy Code, Title 24, Part 6 with July 2024 Supplement](https://codes.iccsafe.org/content/CAEC2022P3). ICC. Available at <https://codes.iccsafe.org/content/CAEC2022P3>.

2 California Energy Commission. 2021. [Form 399 for the Proposed 2022 Energy Code](https://efiling.energy.ca.gov/GetDocument.aspx?tn=237722&DocumentContentId=70943). Docket 21-BSTD-01. TN#237722. Available at <https://efiling.energy.ca.gov/GetDocument.aspx?tn=237722&DocumentContentId=70943>.

3 Institute for Market Transformation, 2010. [Commercial Energy Policy Toolkit — Fact Sheet for Local Governments: Energy Code Compliance](https://www.imt.org/wp-content/uploads/2018/02/Commercial_Energy_Policy_Fact_Sheet_-_Code_Compliance.pdf). Available at https://www.imt.org/wp-content/uploads/2018/02/Commercial_Energy_Policy_Fact_Sheet_-_Code_Compliance.pdf.

Therefore, the benefits of understanding compliance can yield significant positive benefits.

This gap analysis seeks to uncover the possible pitfalls in conducting a comprehensive Energy Code compliance rate study, highlight and analyze the compliance rate evaluation methodologies that have been used by other studies, and provide recommendations for future comprehensive CEC-led compliance improvement efforts.

This gap analysis is split into six chapters:

Chapter 1: Provides **background** on compliance definitions and describes the existing compliance ecosystem, and key interested parties.

Chapter 2: Offers a **literature review** which summarizes work on energy code compliance in different countries, within the United States, and within California.

Chapter 3: Discusses analysis relating to permit data and other **data** resources.

Chapter 4: Inventories the gaps and discusses a gap framework and analysis.

Chapter 5: Discusses a menu of approaches for compliance rate field studies and data-driven studies.

Chapter 6: Provide staff's recommendations on the **next steps**.

This gap analysis is the first step in gathering information, understanding the barriers to quantifying compliance rates, and establishing an understanding of known gaps so that meaningful compliance improvements can be identified. The findings will be used to guide the CEC's efforts in developing and implementing future CEC-led compliance improvement efforts.

1.2 California Energy Code Compliance Ecosystem

The Energy Code is designed to reduce wasteful and unnecessary energy consumption in newly constructed buildings and existing buildings. The Energy Code is updated every three years by the CEC. Each code cycle, there are two primary phases leading up to the adoption of Energy Code updates: (a) the informal pre-rulemaking phase for data gathering and research and (b) a formal rulemaking phase for the official adoption that must be done in accordance with procedures set by CA's Office of Administrative Law. Development and adoption processes are technically rigorous and intentionally incite a tremendous amount of public engagement from a broad range of interested parties.

Once the CEC adopts updates to relevant parts of the California Building Code (CBC or Title 24), the adopted changes are submitted to the California Building Standards Commission (CBSC) for approval. The CBSC formally adopts these updates in conjunction with other updates to the entirety of the CBC. The code takes legal effect on January 1 of the following year, after the formal code adoption, allowing for a year to publish the new regulations and allow the public to prepare and plan.

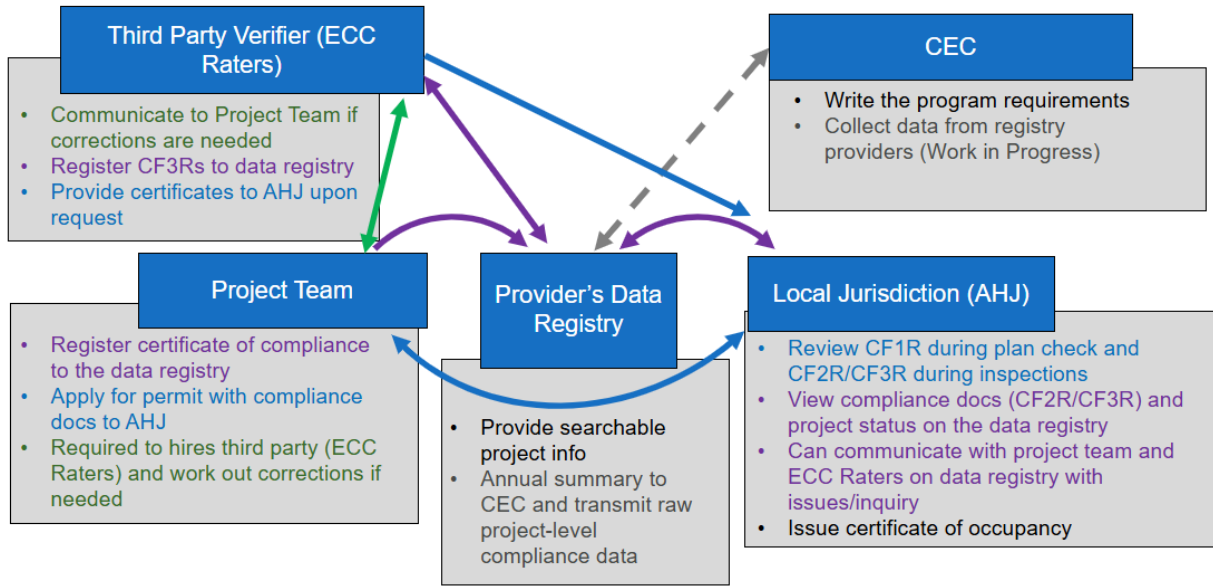
Authorities having jurisdiction (AHJ), which are typically city or county governments but also include other agencies such as the Division of the State Architect, typically have the responsibility of enforcing all parts of the California Building Code. To support the AHJs and other professionals, the CEC provides additional publications and support to help improve compliance with the Energy Code.⁴ The CEC also provides technical assistance through the Energy Code Hotline for the public. Additionally, the statewide Codes & Standards program (administered by the California Public Utilities Commission), regional energy networks (RENs), and California's utilities all partner to provide extended and vital Energy Code support such as training, technical assistance, and programs to support the adoption and implementation of the Energy Code.

In the compliance ecosystem, compliance forms and related documentation enable the identification of applicable requirements and communication between various parties. Third-party verifiers such as Energy Code Compliance (ECC) Raters (formerly known as the Home Energy Rating System [HERS] Raters) and Acceptance Testing Technicians (ATT) provide validation for the energy efficiency performance of what the Energy Code requires. The residential data registry was established earlier than the nonresidential data registry with the HERS regulation and program establishment in the late 1990s whereas the Acceptance Testing Technician Certification Provider (ATTCP) program was formally introduced in the 2013 Energy Code.

Figure 1-1 to Figure 1-3 illustrate the relationship between the compliance documentation and data flow ecosystem for residential, nonresidential, and multifamily building categories. The relationship shown in these figures is not meant to be comprehensive. The illustrations attempt to simplify the key relationships and interactions between major interested parties. The project team refers to building owners, designers/architects/engineers, and installers or general contractors. Solid arrows represent relationships between entities, with arrow colors corresponding to the matching colored text descriptions beneath each entity. Dashed lines indicate data communication pathways between the CEC and either the residential data registry or the ATTCP database.

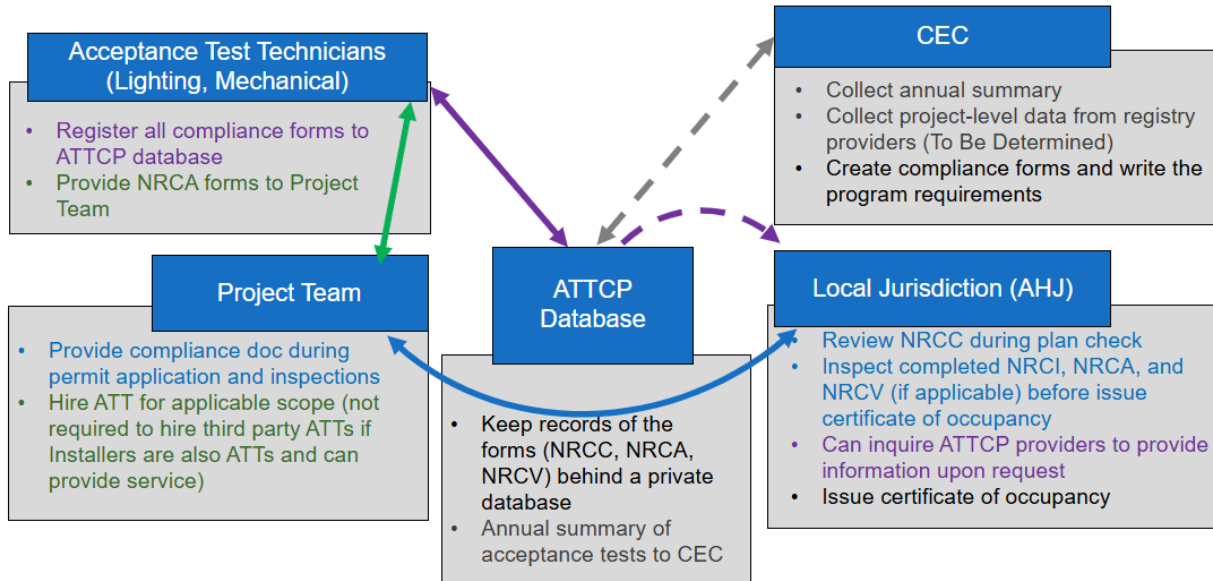
⁴ California Energy Commission staff. 2022. "[2022 Building Energy Efficiency Standards: Supporting Documents – Appendices, Compliance Manuals, and Forms](https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency#accordion-2623)." Available at <https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency#accordion-2623>.

Figure 1-1: Residential Compliance Ecosystem



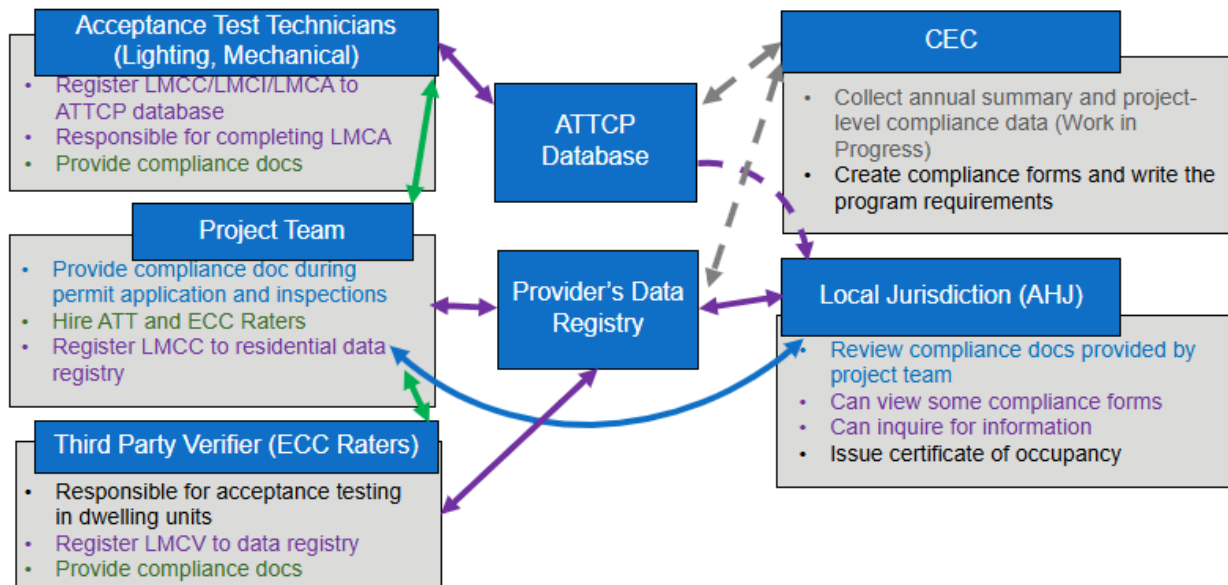
Source: CEC staff

Figure 1-2: Nonresidential Compliance Ecosystem



Source: CEC staff

Figure 1-3: Multifamily Compliance Ecosystem



Source: CEC staff

Local jurisdictions are the main touchpoint of all the comprehensive project data and compliance information. Currently, there is no existing mechanism for local jurisdictions to share this compliance data directly with CEC. The CEC relies on data made available from the data registry Providers or the ATTCP database, however these datasets are limited to registered compliance documents, and links between CEC and Providers are still under development for automatic retrieval and transmittal of compliance data. To better understand rates of compliance in the state, the CEC would benefit from project data (plan drawings, inspection checklist, and more) as well as compliance documents.

The nonresidential compliance ecosystem still has data gaps with automatic transmittance of compliance documents to the CEC. Unlike the residential side, nonresidential compliance documents do not have to be translated and stored into datasets that can be queried. Most nonresidential certificates of compliance (NRCC) forms are registered as PDF exports. The CEC is working to improve the compliance data pipeline for nonresidential projects.

GAP# 1. Manual data collection from AHJs. The CEC must collect data manually from AHJs to assess comprehensive compliance rates. The lack of project specific data will require the CEC to manually collect data from local jurisdictions.

The multifamily compliance ecosystem with specific low-rise multifamily certificates (LMC) forms is newly adopted in the 2022 Energy Code cycle. Previously, multifamily

projects used the combination of compliance form report (CFR) and nonresidential certificates (NRC) forms.

GAP# 2. High scope and costs for nonresidential and multifamily categories. Nonresidential and multifamily scopes vary and require additional subcategories that increase cost and scope. Compliance documentations for multifamily building categories vary because the scope and requirements differ significantly between a duplex and mixed-use high-rise, for example. With mixed use types, typically the ATTs are responsible for the nonresidential portion and ECC Raters are responsible for the dwelling scope. Thus, a future compliance study will need to consider additional subdivision within the multifamily categories to better capture the distinctive trends and to design the study efficiently. Similarly, nonresidential categories also include many building types that differ in characteristics (e.g., a church versus high-rise office building).

1.2.1 Forms

The CEC creates forms, manages reporting requirements, and approves data registries to support the design, construction, and enforcement parties with information to ensure that energy measures are properly installed respectively to their responsibilities and permitting processes. Compliance forms record the project information and energy requirements per the code that require verification and/or additional acceptance testing.

Forms are categorized by project phase as shown in **Table 2** below.

Table 2: Key Compliance Forms by Project Phase

Construction Phase	Residential Forms	Nonresidential and Multifamily Forms
Design – Submitted by designers or energy consultant during permit application.	Certificates of Compliance (CF1R) outline the proposed energy features and serve as the baseline for plan check.	Certificates of Compliance (e.g., NRCC/LMCC or nonresidential and multifamily projects) document the proposed energy features for plan review.
Construction – Submitted by the installing contractor.	Certificates of Installation (CF2R) document the proper installation of approved energy systems.	Certificates of Installation (e.g., NRCI/LMCI) ensure that the installed energy systems align with the approved design.
Verification – Submitted by the	Certificates of Verification (CF3R) confirms the independent verification of key measures, either by Home	Certificates of Acceptance (e.g., NRCA) or Certificates of Verification (e.g., NRCV/LMCV) confirm testing and commissioning

Construction Phase	Residential Forms	Nonresidential and Multifamily Forms
certified HERS Rater or ATTCP.	Energy Rating System (HERS) Raters.	of systems such as heating, ventilation, and air conditioning (HVAC), lighting, and building envelopes, typically verified by Acceptance Test Technicians. NRCV/LMCV can be verified by HERS Raters and is registered with the HERS/residential registry.

Each form is certified and signed by the applicable responsible person as well as any other required signatories. Given the diverse range of construction project scopes, there are many variations of certain form types to address specific needs.

For the 2022 Energy Code cycle, there are approximately 305 forms in total and 105 non-registered forms. CEC staff are continuously working on improving and simplifying the forms. For the 2025 Energy Code cycle, there are approximately 283 forms total and 52 non-registered forms. Out of 283 forms, approximately 108 forms are residential forms. To provide a perspective on the volume of data, CEC staff counted 11.1 million forms total received from CHEERS and CalCERTS through June 2023.

Most forms are required to be registered with a data registry. Non-registered forms do not require submission to a certified data registry. Non-registered forms are typically used for projects or measures that do not necessitate third-party verification or acceptance testing process. Instead, non-registered forms are completed, signed, and retained as part of the project documentation but are not uploaded or tracked electronically. These forms still need to adhere to the Energy Code and be readily available for review during inspections.

1.2.2 Third-Party Providers

Third-party Providers train, certify, and oversee the Acceptance Test Technicians (nonresidential) or Raters (residential) who perform field-verification and diagnostic testing (FV&DT) as required by the Energy Code. These Providers are approved by the CEC through a rigorous vetting process. Every code cycle, Providers must continually make improvements to align with Energy Code updates. They are also required to report to the CEC annually on their performance. In return, the CEC relies on the Providers to train and oversee Raters and technicians. Additionally, a Provider is required to manage complaints submitted to their data registry according to the CEC's standards. CEC oversees the performance of the Providers and can decertify a Provider.

On the residential side, the Home Energy Rating System (HERS) program can be traced back as far as the late 1990s. The CEC approves HERS Providers who then manage

independent, third-party agents called HERS Raters. In the 2025 Energy Code, this program was improved and renamed to the Energy Code Compliance (ECC) program.

On the nonresidential side, the Acceptance Test Technician Certification Provider (ATTCP) program was established in 2014 as part of the 2013 Energy Code. ATTCPs train and certify the Acceptance Test Technicians (ATTs) who perform acceptance tests and verify systems like lighting controls and mechanical setups are functioning per the Energy Code. These Providers maintain their own proprietary electronic databases that track ATTs. Currently, the CEC has approved several ATTCPs. Data Registries and Data Warehouse

Data registries facilitate the secure submission and storage of compliance forms, real-time updates and tracking of projects, and access for all interested parties, including builders, enforcement agencies, and independent verifiers. The Providers are required to operate and maintain a secure data registry that follows the appropriate documentation requirements, accessibility requirements, data retention requirements, and traceability requirements outlined in the Energy Code's Reference Appendices, Section 7 (JA7).

On the residential side, *most* compliance documents except non-registered forms must be submitted to the electronic HERS data registry. During the 2013 code cycle, the CEC implemented requirements to collect data for any data registry from the Provider. On a periodic basis (typically annually), approved residential Providers deposit secured data submissions of their data registry to the CEC in raw forms (.XML) format.

The CEC is working to aggregate the data into a central database, known as the Commission Compliance Documents Repository (CCDR). There are many data challenges in maintaining the extraction, transformation, and loading pipeline with the residential data registries. These include the complexity of the underlying data, changes in schema between code cycles, and continuous improvements/changes in the forms, regulations, and/or the code cycle updates that make it difficult to upkeep.

The CEC uses a data warehouse like Snowflake to store residential registry data for the 2016 and 2019 code cycles. This includes the residential projects registered up to 2021. Staff are actively working on establishing a robust data engineering pipeline for "unprocessed" data received from the Providers. Key considerations include accommodation for data structures changes and data dictionary mapping across code cycles. To provide a perspective on the magnitude of the data warehouse, staff counted 8 million residential forms from the 2016 and 2019 code cycle alone in 2022.

On the nonresidential side, there is no central data registry or warehouse that contains all ATTCP program data, and CEC data collection is pending detailed plans to do so. Additional tools are needed to resolve gaps in nonresidential data processing and collection such as the lack of schema in comparison to residential forms and associated cost as well as market readiness with improving the data standardization. CEC staff is working to understand how to ingest data from various ATTCPs and are actively

assessing if additional regulations, tools, and support are needed to establish a nonresidential database.

Available nonresidential and multifamily data are limited to the verification forms that can be verified by the HERS Raters and are registered in the HERS data registry. In addition, ATTCPs submit an annual report to the CEC and summarize the activities of their program.

1.3 Compliance Definitions

Energy Code compliance can be defined in several ways depending on the context:

1. **Compliance Approaches:** To comply with the Energy Code, project designs must choose to demonstrate compliance using either the prescriptive approach or the performance approach. The prescriptive approach offers a predetermined list of requirements that must be met to comply. The performance approach allows for maximum flexibility by using CEC-approved building energy modeling software to allow for trade-offs. In both cases, whether using the prescriptive approach or the performance approach, mandatory requirements must also be met.
2. **Energy Code Compliance (ECC) Program:** This program ensures installed compliance through field verification and diagnostic testing of specific measures.

When evaluating compliance with the Energy Code, CEC staff consider the number of projects and the degree to which each project adheres to the code. The definition of compliance can vary based on the evaluator's interpretation and the specific research questions. For instance, most studies using the Department of Energy (DOE) field study methodologies define compliance as the installation of required efficiency measures to the expected performance level. Other studies may define compliance as thoroughness of following compliance procedures or if projects energy performance is better than the top 6 to 10 prescriptive measures.

GAP# 3. Variability in compliance definitions. Different use of “compliance” makes it confusing to understand. The definition of compliance is often omitted and assumed in various literatures. Compliance can be defined in different contexts, whether it’s complying with the regulatory processes or complying to the minimum performance requirements set by the Energy Code to meet intent. The research questions must be clear about compliance definitions that can affect the study design.

CEC staff define full compliance as a project that can demonstrate both:

- (a) **Process-Based Compliance:** This involves a project obtaining permit, closing permit, providing accurate documentation (compliance forms and permitted

drawings) to show they meet all Energy Code requirements from design to construction, and passing field verification and testing, and final inspection.

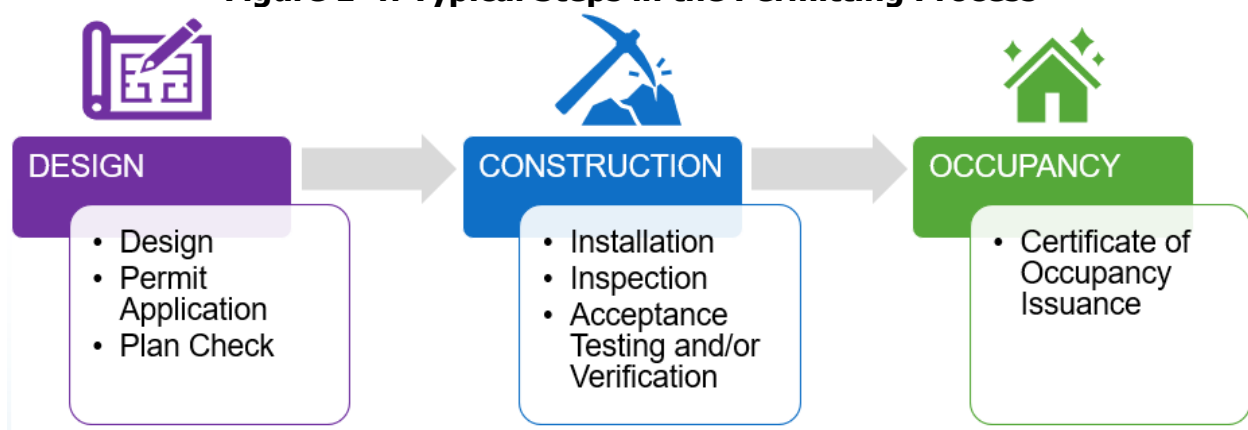
(b) **Energy-Based Compliance:** This approach only assesses the projects' energy performance and whether the installed project's energy efficiency performance meets the intention of the Energy Code upon completion.

The distinctions between the two definitions of compliance are important because defining compliance with process-based compliance alone may not achieve the energy savings intended by the Energy Code. Conversely, projects that bypass process-based compliance may still achieve some intended energy savings. The extent of missed energy savings opportunities is unknown. These uncertainties underscore that energy savings alone cannot be assumed or guaranteed solely through one definition of compliance.

1.3.1 Process-based Compliance

The permitting process contains several stages and steps within those stages as shown in **Figure 1-4**.

Figure 1-4: Typical Steps in the Permitting Process



Source: CEC staff

This classification of 3 stages narrows down relevant stakeholder groups, specific compliance challenges, and key performance indicators (KPI) unique to each stage. Measuring compliance rates across each permitting stage provides the CEC with valuable insights into the root causes where interested parties struggle to meet requirements.

One purpose of process-based compliance is to better understand how closely the correct procedures for verifying and documenting Energy Code compliance are being followed. Prior studies repeatedly identified data quality gaps as one of the key barriers to a successful comprehensive study. Specific studies that looked at process compliance

include the 2015 BayREN PROP report⁵ and the 2007 Quantec Noncompliance Rates⁶ investigation report.

Process-based compliance in each stage evaluates whether sufficient documentation was submitted as required by the Energy Code. A scoring system can be used to identify the completeness of compliance documentation and energy-related information contained in the permit application. It can be useful to identify the trends and features that are often missing or incorrectly done.

While not elaborated in this section, there can be unique challenges to understanding process compliance. For example, it is particularly difficult to evaluate process-compliance during the design stage if certain information is omitted or written “as required by the Energy Code” on plans without calling out what the requirements are.

Evaluators may collect data at each stage to compare to the initial Certificate of Compliance for applicable projects to determine the extent building energy performance has been impacted due to intentional changes or unintentional gaps. As construction activities vary in scope, triggers for Energy Code requirements become scattered and dissimilar across projects, making updating compliance documentation very time-intensive, costly, and difficult.

1.3.2 Energy-based Compliance

Ultimately, California should work to improve full compliance; both process-based and energy-based compliance. However, it's important to establish that the state, authorities having jurisdiction, and other energy professionals play a much larger role in process-based compliance, while energy-based compliance is primarily driven by the installation quality and more difficult to verify depending on the project's scope complexity.

Projects achieve energy-based compliance when the project's energy performance, as installed, meets the intention of the Energy Code regardless of its documentation. This definition is a utilitarian perception to compliance where the end-product, the energy efficiency performance of a building, has met similar goals set by the Energy Code.

While this definition is agnostic of compliance documentation, the lack of documentation (like unpermitted projects for instance) will make it extremely difficult to determine the full extent of energy performance because many requirements are not

⁵ Benningfield Group Inc, BKi, Association of Bay Area Government. 2015. [BayREN Code & Standards Permit Resource Opportunity Program \(PROP\) Final Report and Energy Code Resource Guide](https://www.bayren.org/sites/default/files/2021-11/bayren_cs_prop_final_report_2015_0401_0.pdf). Bay Area Regional Energy Network. Available at https://www.bayren.org/sites/default/files/2021-11/bayren_cs_prop_final_report_2015_0401_0.pdf.

⁶ Khawaja, M. Sami, Allen Lee, and Michelle Levy. 2007. [Statewide Codes and Standards Market Adoption and Noncompliance Rates](https://www.calmac.org/publications/Codes_and_Standards_Final_Report.pdf). Quantec, LLC. Available at [https://www.calmac.org/publications/Codes and Standards Final Report.pdf](https://www.calmac.org/publications/Codes_and_Standards_Final_Report.pdf).

easily inspected or available through a site walk-through without additional testing, physically removing finishes, verifying controls sequences, etc.

The diverse requirements per project and the need to sample many buildings adds to the complexity in energy-based compliance evaluation. Through the literature review, staff found there are many approaches to evaluate energy-based compliance including by measure level, by building system level, or by whole building level.

Since code adoption relies on new measures and their cost-effectiveness, understanding compliance at the measure level offers the most valuable insights for future code development. However, the measure level approach can be less useful to the higher-level policy decision maker to understand the holistic impact of noncompliance savings due to technical considerations for interactive effects and relative importance of scale. Because IOU C&S programs have claimed whole-building savings between 2015-2019, the CPUC's 2016 evaluation based on energy performance on a whole-building approach instead of a measure level approach during the 2013-2015 Program Cycle.⁷

Evaluators typically use building energy modeling software to calculate whole-building energy usage. The inputs to an energy model may vary from simple (~20 to 50 variable inputs), moderate (most typical, 100-300 inputs), to complex (typically large nonresidential buildings, 500 to 1000 inputs). Thus, evaluators often may trade precision with simplification of the evaluation through lesser stringent interpretation of what it means to minimally meet the performance by the Energy Code. **Table 3** below describes the stringency levels, interpretation, and possible evaluation approaches.

Table 3: Various Depth of Energy-based Compliance Definitions

Stringency / Depth	Interpretation
Loose / Less depth and may use reasonable assumptions in place of field data	A project with overall energy performance that meets or exceeds the Energy Code will be considered compliant. The project may not comply with some measures as prescribed by the Energy Code but cannot be disqualified from being considered energy-based compliant.
Medium / Limited in-depth investigation and effort	A project's ability to meet the energy performance intended by the Energy Code is measured on a spectrum or scale. Not every

⁷Cadmus, DNV GL. 2017. *California Statewide Codes and Standards Program Impact Evaluation Volume Two: 2013 Title 24, Page 17*. California Public Utilities Commission. Available at <https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fpda.energydataweb.com%2Fapi%2Fview%2F1861%2FCPUC%2520CS%2520Volume%25202%2520Report%2520DRAFT%252005232017.docx&wdOrigin=BROWSELINK>.

	mandatory measure and prescriptive measure will be investigated. Only limited key measures that are impactful to the overall energy performance evaluation will be investigated.
Stringent / Thorough investigation and effort to collect data for all applicable measures including mandatory measures	A project must meet every requirement set by the Energy Code, including all mandatory measures and achieve savings equal or greater than prescriptive measures. If the project misses any measure, it will be considered noncompliant.

Based on the literature review in Chapter 2, all existing studies have adopted “Loose” to “Medium” stringency interpretations due to the complexity and resources required for more in-depth analysis. None of the studies investigated the conformance of every single requirement to the letter of the Energy Code.

GAP# 4. No single methodology to quantify compliance rates. It is difficult to implement a comprehensive study that applies the “stringent” interpretation of the requirements. The variance in interpretation stringency, depth of investigation, and resources available add to the complexity of how a compliance rate study should be conducted. Past studies tried to simplify the study design to obtain actionable insights to improve compliance and did not check every requirement to the letter of the code. The extent of rigor and how the study is designed can be a source of confusion and point of debate with external interested parties.

The energy-based compliance definition has limitations in that it does not clearly establish accountability when compliance failures occur or identify responsible parties. However, quantifying energy savings impacts from Energy Code compliance provides valuable information for building code interested parties and policy makers in their decision-making processes.

CHAPTER 2:

Literature Review

This literature review for Energy Code compliance evaluations encompasses a comprehensive examination of existing research that investigates building energy code compliance practices in different countries, within the United States, and within California historically.

The literature around the topic of compliance evaluation is not easily summarized because the most relevant publications are privately stored or published through private portals. Some studies are no longer available through retired websites and are not readily accessible online such as the retired Western HVAC Performance Alliance (WHPA) library.

Out of approximately 1,400 files and 240 folders gathered related to the relevant topics of how to evaluate building energy code compliance, CEC staff narrowed the analysis' relevant studies and extracted key themes. Given the extensive volume of literature, data sources, and online websites examined, the research team prioritized comprehensive content analysis and extracting substantive insights over meticulous bibliographic organization. This gap analysis will highlight the most relevant sources distilled from our findings. Expanding on the preliminary work of previous staff, this literature review aims to strengthen our understanding of energy code compliance evaluations and establish a more solid foundation for prioritizing future contributions to the field.

2.1 Compliance Evaluation Practices Internationally

Scholarly research on international building energy code compliance standards remains limited and fragmented in isolated pockets, with only a handful of publications found on exploring compliance practices across different countries. An American Council for an Energy-Efficient Economy (ACEEE) publication on **China**⁸, which has the world's largest new construction residential and nonresidential markets, claims a 95%+ rate of compliance due to rigorous oversight from the government, particularly in urban areas. The publication notes that compliance rates improved from 2005 to 2011, reaching 100% in design and 95% in construction. However, the authors cautioned that the near-perfect compliance rates can be misleading due to how compliance rates were defined and the lack of data quality. The stringent compliance framework is likely more applicable in urban areas or jurisdictions and to large new buildings only. Additionally,

⁸ Bin, Shui and Steven Nadel, 2012. "[How Does China Achieve a 95% Compliance Rate for Building Energy Codes?: A Discussion about China's Inspection System and Compliance Rates](https://docslib.org/doc/1856105/a-discussion-about-chinas-inspection-system-and-compliance-rates)". 2012 ACEEE Summer Study on Energy Efficiency in Buildings. Available at <https://docslib.org/doc/1856105/a-discussion-about-chinas-inspection-system-and-compliance-rates>.

some of the enforcement strategies include penalties for non-compliance, use of third parties (in both design and construction) in enforcement of building energy codes, and strict quality control/supervisions to enforcement through scheduled or random inspections, in addition to daily on-site inspections and annual inspections.

Japan employs an annual survey method to monitor compliance with its Building Energy Efficiency Act for newly built residential and nonresidential buildings.⁹ For smaller buildings under 300 m², the questionnaire survey is sent to builders while the Ministry of Land, Infrastructure, Transport and Tourism manages surveys for larger buildings by collecting information from building owners.

GAP# 5. Voluntary participation for field data collection. Field data collection requires voluntary participation from building owners and local jurisdictions. The United States, including California, does not have regulations to demand random and periodic audits of compliance with the Energy Code. Thus, data collection is dependent on building owner and local jurisdiction decision and willingness to share data access to the State's evaluation team(s). This recruitment process differs from an obligation by law that all building owners must allow the State to conduct a compliance audit.

In the **United Kingdom**, non-compliance was found prevalent in approximately two-thirds of newly built dwellings completed between 2006 to 2009.¹⁰ The compliance profile was influenced by several factors including the calculation submissions requirements, builders' experience, building controls, energy performance certificate, construction method, dwelling types, and project sizes. Greater compliance was observed in timber-framed dwellings over masonry dwellings as well as flats (apartment complexes) over single-family houses.

A national study in **Australia** examined the discrepancies between building design and construction, identifying points of non-compliance with code across jurisdictions.¹¹ The study concluded that low levels of enforcement and insufficient government resources

⁹ Delgado, Alison, Andrea Mott, and Meredydd Evans. 2021. *Best Practices for Building Energy Code Compliance*. Pacific Northwest National Laboratory. Available at https://www.iea-ebc.org/Data/publications/EBC_WG_BECs_Codes_Compliance_Practices_November_2021.pdf.

¹⁰ Wei Pan, Helen Garmston, 2012. Compliance with building energy regulations for new-build dwellings, *Energy*, Volume 48, Issue 1, Pages 11-22, ISSN 0360-5442. Available at <https://doi.org/10.1016/j.energy.2012.06.048>.

¹¹ Harrington, P. and M. Johnson. 2014. National Energy Efficient Building Project. Pitt & Sherry. Ref: HB13477H004. Available at https://energymining.sa.gov.au/data/assets/pdf_file/0009/658494/NEEBP-final-report-November-2014.pdf.

for auditing created minimal consequences for non-compliance, ultimately resulting in an opaque and ineffective energy code enforcement process.

In **Europe**, a study comparing building permit procedures across 27 European countries found that countries with more streamlined and efficient permitting processes may achieve higher compliance with building regulations, including energy regulations, as these systems facilitate quicker approvals and encourage adherence to standards.¹² Nevertheless, energy code compliance rates vary significantly across countries, with most studies indicating substantial gaps between design and actual construction performance. A 2015 study by the European Commission found that most European countries struggle with effective energy code enforcement and produced compliance rates range between 30-70% by country and by building types. Barriers to compliance included lack of monitoring mechanisms, insufficient penalties for enforcement, limited technical expertise among builders, and complex regulatory frameworks.¹³

Overall, the literature review of the energy code compliance rates for foreign countries does not demonstrate in-depth explorations into the compliance evaluation methods and generally discusses compliance rates at a high level. It is possible that there is a language gap, leading to the literature gap of understanding how foreign countries employ compliance evaluation methods. The next two sections are focused on the compliance evaluation methods that were used within the United States and methods that were used specifically in California.

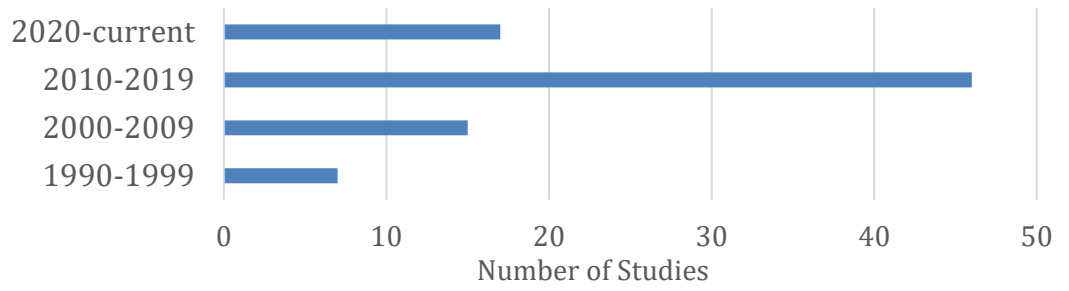
2.2 Compliance Evaluation Practices in the United States

In the United States, energy code compliance evaluation studies have been done as early as the 1990s as shown in **Figure 2-1**. Most studies conducted energy code compliance evaluations through field studies based on a sample of buildings. CEC staff focuses on the literature review around field studies in this section. Alternative approaches using other data sources are discussed in Chapter 3.

¹² Pedro, João, Frits Meijer, and Henk Visscher. 2011. *Comparison of building permit procedures in Europe in European Union countries*. COBRA 2011 – RICS Construction and Property Conference. Available at <https://www.researchgate.net/publication/257527312>.

¹³ European Commission: Directorate-General for Energy, Arbon, J., Allington, M., Lonsdale, J., Brajterman, O. et al. 2015. *Energy Performance of Buildings Directive (EPBD) – Compliance study – Final report*. Publications Office of the European Union. Available at <https://data.europa.eu/doi/10.2833/281509>.

Figure 2-1: US Energy Code Compliance Publications Over Time



Source: CEC staff

Typically, field studies are separated by building categories, such as nonresidential, residential, and multifamily. Multifamily like townhouses, duplexes, apartments, and others are typically evaluated within the residential building category. **Figure 2-2** to **Figure 2-4** below show the number of publications reviewed for each state.

Figure 2-2: Nonresidential Field Studies Publications by State

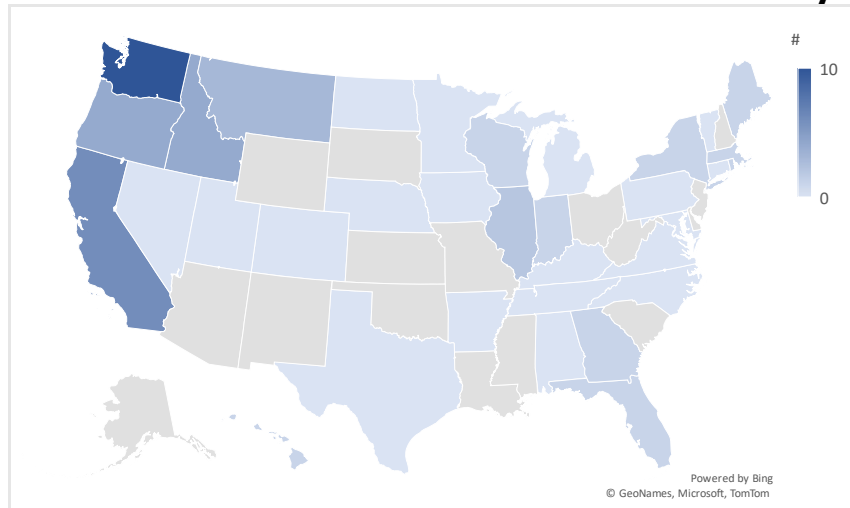


Figure 2-3: Residential Field Studies Publications by State

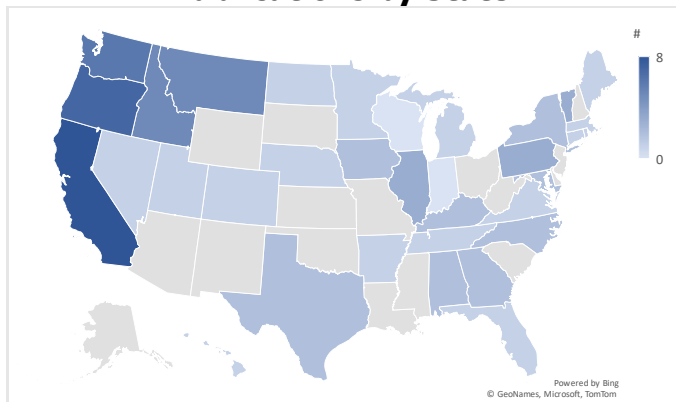
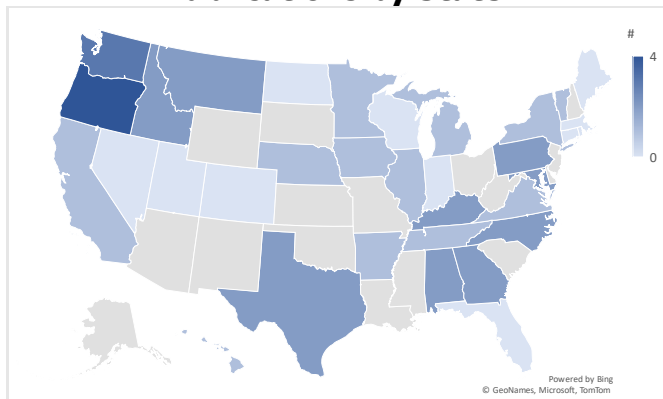


Figure 2-4: Multifamily Field Studies Publications by State



Source for Figures 2-2 to 2-4: CEC staff

The west coast states showed a higher number of studies conducted for Residential and Nonresidential. Studies in Washington, Oregon, Idaho, and Montana were conducted by Northwestern Energy Efficiency Alliance's (NEEA) since the late 1990s. Duplicative publications covering multiple states for the same code cycle evaluation can increase the number of studies shown in the graphs.

Other resources on this topic include the Department of Energy (DOE), providing a map showing which states conducted field studies.¹⁴ Several papers provide excellent references to the body of work conducted in United States.¹⁵

All in all, there is no single methodology to calculate compliance rates. To simplify the many variations in energy code compliance evaluations, CEC staff categorized studies into several categories shown in **Figure 2-5**.

APPENDIX A: Table of Field Methodologies, provides a detailed description of each method, its variations, disadvantages, advantages, and references.

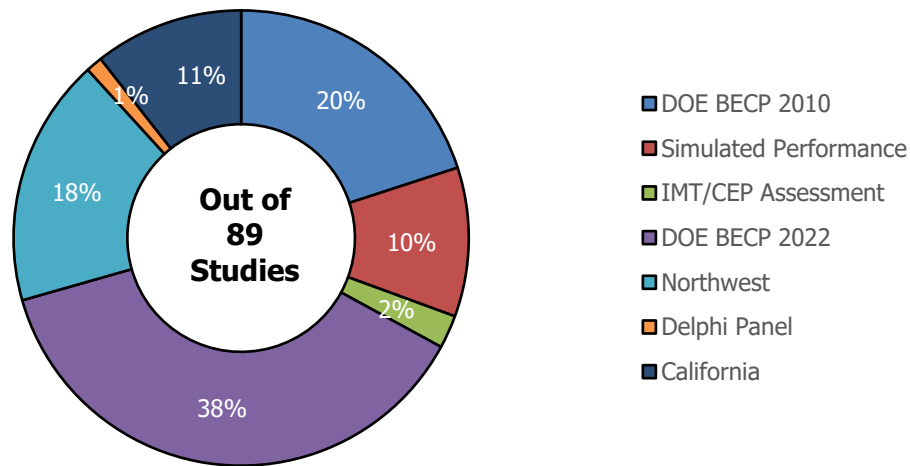
¹⁴ Building Energy Codes Program. 2023. "[Energy Efficiency Field Studies](https://www.energycodes.gov/energy-efficiency-field-studies)." US Department of Energy. Available at <https://www.energycodes.gov/energy-efficiency-field-studies>.

¹⁵ Notable literature reviews accomplished by other researchers can offer more nuanced interpretation given the inherent complexity of energy code compliance assessment methodologies.

Yang, Brian. 2005. [Residential Energy Code Evaluations: Review and Future Directions](https://www.nrc.gov/docs/ML1123/ML11231A844.pdf). Building Codes Assistance Project. Available at <https://www.nrc.gov/docs/ML1123/ML11231A844.pdf>

Xie, Yulong, Mark Halverson, Rosemarie Bartlett, Yan Chen, Michael Rosenberg, Todd Taylor, Jeremiah Williams, and Michael Reiner. 2020. [Evaluating Building Energy Code Compliance and Savings Potential through Large-Scale Simulation with Models Inferred by Field Data](https://doi.org/10.3390/en13092321). Energies 13, no. 9: 2321. Available at <https://doi.org/10.3390/en13092321>

Figure 2-5: Studies by Field Evaluation Methodology



Source: CEC staff

The DOE, with significant input from the Pacific Northwest National Lab (PNNL), is considered a national leader in developing consistent methodologies and protocols for the type of data collected and analyzed in the last two decades. Hence, most energy code compliance studies for other states followed the DOE methodologies. Recent NEEA studies, particularly for the residential building category, provided PNNL with additional metrics for analysis because evaluators conducted their own analysis and data collection that expanded on the DOE methodology. Prior studies in California did not follow the DOE protocols and are discussed in greater details in Section 2.3 and Appendix B Compliance Evaluation Practices in California.

Prior to 2010, the DOE created standard field study methodologies to measure statewide energy code compliance (referred to as DOE BECP 2010 method). BECP stands for Building Energy Codes Program, an office within DOE that helps fund the development of field study protocols. PNNL updated these methodologies for residential, nonresidential, and low-rise multifamily buildings (referred to as DOE BECP 2022 method) between 2014-2022. The updated methodologies introduced a significant change: instead of simply determining whether a measure complies or not, it provides a performance scale for compliance.

Although the standard field study protocols outline the necessary steps and tools for states to assess compliance, the specific methods for data collection and evaluation can change based on data availability and study objectives.

In the 2022 DOE residential field methodology, the process included several steps:

1. The project team determined a sample size based on geographical area and key energy efficiency measures (63 samples for each of the 8 measures) that have the most impact on energy savings.

2. The project team obtained sample data through Dodge Analytics' new construction data or directly from building departments.
3. The team conducted site visits to willing participants where construction was complete.
4. The project team checked the installed measures against construction documentation for accuracy.
5. From the site visit data, the project team analyzed statewide compliance rates by comparing deviations from the installed measures to the construction documentation. Since a single site visit per home may lack complete data, this creates an analytical challenge to create a full set of inputs to an energy model that will generate reliable results. Hence, the project team also calculate the statewide energy savings by using the Monte Carlo simulation methods and simulate thousands of "pseudo homes" that provide a statistical representation of the newly constructed homes population for a given state.

The goal is for the states to conduct similar studies every 3 to 5 years to track trends and identify areas needing improvement. For the nonresidential field study, the sample size contains 63 to 67 samples per measure, focusing on nonresidential office and retail buildings across two ASHRAE climate zones in a pilot project.

Despite these nationally recognized methods for understanding compliance, the authors acknowledge that a single site visit doesn't provide a meaningful compliance rate metric. These studies often result in detailed analyses of targeted measures and potential savings, which can vary significantly between measures and states. Furthermore, this methodology does not tell us more about untargeted measures or whole-building noncompliance savings.

Staff noted that these field studies are so expensive that scope needs to be limited to certain measures to conduct a detailed evaluation. Otherwise, broader and more general studies may not include the level of detail warranted or desired by other interested parties.

CEC staff also researched the cost of past field studies and found the range of costs was significant. Most studies vary between a few hundred thousand to several million dollars. PNNL researchers, who typically have PhDs, were heavily involved in the analysis where unknown costs are absorbed elsewhere. Discussion between CEC staff with the NEEA field studies team revealed that their contract covers data collection and specific analysis while DOE covers the cost for PNNL researchers to conduct their analysis.

GAP# 6. Field studies only provide a snapshot of compliance in time. Comprehensive studies are expensive and time consuming, hence most experts recommend conducting a field study every 3 to 5 years. Even though by the time study is completed, findings may be outdated.

Methodologies like the Northwest, Simulated Performance, California, and IMT/CEP Assessment follow similar steps like the DOE field studies protocols (figure out your sample size, design the survey experiment, collect data, and perform analysis). However, they differ in data collection methods, types of data gathered, sources of data, and analysis techniques for determining compliance rates. Recent Northwest studies have adopted their own strategies while also gathering data required by PNNL/DOE field studies. This dual approach aims to enhance the value of their data collection efforts.

Overall, recent California studies related to compliance rates are mostly derived from the Codes and Standards program Impact Evaluation and differs between evaluation cycle. In general, California studies aimed to use whole building analysis to capture compliance and noncompliance savings to avoid double counting and account for interactive effects rather than just compliance at the measure-level. One study attempted to quantify compliance at three stages within the permitting process.

Overall, California faces challenges in adopting the DOE field methodology because:

1. The DOE field studies method is designed around model codes such as IECC and ASHRAE 90.1 that may overlook specific requirements in California's Title 24.
2. The measure-level focus is highly resource intensive, requiring substantial time, funding, and skilled personnel for fieldwork, data analysis, and reporting. Establishing a partnership or agreement with PNNL/DOE to leverage PNNL researchers' experience will be necessary to ensure conformance to this methodology.
3. The DOE field studies scopes are limited to permitted project and reliance on available data that can be subjected to sampling bias or convenience sampling. In addition, there's a lack of focus on understanding unpermitted rates and addressing unknown gaps in the current market that can lead to significant impact.

2.3 Compliance Evaluation Practices in California

California has long been recognized as a trailblazer in energy efficiency standards, yet comprehensive statewide Energy Code compliance studies remain limited. CEC staff aim to provide critical context by offering a high-level overview of California's Energy Code,

examining existing evaluation practices and studies, and identifying key insights into current compliance assessment methodologies.

2.3.1 Overview of General Timelines

The history of Energy Code compliance practices in California is marked by legislative action, evolving policies, and collaborative efforts among various interested parties relating to Energy Code compliance evaluations. Here's an overview of key milestones:

1. **Warren-Alquist Act (1974):** Established the California Energy Commission (CEC), laying the groundwork for energy efficiency standards.
2. **Introduction of Title 24 (1978):** Marked the adoption of California's first Energy Code, which set energy efficiency standards for residential and nonresidential buildings.
3. **1990s - Market Assessment & Evaluation (MA&E) Study:**¹⁶ This groundbreaking study evaluated trends and challenges in implementing the Energy Code. It provided recommendations for improving energy efficiency in new construction, setting the stage for future compliance evaluations.
4. **AB970 and Time-Dependent Valuation (TDV) (2000):** Introduced a performance-based compliance approach to supplement the prescriptive compliance approach.
5. **Residential New Construction (RNC) Program Evaluation (2004):**¹⁷ PG&E commissioned study to determine compliance rates for new homes outside of the RNC program, analyzing a representative sample of 600 single-family homes. The study used on-site survey data with the MICROPAS modeling tool to evaluate compliance and calculated savings. Some considered this the California baseline compliance rates study.¹⁸

¹⁶ Pacific Consulting Services et al. 2000. *MA&E Study in Support of Codes & Standards, Vol. 1 – Final Report*. Pacific Gas and Electric. ID-411. Available at <https://www.calmac.org/publications/20000831PGE0020ME.PDF>.

¹⁷ Gobris, Mary Kay. 2004. *Residential New Construction Baseline Study of Building Characteristics – Homes Built After 2001 Codes. Prepared for Pacific Gas and Electric*. Itron, Inc. Available at https://www.calmac.org/publications/RNC_2003_Final_Report1.pdf

¹⁸ State Compliance Studies. 2007. *Statewide Codes and Standards Market Adoption and Noncompliance Rates*. Available at <https://bcapcodes.org/state-studies/>

6. **California Energy Efficiency Evaluation Protocols (2004-2006):**¹⁹ Introduced a formal attribution approach, crediting utilities for their role in Energy Code implementation. These protocols standardized evaluation methodologies for compliance rates and savings attribution. Documentation is publicly available through clearinghouses.²⁰
7. **CPUC Long Term Energy Efficiency Strategic Plan (2008):** Provided a roadmap for achieving California's energy efficiency goals through enhanced building and appliance codes. The plan emphasized code compliance as a critical tool for reducing greenhouse gas emissions.

The following section will elaborate on the California Energy Efficiency Evaluation Protocols (2004-2006) that support a series of studies with the most relevant data for compliance rates.

2.3.2 California Evaluation Framework

California uses two key documents to guide its energy efficiency program evaluations.

- **The California Evaluation Framework (2004)**²¹ provides a systematic approach for planning and conducting program assessments. While not a detailed procedures manual, it helps evaluators decide when and how to conduct different types of assessments.
- Building on this foundation, the **California Energy Efficiency Evaluation Protocols: Technological, Methodological, and Reporting Requirements for Evaluation Professionals (2006)**²² offers more specific technical and methodological requirements. This document introduces the Compliance Enhancement Program Evaluation Protocol, **Figure 2-6**, which outlines multiple key areas for evaluation. This includes process evaluation (how well programs operate),

¹⁹ Methodologies employed for building Energy Code evaluation efforts in the state were first notably outlined in 2004 through the collaboration of third-party consultants and a CPUC advisory group and published as "The California Evaluation Framework".

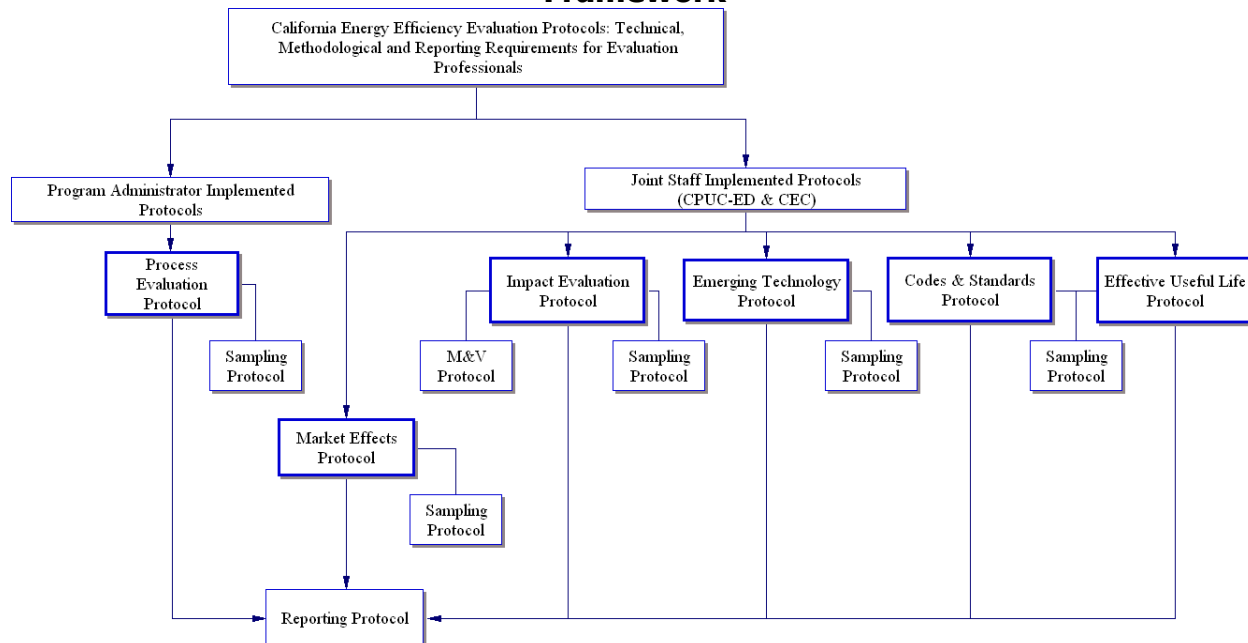
²⁰ A comprehensive history of EM&V Codes & Standards program evaluations, research plans, and related documents can be tracked in the following online publication databases: the California Measurement and Advisory Council's (CALMAC) searchable database (<https://www.calmac.org/>), the CPUC Energy Division's Public Document Area (<https://pda.energydataweb.com/>), and Project Status Report system (<https://psr.energydataweb.com/>).

²¹ TechMarket Works et al. 2004. [The California Evaluation Framework](https://www.raponline.org/wp-content/uploads/2023/09/tecmarket-caevaluationframework-2004-06.pdf). California Public Utilities Commission. Available at <https://www.raponline.org/wp-content/uploads/2023/09/tecmarket-caevaluationframework-2004-06.pdf>.

²² TecMarket et al. 2006. [California Energy Efficiency Evaluation Protocols: Technical, Methodological, and Reporting Requirements for Evaluation Professionals](https://www.researchgate.net/publication/304675662_California_Energy_Efficiency_Evaluation_Protocols_Technical_Methodological_and_Reporting_Requirements_for_Evaluation_Professionals). California Public Utilities Commission. Available at https://www.researchgate.net/publication/304675662_California_Energy_Efficiency_Evaluation_Protocols_Technical_Methodological_and_Reporting_Requirements_for_Evaluation_Professionals.

impact evaluation (program outcomes), and codes and standards evaluation (compliance and effectiveness of Energy Codes).

Figure 2-6: Protocols within California Energy Efficiency Program Evaluation Framework

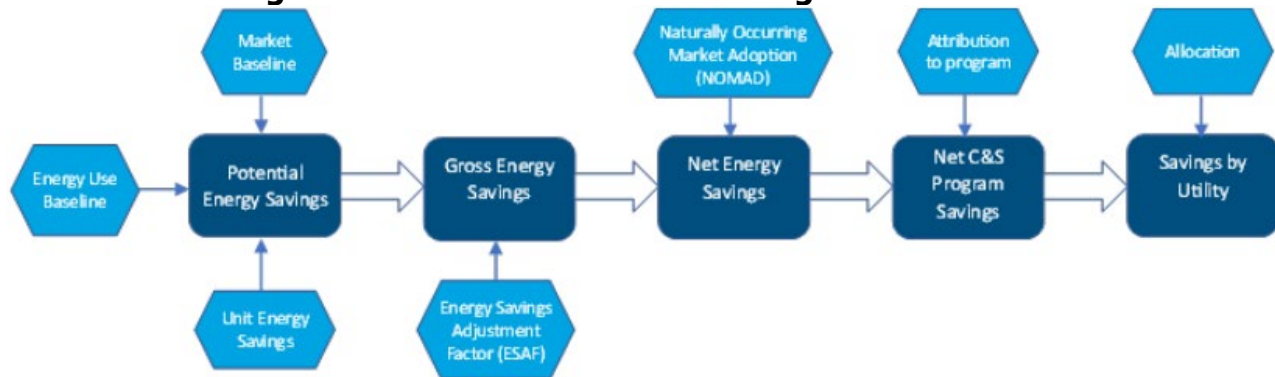


Source: TecMarket Works Team, 2006.²²

The 2006 document recommended measuring compliance rates both before and after program interventions to track market changes. Evaluators can use multiple methods to assess compliance, including but not limited to interviews and surveys, plan and document reviews, site visits and field verification, market research, economic analysis, and building simulation modeling. Importantly, the protocols recognize that compliance rates change naturally over time due to market forces and regulations.

To calculate the savings claims by utility, evaluators identify a “compliance adjustment factor” and other rates for each program cycle (typically every 3 years). These rates feed into the Integrated Standards Savings Model (ISSM), which serves as the central calculation tool. **Figure 2-7** shows the overall workflow to calculate the attribution savings.

Figure 2-7: CPUC Attribution Savings Framework



Source: Opinion Dynamics, 2024.

The ISSM evolved from a simpler tool - the Savings Estimate Spreadsheet (SES) - which Hescong Mahone Group developed in 2005.²³ That early version used a flat 30% non-compliance rate for all building measures. Today's ISSM represents more sophisticated statistical methodologies and shifting approaches toward compliance adjustments calculations.

2.3.3 Codes & Standards Evaluation Studies

The CPUC's Codes & Standards Evaluation Studies track the impact of statewide programs on a subset of Energy Code compliance and energy savings based on the scope of the IOU advocacy efforts. These programs encompass Building Codes Advocacy, Appliance Standards Advocacy, Compliance Improvements, Reach Codes, and Planning and Coordination. The studies evaluate impacts from the IOU advocacy efforts associated with both Title 20 (Appliances) and Title 24 (Building Codes) regulations. The most recent analysis, covering program years 2016-2018, revealed that Title 24 advocacy accounted for 24% of the IOU C&S program gross savings, while Title 20 advocacy contributed to the remaining 76%. The following sections focus specifically on key findings from the evaluations of the IOU statewide C&S Building Code Advocacy Program.

These studies measured "compliance" for specific measures through one metric, coining the few names such as Compliance Rates (CR), Compliance Adjustment Factor (CAF) and Energy Savings Adjustment Factor (ESAF).

Evolution of Compliance Metrics and Methodologies

1. **Early Evaluations (2006-2012) Key Metric:** Compliance rates were initially defined as the ratio of energy saved between the current standard and as-built

²³ Mahone, Douglas and Hescong Mahone Group Inc. (HMG) 2005b. *Codes and Standards Savings Estimate Spreadsheet Model*. CALMAC. Study ID: SCE0241.02. Available at https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fwww.calmac.org%2F%255C%255C%2Fpublications%2Ftotal_CS_Savings_HMG_-_Posted_v3b.xls&wdOrigin=BROWSELINK.

projects over the projected savings between the previous and current standard. CAF was introduced in the 2010-2012 cycle to adjust compliance rates by considering the actual energy performance of measures.

- **Methodology:** Early studies relied on tools like MICROPAS for residential buildings and measure-specific spreadsheets for nonresidential properties. Compliance rates were calculated based on plan reviews, field inspections, and building simulations.
 - **Findings:** Residential compliance rates varied regionally, while nonresidential compliance analysis faced challenges due to data limitations and sampling issues.
2. **Shift to ESAF (2013-2015) Key Metric:** ESAF replaced CAF for Title 24 evaluations, focusing on energy performance rather than strict code adherence.
- **Methodology:** ESAF measured compliance as a ratio of evaluated savings to expected savings, using whole-building simulations to account for interactive effects among measures.
 - **Findings:** Compliance rates ranged widely, reflecting differences in methodology, building types, and regional practices. The introduction of bounded and unbounded ESAF metrics highlighted variability in energy performance.
3. **Refinements in Recent Cycles (2016-2018) Key Metric:** ESAF was further refined to incorporate field inspection data and whole-building energy modeling.
- **Methodology:** Compliance was defined specifically as alignment with approved building plans, shifting focus from individual measures to overall energy outcomes. Sampling plans prioritized climate zones and high-impact measures.
 - **Findings:** Compliance rates exceeded 95% for many categories, but issues with multifamily sampling and non-random selection raised concerns about generalizability.

Ultimately, all evaluations faced difficulties in obtaining representative samples by building type, especially for nonresidential buildings.

GAP# 7. Increased coordination with CPUC C&S program evaluations. The methods employed in the CPUC's C&S evaluation leaned toward energy-based compliance definition and specific to certain measures under the IOUs programs. There are no cyclical studies that focused on process-based compliance rates although there were a few studies that tried to capture process-based compliance in the process evaluation reports. If CEC is to conduct studies to evaluate energy-based compliance, this may appear to have some overlap with the existing CPUC's scope in their energy efficiency program evaluation. Where practical, coordination between the CEC and CPUC can address potential overlapping research efforts and ensure complementary research approaches.

The evolution of CAF and ESAF metrics reflects California's commitment to refining its Energy Code compliance evaluations. Despite the ratio of actual savings over projected code savings are unchanging, there are still differences in definitions and methodologies across evaluation cycles that complicate cross-year comparisons.

The CPUC made a notable transition shifting from measure-level analysis to whole-building methodologies during the 2013-2015 cycle. This transition reflected the whole building claims that IOU program reported, improved the CPUC's ability to capture real-world energy performance, avoid double counting, and account for interactive effects while addressing ongoing challenges in data collection and analysis.²⁴

Nevertheless, there are some disagreements among interested parties regarding the scope and validity of current studies – which were designed to assess savings specifically attributable to the IOU C&S Building Code Advocacy program, of which the compliance rate is just one part of the entire study - to truly evaluate state-wide compliance rates, citing bias in the sampling design and lack of in-depth investigation in the analysis.²⁵

Whole-building approaches improved accuracy but required significant resources and consistent data collection practices. There are hundreds to thousands of input variables to whole building analysis. Furthermore, managing scope to accurately simulate hundreds of random buildings with verified field data can present a significant practical challenge and require highly skilled statisticians and building energy modelers. The Energy Code requirements vary across projects, making technical assessments time and resource intensive. There hasn't been a single standard survey design that promises to

²⁴ It is worth noting that the 2019-2024 IOU C&S program claims have been measure-specific, and the CPUC is considering utilizing measure-level evaluation approaches accordingly.

²⁵ See Appendix B for detailed analysis of stakeholder feedback.

deliver meaningful results while avoiding excessive complexity that could lead to human error and reduce result reliability.

Additionally, comments from utilities and industry experts emphasized the need for greater precision and transparency in compliance evaluations. This leads to a dilemma: the desire for both high accuracy and high precision must be balanced against the practical limitations of data sensitivity and inherent uncertainty. These goals are in conflict because the whole-building compliance assessment method, while thorough, presents a transparency and precision challenge. The sensitive nature of input data limits public dissemination of full results, and the precision is sensitive to input variations.

Table 4 below summarizes studies from C&S program evaluations except the first two studies that conducted field data collection to quantify compliance rates but do not necessarily follow the similar methodology and hold to the same protocol as the C&S evaluation plan. The first was from the 2004 Residential New Construction program. The second was from the Market Assessment and Process Evaluation report in 2007 by Quantec.

GAP# 8. Challenges and costs of whole-building compliance assessments. Whole-building compliance assessment, while thorough, presents challenges in transparency and precision due to the amount of diverse data required and efforts to site verify. Prioritizing this method may present significant cost and technical risks.

GAP# 9. Limited compliance investigation coverage in rural service. The CPUC's C&S evaluation reports serve to quantify savings attributable to each of the primary IOUs (PG&E, SDG&E, and SCE) programs. There is potential to enhance the data collection process by extending coverage to rural areas that may fall outside of traditional IOU program implementation zones. Since the data collection process largely depends on willing participants, expanding to rural areas may present unique recruitment challenges and require tailored approaches to obtain representative data.

Table 4: Summary of Scope and Results from Codes and Standards Evaluation Studies

Program Years (Primary Study Authors)	Building Categories Evaluated	How compliance rates were calculated	Compliance Rates or Adjustment Factors Results from Program Year Study
2005 (Itron)	Newly constructed residential	MICROPAS, a building simulation program, was used to translate on-site survey data and used to perform technical analysis. Compliance results developed for 575 homes and calculated weighted average compliance margin by region.	▪ Overall, the statewide newly constructed residential compliance rate is 73% ▪ South Coast region has the highest compliance rates of 95% ▪ Desert and Mountain areas have the lowest compliance rates of 61% ▪ Percent of glazing area has a high impact on compliance
2007 (Quantec)	Specific measures for Residential and Nonresidential	Each permit project was reviewed and given a score in each of 3 compliance categories (score =1 mean noncompliance existed with no intent to comply, score = 0.5 means partial compliance and attempt to comply, and score = 0 for full compliance) for each stage of the permitting process (Process, Design, Field Inspection). All noncompliance scores were weighted according to building department valuation values.	These are <u>noncompliance rates</u>. ▪ Residential: hardwired lighting – 28% ± 3%; window replacement – 68% ± 7%; duct improvement – 73% ± 1% ▪ Nonresidential: Lighting controls under skylight – 44% ± 10%; cool roof – 50% ± 3%; bi-level lighting controls – n/a; ducts in existing buildings – 100% ± 2%; ducts testing/sealing in new buildings – 100% ± 1% Noncompliance for each of the processes are not shown here. However, the noncompliance rates between each step of the process can vary

Program Years (Primary Study Authors)	Building Categories Evaluated	How compliance rates were calculated	Compliance Rates or Adjustment Factors Results from Program Year Study
			significantly. For example, nonresidential cool roof showed design noncompliance rate to be 99% due to lack of documentation whereas site visit confirmed approximately 8% noncompliance rate.
2006-2008 (KEMA; currently known as DNV)	Residential and Nonresidential; both newly constructed and existing	Compliance rates (redefined as CAF in later program year evaluation) = (energy use from 2001 Title 24 – as-built consumption under 2005 Title 24)/ (energy use from 2001 Title 24 – energy use from 2005 Title 24)	▪ Residential: whole house compliance estimated to be 120% - 235%. Specific measures under Residential: Compliance rate for lighting measures was 113%. Duct sealing showed a compliance rate of 59%. ▪ Nonresidential: 25% for existing alterations; 61.5% for new construction; 25% for multifamily. Results may not be valid due to sampling issues. Compliance rates by measure range from 8% to 100% per measure. Skylight was 8.3%, duct sealing requirements in existing buildings was 75%, cool roof in existing buildings was 75%, bi-level lighting controls compliance was 79%.
2010-2012 (Cadmus)	Nonresidential; newly constructed and existing	Compliance rate (CR) = model that minimally meets 2008 Title 24 / as-built consumptions at each site. CR values less than 1 indicated noncompliance. Compliance Adjustment Factor (CAF) = (model that minimally meet 2005 Title	▪ Nonresidential: CR: 101 to 115% for new construction (90 sites), 107-108% for lighting alterations (68 sites), ~82% for envelope and cool roof/reroof projects

Program Years (Primary Study Authors)	Building Categories Evaluated	How compliance rates were calculated	Compliance Rates or Adjustment Factors Results from Program Year Study
		24– as-built) / (model that minimally meets 2005 Title 24 – model that minimally meet 2008 Title 24) at each site.	CAF: 141-397% for new construction; 476-580% for lighting alterations; ~83% for envelope insulation and cool roof measures; 83% used as the default estimate if no other evidence is available
2013-2015 (Cadmus)**	Residential and Nonresidential	Energy Savings Factor (ESAF) was newly defined specifically for Title 24 evaluation. ESAFs are like CAFs in previous year where it's a ratio of estimated total evaluated savings to total expected savings within a building type. ESAF was defined as bounded when compliance scale is 0% to 100% and unbounded reflected the CAF metric in previous year where rates can be above 100%.	▪ Nonresidential ESAF bounded: For new construction, 89-91% For lighting alterations, 82-93% ▪ Nonresidential ESAF bounded: For new construction, 149-156% For lighting alterations, 148-165% ▪ Residential ESAF bounded: 53 to 87% ▪ Residential ESAF unbounded: 53% to 196%
2016-2018 (Opinion Dynamics, Guidehouse,	Nonresidential and Low Rise (Residential) Multifamily	ESAF equation remains the same as the previous year. However, the savings are evaluated differently based on the compliance definition. Hence, ESAF is a function of the total number of projects that were field inspected matching the	ESAF across all categories: 95%+ compliance across all categories

Program Years (Primary Study Authors)	Building Categories Evaluated	How compliance rates were calculated	Compliance Rates or Adjustment Factors Results from Program Year Study
Market Logics)		plans divided by total number of projects reviewed. Building simulation model was used to calculate the savings not built "as planned" from field inspection data to calculate difference in projected savings.	

2.3.4 Process Evaluation Reports

Several relevant reports from the Process Evaluation Protocol provide insights into the barriers and opportunities for improving Energy Code compliance in California:

1. **2007 Statewide Codes and Standards Market Adoption and Noncompliance Rates:**²⁶ Quantec conducted a study to refine the original estimates of noncompliance rates (30% for all measures) and other market related metrics and to test the process laid by the 2006 California Energy Efficiency Evaluation Protocols. This study was unlike the C&S evaluation studies in its methodology where it focused on understanding compliance at each step of the permitting process and utilized a categorical scoring approach. The authors reviewed 418 records representing 437 measures for both residential and nonresidential building categories, finding noncompliance estimates to be between 30% to 100% for various measures.
2. **2016 Codes & Standards Compliance Improvement Program Year 2013-2014 Process Evaluation Final Report:**²⁷ DNV GL conducted research to determine if the compliance improvement program activities are impactful to address barriers to Energy Code compliance and which components are effective in changing behaviors in effecting compliance through document review, telephone interviews, web surveys, and follow up telephone reviews. This qualitative process evaluation report identified remaining barriers to energy compliance including complexity of compliance, lack of incentives for permit compliance, quality installation not addressed within the Energy Code, and lack of clarity of what is required to comply.
3. **2019 C&S Attribution Study:**²⁸ TRC provided a high-level process evaluation of attribution methodologies, including compliance evaluation, and offered recommendations for improvement. TRC criticized the binary approach for estimating compliance, advocating for whole-building energy performance methodology. The authors also recommended to explore streamlined compliance assessment to reduce cost and improve transparency regarding savings, particularly over-compliance impacts.

2.3.5 Peripheral Studies on Compliance and Unpermitted Markets

California's past Energy Code compliance efforts have largely focused on permitted projects, yet a significant portion of construction activity exists outside the formal permitting process. This unpermitted market represents a complex and understudied segment that poses unique

²⁶ Khawaja, M. Sami, Allen Lee, and Michelle Levy. 2007. [Statewide Codes and Standards Market Adoption and Noncompliance Rates](https://www.calmac.org/publications/Codes_and_Standards_Final_Report.pdf). Quantec, LLC. Available at https://www.calmac.org/publications/Codes_and_Standards_Final_Report.pdf.

²⁷ DNV GL. 2016. [Codes & Standards Compliance Improvement Program Year 2013-2014 Process Evaluation Final Report](https://www.calmac.org/%5C%5C/publications/ComplianceImprovementImpactEvaluationDraftReport_FINAL-OUT.pdf). California Public Utilities Commission. CALMAC Study ID CPU0129. Available at https://www.calmac.org/%5C%5C/publications/ComplianceImprovementImpactEvaluationDraftReport_FINAL-OUT.pdf.

²⁸ TRC. 2019. [Codes and Standards Attribution Study](https://www.calmac.org/publications/Final_Report_CS_Attribution_Study_Mar_2019_(002).pdf). Southern California Edison. Available at [https://www.calmac.org/publications/Final_Report_CS_Attribution_Study_Mar_2019_\(002\).pdf](https://www.calmac.org/publications/Final_Report_CS_Attribution_Study_Mar_2019_(002).pdf).

challenges for compliance evaluation. The following studies provide critical insights into both permitted and unpermitted markets, offering a broader understanding of compliance dynamics and highlighting potential areas for improvement. Key findings include:

2015 – BayREN Code & Standards Permit Resource Opportunity Program (PROP) Final Report and Energy Code Resource Guide²⁹ aimed to evaluate permitting and compliance processes in Bay Area jurisdictions.

- **Method:** BayREN conducted a stakeholder survey with various building departments, several plan reviews, and shadow field inspections to understand Energy Code compliance and permitting processes.
- **Findings:** The study found significant discrepancies were observed between plan reviews and actual field conditions. Challenges included inconsistent enforcement, lack of resources, and varied levels of staff training. Recommendations included streamlining the permitting process, improving digital infrastructure, and enhancing training programs for code officials.

GAP# 10. Poor data quality in the compliance process. Data quality in the compliance process is likely low, making it more difficult to fully assess compliance. The data quality (including omission and completeness) in the data collection process is likely going to be a barrier to quality analysis and a risk to scope and cost.

2017 – The Case of Informal Housing in Southern California³⁰ - The authors conducted interviews with code officials on their perception of unpermitted housing Southern California and provide a perspective of the difficulty in code enforcement. This provides an in-depth investigation into the challenges AHJs face beyond the resources constraints that are often cited as a barrier to enforcement. The issues such as equity, political pressure, prestige, and lack of leverage against violators are key concerns that were brought up through the interviews.

2017 – Responsible Contractor Policy for EE Programs: Market Intelligence Study³¹ – Opinion Dynamics conducted literature research on the current state of contractor requirements in Program Administrator’s (PAs) retrofit installation and maintenance program, including code compliance and enforcement programs. Additionally, they investigated the deeply rooted issues that influence Energy Code compliance statewide.

²⁹ Benningfield Group Inc, BKi, Association of Bay Area Government. 2015. [BayREN Code & Standards Permit Resource Opportunity Program \(PROP\) Final Report and Energy Code Resource Guide](https://www.bayren.org/sites/default/files/2021-11/bayren_cs_prop_final_report_2015_0401_0.pdf). Bay Area Regional Energy Network. Available at https://www.bayren.org/sites/default/files/2021-11/bayren_cs_prop_final_report_2015_0401_0.pdf.

³⁰ Wegman, Jake and Jonathan P. Bell. 2017. [The Invisibility of Code Enforcement in Planning Praxis: The Case of Informal Housing in Southern California](https://digitalcommons.calpoly.edu/cgi/viewcontent.cgi?article=1349&context=focus). Focus 13 Peer Reviewed. Available at <https://digitalcommons.calpoly.edu/cgi/viewcontent.cgi?article=1349&context=focus>.

³¹ Opinion Dynamics. 2017. [Responsible Contractor Policy for EE Programs: Market Intelligence Study. California Public Utilities Commission](https://www.calmac.org/publications/Responsible_Contractor_Policy_Study_Report_FINAL.pdf). CALMAC Study ID: CPU 0178. Available at https://www.calmac.org/publications/Responsible_Contractor_Policy_Study_Report_FINAL.pdf.

- **Method:** Literature review and interviews with stakeholder focus groups.

Findings: Concern over pulling permits for large nonresidential sector is not significant or even perceived as a concern. Permit compliance is a significant issue in small nonresidential and residential space. In HVAC, compliance is a significant concern, especially with the residential sector. The study noted that permit rates are likely between 10% to 38% from various studies. Overall, many interested parties perceive little value in complying with the Energy Code and explained the decision to pull a permit in most cases comes down to cost.

2017 – HVAC Permit and Code Compliance Market Assessment^{32,33} – DNV GL estimated the prevalence of unpermitted HVAC installations in residential buildings.

- **Method:** Employed a dual approach combining field surveys and data analysis. A top-down approach compared estimated HVAC sales to the number of known permits. The estimated HVAC sales were derived from census data, end-of-useful-life data, and other data sources to estimate the number of HVAC equipment that need to be replaced to represent estimated HVAC equipment sales and crossed checked with Air-Conditioning, Heating, and Refrigeration Institute (AHRI) national HVAC sales numbers. The bottom-up approach uses site surveys to analyze a representative sample of data to estimate the total number of HVAC changeouts (actual) vs. the total number of permitted HVAC changeouts.
- **Findings:** Unpermitted HVAC changeouts were prevalent, driven by homeowner preferences, competitive pressures, and minimal enforcement consequences. The rate of installations permitted ranges from 8% to 29%. Highlighted the need for targeted legislation and outreach programs to encourage permit compliance. DNV GL found similar levels of efficiency for equipment at permitted and nonpermitted sites in a representative statewide sample, suggesting permitting does not necessarily mean increase in energy efficiency of HVAC changeouts. In addition, there are documentation gaps where not all permitted installations require HERS compliance forms. Among the submitted forms, only a subset contained a complete set of required tests. DNV GL replicated their own performance test and found some systems were out of compliance even though the HERS documentation noted they complied.

Significance: This study was widely acknowledged by industry, often cited by interested parties in advocating for higher permitting rates and was cited in assembly committees of proposed legislation.³⁴

³² DNV GL. 2017. [2014-2016 HVAC Permit and Code Compliance Market Assessment \(Work Order 6\) Final Report](https://www.calmac.org/publications/HVAC_WO6_FINAL_REPORT_VolumeI_22Sept2017.pdf). California Public Utilities Commission. CALMAC Study ID: CPU0172.01. Available at https://www.calmac.org/publications/HVAC_WO6_FINAL_REPORT_VolumeI_22Sept2017.pdf.

³³ DNV GL. 2017. [2014-2016 HVAC Permit and Code Compliance Market Assessment \(Work Order 6\) Final Report - Appendices](https://www.calmac.org/publications/HVAC_WO6_DRAFT_REPORT_APPENDICES_VolumeII_22Sept2017.pdf). California Public Utilities Commission. CALMAC Study ID: CPU0172.01. Available at https://www.calmac.org/publications/HVAC_WO6_DRAFT_REPORT_APPENDICES_VolumeII_22Sept2017.pdf.

³⁴ Garcia, Eduardo. 2022. [SB-1164 \(Stern\)](https://autl.assembly.ca.gov/sites/autl.assembly.ca.gov/files/SB%201164%20%28Stern%29.pdf). Assembly Committee Hearing. Available at <https://autl.assembly.ca.gov/sites/autl.assembly.ca.gov/files/SB%201164%20%28Stern%29.pdf>

2017 – WHPA Contractor Survey³⁵ sought to understand contractors’ motivation for bypassing the permitting process through a survey. Contractors cited homeowner reluctance, cost concerns, and competitive disadvantages as key barriers to obtaining permits. Recommendations included incentivizing compliance through rebates and imposing stricter penalties for non-compliance.

3C REN Permit Study Finding and Jurisdiction Need Assessments³⁶ conducted literature reviews and interviews with building departments and contractors to understand the challenges with permitting and Energy Code compliance. This outlines many obstacles that have are often brought up in public discourse, pointing to knowledge gaps, familiarity, lack of digital infrastructure to facilitate streamlined permit review, and frequent corrections. It also highlights geographical needs and challenges for certain geographical areas for California can differ from others (compared to the BayREN permit study).

2024 – Not (Officially) In My Backyard³⁷ – Stanford researchers assessed the scale of unpermitted accessory dwelling units (ADUs) in San Jose using an innovative method.

- **Methods:** Using satellite imagery and computer vision to estimate detached unpermitted ADUs in the City of San Jose.
- **Findings:** Approximately 75% of detached ADUs were unpermitted. Highlighted equity and safety concerns, as well as gaps in enforcement. Recommended leveraging technology to identify unpermitted units and create pathways for legalization.

GAP# 11. Diverse building categories necessitate multiple analytical methods. Quantifying unpermitted activity across diverse building categories may necessitate employing multiple data driven analytical methods to enhance detection accuracy. Analyzing unpermitted construction rates remains a critical area for understanding compliance risk comprehensively. Preliminary findings suggest that data techniques such as permit-to-project matching and anomaly detection are more effective at identifying unpermitted activity in new construction than in existing buildings, where data is often fragmented or incomplete. Unpermitted work may significantly affect compliance outcomes across multiple building categories, but limited and inconsistent data sources constrain quantification. Targeted research is needed to refine detection methods and assess the potential impact of unpermitted activity on compliance metrics and savings estimates.

³⁵ Western HVAC Performance Alliance (WHPA). 2017. *Understanding the Residential HVAC Compliance Shortfall*. Available at http://www.performancealliance.org/Portals/4/Documents/Committees/Goal1/WHPA%20Compliance%20White%20Paper%20DRAFT2_7.12.17%20with%20Comments.pdf

³⁶ TRC, unknown year. *Permit Study Findings and Jurisdiction Need Assessments*. 3C-REN. Internal Report.

³⁷ Jo, Nathanael, Andrea Vallebuena, Derek Ouyang, and Daniel E. Ho. 2024. *Not (Officially) In My Backyard*. Stanford RegLab. Journal of the American Planning Association. 2024 Vol 0. Number 0. Available at <https://dho.stanford.edu/wp-content/uploads/JAPA.pdf>.

2.3.6 Energy Code Noncompliance Savings

The methods to calculate energy code noncompliance savings are not consistent across the different categories of studies. Most studies don't explicitly define the inner steps of their analysis and only present the results. Moreover, noncompliance savings are not often calculated compared to compliance savings since some studies are using the results to attribute savings to programs. CEC staff try to distill how various methodology categories calculate energy code noncompliance savings are calculated in **Table 5**.

Table 5: Noncompliance Savings Calculation by Method Category

Method Category	How Noncompliance Savings are Calculated
DOE BECP 2010	Due to the method being pass/fail to single criterion of the energy code, the researchers writing the methodology noted that the compliance rates calculated from this approach are not conducive to provide a valuable view of the potential energy savings from noncompliance in a state. ³⁸
DOE BECP 2022	An energy analysis, using the statistical analysis results, model an average statewide EUI in a typical home from 1,500 "pseudo home" models using a Monte Carlo simulation (randomly draw probability distribution for key items to create pseudo homes). These pseudo homes encompass the most possible combination of key items values in proportion to the distribution found in the observed field data. DOE did not explicitly discuss how noncompliance savings can be calculated and only indicated that this statewide EUI energy use analysis can indicate average energy use in a defined region relative to what would be expected based on the established baseline.
Northwest	Compliance savings were estimated based on the compliance rates for each measure that would accumulate over 5, 10, and 30 years of construction. NEEA also focused on looking at "Above Code Observations" to identify the overall energy use intensity (EUI) for a surveyed home to the standard code compliant home.
CPUC's IOU C&S Advocacy Program Impact Evaluations	Compliance rates adjust Potential Savings to estimate projected Gross Savings. Gross Savings are then multiplied by NOMAD and Attribution rates to determine the Net Program Savings statewide. Statewide savings are adjusted to include only the IOU service territories. Noncompliance savings are not normally calculated.
Simulated Performance	Use energy modeling software to simulate energy performance for specific measures or specific building component or whole-building to estimate savings between actual as-built data points to its standard projected savings. The analysis steps are unclear and typically require

³⁸ PNNL. 2010. [Measuring State Energy Code Compliance](https://www.energycodes.gov/sites/default/files/2023-07/MeasuringStateCompliance.pdf). Report # PNNL-19281. Available at <https://www.energycodes.gov/sites/default/files/2023-07/MeasuringStateCompliance.pdf>.

Method Category	How Noncompliance Savings are Calculated
	some statistical analysis or weighting to come up with overall saving estimates for a building category.
IMT/CEP	Suggested the use of energy modeling to estimate noncompliance savings. No other specificity is provided.
Delphi Panel	Compliance/noncompliance rate is expressed as a percentage. It is assumed that noncompliance savings are equal to non-compliance rates times the energy code projected savings.

CHAPTER 3:

Data

A wide range of existing data sources are available to support compliance rate analyses. These include building construction data, construction permit data, compliance documentation, field survey data, appliance sales data, and many other valuable sources. These data sources play a crucial role in formulating accurate compliance rates.

Staff conducted thorough research to identify and catalog these data sources. This chapter highlights the various sources available and discusses how they can be utilized in a comprehensive compliance analysis. Gaps within the current data are also addressed. Many of these sources were used in previous compliance studies and were identified through a literature review.

Additionally, the chapter explores potential data sources that could support future compliance analysis. While these sources are relevant to building construction, further investigation is needed to assess their feasibility and applicability.

Lastly, the chapter covers data sampling techniques. For field survey-based compliance rate analysis, applying proper sampling methodologies is essential to ensure that findings are both accurate and reliable and enable scoping cost for future studies.

3.1 General Building Market Characterizations

Effective evaluation of energy code compliance begins with understanding how the Energy Code applies to the building stock. The Energy Code is divided into chapters by building categories (residential, nonresidential, multifamily) and project scopes (new construction, addition and/or alterations). Energy Code requirements are determined based on the permit issuance date, which defines which code cycle is effective, and the project's scope, which defines the extent of the requirements.

CEC staff propose a structured classification of the building market into seven (7) building categories to delineate scope and perform targeted analysis. The building categories are:

- Newly Constructed Single-Family Residential
- Existing Single-Family Residential
- Newly Constructed Multifamily (2 or More Units)
- Existing Multifamily (2 or More Units)
- Newly Constructed Nonresidential
- Existing Nonresidential
- Covered Processes

Typically, work that warrants a permit is likely to contain applicable Energy Code requirements. The scope of work that typically does not trigger the Energy Code requirements include minor repairs and maintenance that do not alter building systems, purely cosmetic

renovations, some replacement of individual equipment without changing system configuration (e.g. replacing failed motor with equivalent motor of the same horsepower and efficiency), and temporary structures or emergency repairs. Specific exemptions depend on the enforcing agencies and the extent of the work performed.

CEC staff conducted preliminary market research by examining census and permit data.

3.1.1 Primary Data Sources

CEC staff utilized the data sources below to describe the existing building stock and permitted construction activities trends in this chapter. Other relevant data sources such as projected building constructions are not included in this section and are discussed in sequential sections in this chapter.

- **The U.S. Census Bureau** collects and provides comprehensive demographic, economic, and social information about the nation's population conducted every 10 years to determine congressional representation, federal funding distribution, and policy decision. The Census Bureau conducts surveys like the American Community Survey (ACS) and the Economic Census that are more frequent (annually or every 5 years) that offer similar insights such as income, education, employment, housing, and business trends. California's Department of Finance generates data products for California from the 2020 Census.³⁹
- **Building Permit Survey by the U.S. Census Bureau and California Department of Finance Construction Permits Data:**⁴⁰ The California Department of Finance utilized the (free) Building Permit Survey to estimate construction permits in California. This data focuses on residential and multifamily buildings, not nonresidential or industrial.
- **The Annual Progress Report (APR) from the California Department of Housing and Community Development (HCD):**⁴¹ Collected from local governments on their housing element implementation from their general plan, this data source includes reports of housing permits issued, house production goals, affordable housing development, and compliance with Regional Housing Needs Allocation (RHNA).
- **Construction Industry Research Board (CIRB) Data:** The California Homebuilding Foundation provides building permit data through California Industry Research Board (CIRB), covering both nonresidential and residential building production from most jurisdictions in California. The California Energy Commission subscribes annually to access detailed permit-level data from 2023 onward and aggregated city-level data prior to 2023. CIRB data contains only issued permits per calendar year; closed permit data is not presently available.

³⁹ California Department of Finance (DOF). 2025. "[2020 Census Data.](https://dof.ca.gov/forecasting/Demographics/2020-census-data/#CDP)" State of California. Available at <https://dof.ca.gov/forecasting/Demographics/2020-census-data/#CDP>

⁴⁰ State of California Department of Finance. 2025. "[Construction Permits.](https://dof.ca.gov/forecasting/economics/economic-indicators/construction-permits/)" Available at <https://dof.ca.gov/forecasting/economics/economic-indicators/construction-permits/>.

⁴¹ California Department of Housing and Community Development (HCD). 2025. "Annual Progress Report." State of California. Available at <https://www.hcd.ca.gov/planning-and-community-development/annual-progress-reports>.

- **Unpermitted Construction Data:** There is no dataset that explicitly tracks unpermitted construction. Unpermitted construction activities discussed in this gap analysis will be rough estimates based on the best available data points.

3.1.2 General Trends

California's geography and regional economy are among the most diverse and dynamic in the United States, making it unique compared to the rest of the country. In 2023, California had the highest gross domestic product (GDP) in the country.⁴² With a population 4 times larger than the combined Northwestern states⁴³, California demands a more precise study to reflect its demographic diversity.

In 2020, California's population was about 39 million.⁴² In 2023, the California Department of Finance (DOF) forecasts the State will grow to 41.7 million people by 2050⁴⁴ a reduction from the previous forecast in 2019 of 50 million people.⁴⁵ This observation in the changing population forecast coupled with cost of housing indicates that fast changes in construction activity, demand, and market can impact the context of an Energy Code compliance study design. Since a study provides a snapshot of market conditions at a specific point in time, understanding the demographics of housing and cost of housing data can be contextual for an Energy Code compliance study.

3.1.3 Residential and Multifamily Building Market Characteristics

Residential data from reliable sources such as Census data is typically expressed as housing data, which includes single-family and multifamily residences.

California's Existing housing stock is largely comprised of approximately 9.2 million single-family homes and 4.5 million multifamily units.⁴⁶ Around 65% of the population resides in single-family homes, 31% reside in multifamily units, and the remaining 4% in other housing types such as mobile homes or manufactured homes.⁴⁷ The large occupancy of single-family homes reflects the focus on single-family residences in the research landscape where single-family residences dominate in studies and dataset availability.

⁴² BEA. 2024. "[GDP by State](https://www.bea.gov/data/gdp/gdp-state)." Available at <https://www.bea.gov/data/gdp/gdp-state>

⁴³ StatsAmerica. 2024. "[Population Estimate for 2024](https://www.statsamerica.org/sip/rank_list.aspx?rank_label=pop1)." US Economic Development Administration (EDA). Available at https://www.statsamerica.org/sip/rank_list.aspx?rank_label=pop1. Population of California is approximately 39 million compared to roughly 15 million for the Northwestern states (Washington, Oregon, Idaho, Montana).

⁴⁴ State of California Department of Finance. 2023. "[Projections](https://dof.ca.gov/Forecasting/Demographics/projections/)." Available at <https://dof.ca.gov/Forecasting/Demographics/projections/>

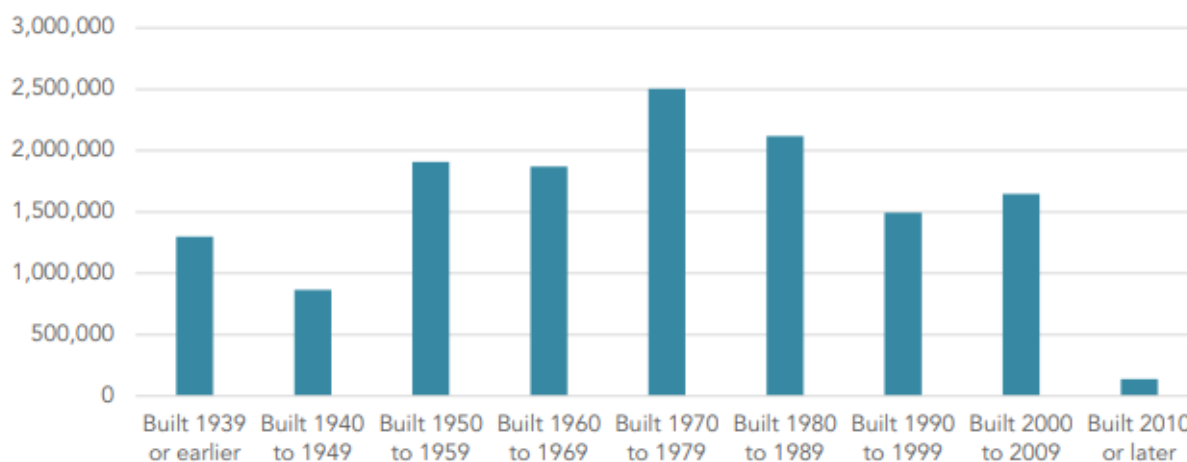
⁴⁵ Mahone, Amber, Charles Li, Zack Subin et al. 2019. *Residential Building Electrification in California*. Chapter 2.2. ETHREE. Available at https://www.ethree.com/wp-content/uploads/2019/04/E3_Residential_Building_Electrification_in_California_April_2019.pdf.

⁴⁶ Kenney et al. 2021. *California Building Decarbonization Assessment - Final Commission Report*. California Energy Commission. Publication Number: CEC-400-2021-006. Available at <https://www.energy.ca.gov/publications/2021/california-building-decarbonization-assessment>.

⁴⁷ California Department of Housing and Community Development. 2018. *California's Housing Future: Challenges and Opportunities. Final Statewide Housing Assessment 2025*. Available at https://www.hcd.ca.gov/policy-research/plans-reports/docs/sha_final_combined.pdf.

About half of California housing stock predates 1970 as shown in **Figure 3-1**, before the first Energy Code came into effect in 1978. With most homes built before 1980, these older structures often require more rehabilitation and tend to be less energy efficient. This implies that Energy Code saving opportunities in existing buildings can be complex depending on structural conditions and may lead to higher uncertainty if savings are assumed on average.

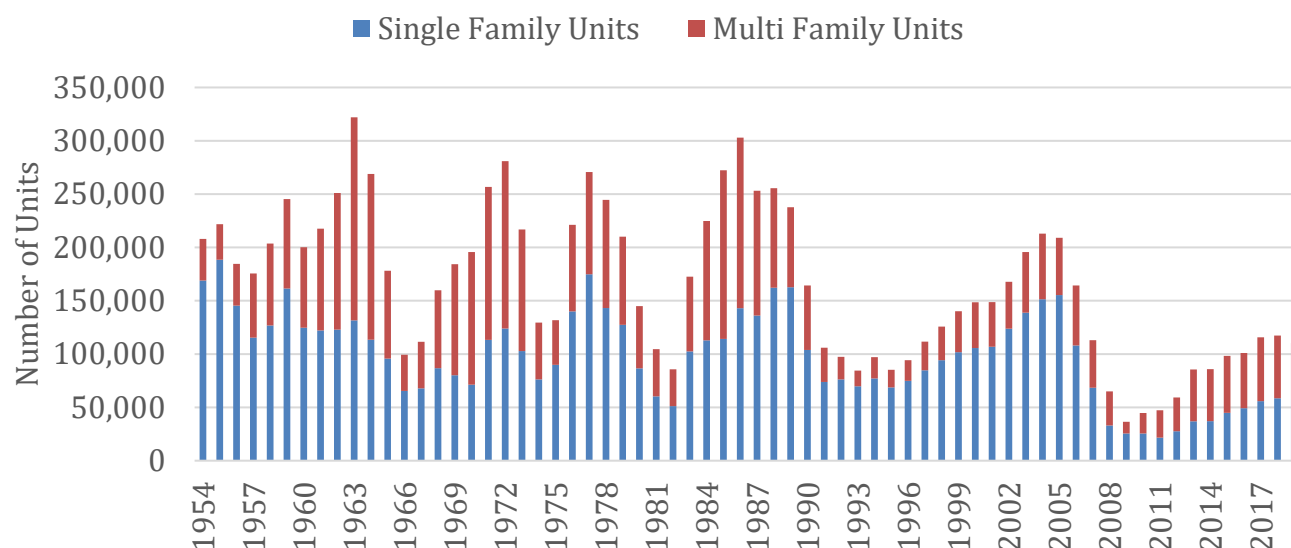
Figure 3-1: California Housing Stock by Vintage
Majority of California Housing More Than 35 Years Old
Age of Housing in California 2011-2015 Average



Source: Graphic by Housing and Community Department. Data sources from U.S. Census Bureau, 2011-2015 American Community Survey 5-Year Estimates, DP04.⁴⁷

For newly constructed activities, the DOF estimates that approximately 58,500 new single-family home permits and 53,000 multifamily home permits were issued in 2023.³⁹ In recent years, California has averaged around 100,000 new homes annually. **Figure 3-2** shows how California had averages of more than 200,000 new homes annually before the economic downturn in the mid-2000s. This indicates that housing production has not returned to the level in previous decades to meet the projected housing needs.

Figure 3-2: Annual Permitting of Housing Units 1954-2019



Source: Graph by CEC staff. Data source from CIRB.⁴⁸

The percentage of multifamily housing has been increasing relative to single-family residences. Recent policy such as SB375 promotes high density and mixed-use development. As population demographics and housing trends change, future Energy Code compliance studies may consider shifting study focus to current needs.

CEC staff analyzed the detailed permit data from CIRB in 2023 to observe the majority of California permit market size by building categories.

Table 6 represents the estimated size of the residential market by permits and by units. This includes permitted construction activity from CIRB. There are two caveats to consider. First, recorded permits do not always directly translate into constructed units. CIRB provided unit counts for all permit types except alterations/additions, new/altered garages, and other structures. Where missing, CEC staff assumed a 1:1 ratio of permits-to-units for these denoted by an “*”. Second, distinctions between building types are inconsistent in alterations/additions. This lack of clarity is most evident for single-family and multifamily projects where alterations/additions permit for both categories are aggregated. Additionally, a single multifamily permit can have multiple units.

Table 6: 2023 CIRB Estimated Residential Permit Market Size

Residential Permit Types	Count Permits	Count Units
HVAC changeouts/repairs	25,658	26,112
Other Structures	33,449	33,449 *
Solar	56,585	56,861

⁴⁸ California Building Industry Association (CBIA). 2025. “[CIRB Historical Data 1954-2019](https://cbia.org/cirb-historical-data-1954-2019/).” Available at <https://cbia.org/cirb-historical-data-1954-2019/>.

Residential Permit Types	Count Permits	Count Units
New Single-Family Homes	42,464	42,464
New ADU	13,124	13,131
New 2 to 4 units	1,755	4,425
New 5+ units	2,071	70,911
New/alterd garages	3,564	3,564 *
Alteration/Addition (include Multifamily)	108,227	108,227 *
Totals	286,897	359,144

Note: *Raw data is missing. Staff assume 1 permit to 1 unit ratio.

Source: Table by CEC staff. Data source from CIRB 2023 Annual Report.

Table 7 and **Table 8** are the single-family and multifamily components of the residential market. CEC staff excluded solar permits and other structure permit categories to narrow down the studied population. Alterations/Additions of existing buildings account for a large proportion of both categories.⁴⁹ Staff assumed a 50:50 ratio between the single-family and multifamily categories based on new construction trends shown in **Figure 3-2**. This highlights a gap in the existing permit database where building classifications are still not inherently clear across jurisdictions in how the permit databases are structured, thus requiring additional efforts for data cleaning and interpretation.

Table 7: Permitted Single-Family Units

Single-Family Residential Permit Type	Annual Report Count Units
HVAC Changeouts/Repairs	26,112
New/Altered Garages	3,564
New ADU	13,131
New Single-Family Home	42,464
Alteration/Addition (may include Multifamily)	54,114*
Total	139,385

Note: *Raw data is missing. Assumed multifamily units are of half alt/add permits.

Source: Table by CEC staff. Data source from 2023 CIRB Annual Permit Data.

⁴⁹ CIRB aggregates the alterations/additions for all residential building subcategories

Table 8: Permitted Multifamily Units

Multifamily Permit Type	Annual Report Count Units
New 5+ Units	70,911
New 2 to 4 Units	4,425
Alteration/Addition (may include Multifamily)	54,114*
Total	129,450

Note: *Raw data is missing. Assumed multifamily units are of half alt/add permits.

Source: Table by CEC staff. Data source from 2023 CIRB Annual Permit Data.

Figure 3-3 and **Figure 3-4** illustrate the size of construction activity for single-family and multifamily residential, respectively. Permit categories such as alteration/addition and HVAC changeout/repairs in the existing single-family residential category and totaled to be 58%, which is the majority for single-family residential. On the other hand, newly constructed multifamily is the majority compared to existing multifamily category. The CIRB database provides us with an industry standard of data quality. However, future studies will require Energy Code experts to further validate key information and scope eligibility from recorded permits. Based on these findings, staff recommend prioritizing building categories to include existing single-family and newly constructed multifamily categories.

Figure 3-3: Single-Family Residential

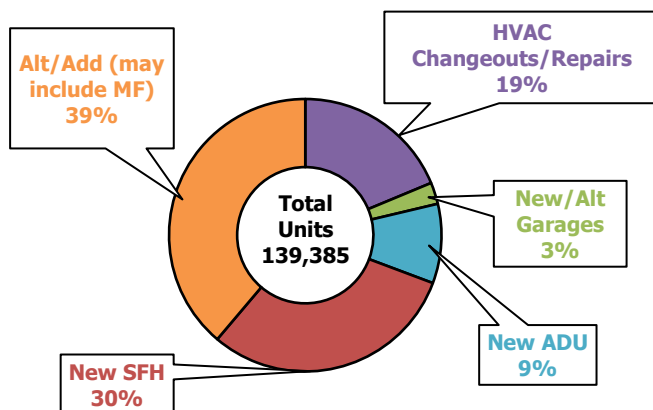
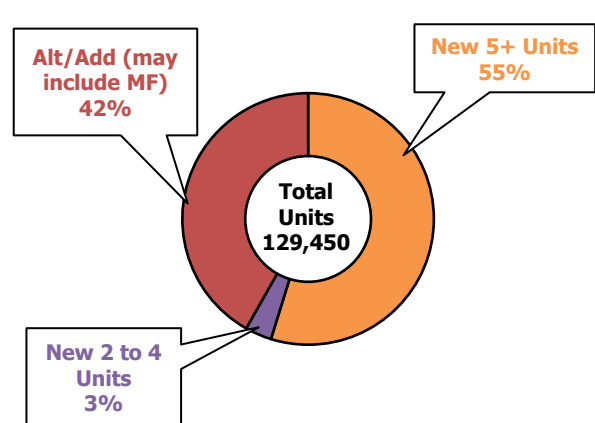


Figure 3-4: Multifamily Residential



Source: CEC staff analysis of 2023 CIRB Annual Report

GAP# 12. Prioritizing the existing single-family residential building category. Permit data for existing single-family and multifamily are often grouped together. Lack of clarity in the CIRB permit database as to the number of units of existing single-family versus multifamily make it more difficult to quantify the studied population. Nevertheless, permitting in the existing single-family scope of work is a larger piece of the picture that may warrant priority in future studies.

GAP# 13. Prioritizing newly constructed multifamily over existing. Newly constructed multifamily units are more prevalent in the permit market than they seem when only looking at permit data. This means from a permitting lens they could be grossly underrepresented. Existing multifamily faces several challenges that will make obtaining samples costly. Additionally, data for this subcategory is aggregated with other residential subcategories into the “alteration/addition” classification.

3.1.4 Nonresidential Construction Activities

Nonresidential spaces in California occupy more than 7.5 million square feet.⁴⁶ In addition to alterations to existing buildings, interested parties generally construct 163 million square feet of new nonresidential space per year. **Table 9** represents the 2023 annual nonresidential permits by CIRB. Verified unit counts for new nonresidential construction and alteration/addition were not available. Where applicable, staff assumed a 1:1 ratio of permits-to-units denoted by an “*”.

Table 9: 2023 Nonresidential Permit Market

Nonresidential Permit Types	Count Permits	Count Units
New construction	8,327	8,327*
Solar Installations	560	579
HVAC Changeouts/Repairs	1,725	2,757
EV Charging Stations	3,837	6,134
Alt/Addition	23,967	23,967*
Total	38,416	41,764

Note: *Raw data is missing. Assume 1 permit to 1 unit ratio.

Source: Table by CEC staff. Data source from 2023 CIRB Annual Permit Data.

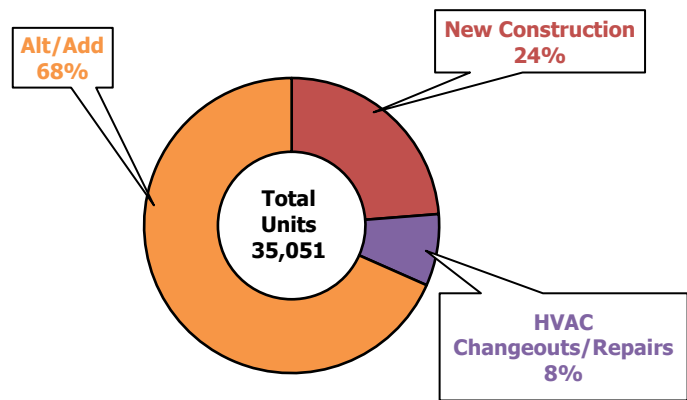
Unlike the residential category, there are no data sources or literatures on the unpermitted work for the nonresidential category. Anecdotally, unpermitted work in the newly constructed nonresidential building category is thought to be low as nonresidential buildings tend to be large and noticeable.

Figure 3-5 shows the existing nonresidential building category to be 76% of the total units observed which include both alteration/addition and HVAC changeouts/repairs. The new construction nonresidential category is 24%, indicating a smaller percentage of permits but may have higher overall valuation. Where data was missing, staff assumed a 1:1 ratio of

permits-to-units. Like multifamily, nonresidential projects can have unequal permit-to-unit counts. Depending on the jurisdictions, multiple permits are likely associated with one project, especially for large and complex sites.

Nonresidential alteration/addition permits account for 68% of the 35,051 nonresidential units presented. These exclude installation permits that cover electrical, encroachment, plumbing, reroofing, racking, fire escapes, signs and elevators. Despite this, newly constructed nonresidential activity represents a significant opportunity for assessing code compliance. Existing nonresidential activities can vary in scope and make it more challenging to assess compliance levels.

Figure 3-5: 2023 Nonresidential Units Built



Source: CEC staff analysis of 2023 CIRB Annual Report

GAP# 14. Prioritize new construction nonresidential buildings over existing. Although the number of permits for existing nonresidential construction exceeds those for new construction, assessing compliance in new buildings may be simpler due to their more standardized scope and rigorous documentation. In contrast, existing buildings present a wider range of complexities in the compliance process, the creation of a sampling plan, and stakeholder recruitment. Additionally, nonresidential projects often require multiple permits under different jurisdictions, making it difficult to determine the exact number of units based solely on permit data. As a result, the reported number of nonresidential units may be lower than the total number of permits issued.

3.1.5 Covered Process

The size of the covered process market is closely tied to the data on the nonresidential buildings market. Section 100.1 of the Energy Code defines processes, covered processes, and exempt processes. It also distinguishes between process loads and process spaces. All references to regulated “covered” processes can be found in Sections 120.6(a-j) and 140.9(a-c). High impact covered processes include controlled environmental horticulture (CEH), steam traps, computer room economizers, and process boilers.

After parsing the 2023 CIRB database, staff found few permitted industrial processes compared to the other six building categories. This shortfall is multifaceted. CIRB's classification of industrial processes does not directly correlate to the Energy Code's, hence manual data interpretation is required. In California, classification and permitting of industrial processes are dependent on the individual process and not necessarily the building(s) they are associated with. This makes understanding and quantifying the covered processes population difficult.

This represents a gap in how Energy Code compliance is assessed. We cannot assess statewide industrial covered processes without additional work to understand and validate how industrial processes are characterized in permit data.

GAP# 15. Lower priority for covered process. Unlike other building categories, covered process measures can be implemented across various nonresidential building types that are not easily identified in the existing data, making it difficult to define the studied population and generate sample size. Future evaluation for this category will likely demand specialized expertise.

Each of the building categories has unique building characteristics and even includes more subcategories. The distinct building characteristics can influence evaluation design, data collection, and sample design. The data gaps in the permit data make it challenging to identify the studied population for some categories, especially for the existing building categories. The lack of standardization across online permitting systems across jurisdictions can contribute to some data gaps. Based on the preliminary analysis of the permit data, CEC staff identified gaps by building categories and recommended prioritization discussed in Chapter 6.

3.1.6 Unpermitted Building Construction Activities

The data for unpermitted construction activities are not conveniently available. Literature research revealed very few studies that investigated unpermitted work and tried to quantify the extent of unpermitted work, particularly in the residential space. Anecdotal observations suggest that newly constructed nonresidential and multifamily buildings are likely to be permitted due to their high visibility and likelihood of attracting attention from the public who may report violations to the city.

These are highlighted literatures reviewed discussing unpermitted activities:

- As summarized in Chapter 2.3.5, DNV GL 2017 HVAC Assessment study indicated 8 to 29% of residential HVAC changeouts work are permitted, indicating high level of unpermitted work in this category for California.
- Stanford RegLab publishes a study in 2024, showing 3 out of 4 new detached ADUs are unpermitted in the City of San Jose, using advance machine learning technique such as computer vision and satellite images. These two studies are the best available data that are most recent and indicative of big issues in compliance and enforcement.

- In 2016, Center for Sustainable Energy (CSE)⁵⁰ attempted to calculate the permit compliance rate for residential HVAC changeouts using HERS registry data and distributor sales data. However, CSE was not able to obtain distributor sales data from AHRI or HARDI due to concerns with data privacy, confidentiality, fear of new regulations, and distributor data not indicative of installations made in a particular area.⁵¹
- The Compliance Improvement Advisory Group from the statewide C&S program Compliance Improvement published a paper in 2013⁵² and recommended a database run by an independent third party to track model and serial numbers of equipment sold directly from distributors to understand the extent of unpermitted activities. The paper also discussed an alternative using the Effective-of-Useful-Life (EUL) analysis or use sales tax information from the local jurisdictions' tax offices.
- Wegmann and Bell⁵³ drew the connection between the case of informal housing in Southern California and the code enforcement experience related to planning. It highlighted the root causes of unaffordability and disconnected resources for enforcement, particularly in Los Angeles.
- A pilot study in Puget Sound referenced in a Puget Sound Institute Brief⁵⁴ used boat surveys and site visits to rigorously inventory shoreline structure at the parcel scale to identify unpermitted shoreline construction. The original study⁵⁵ indicated rigorous survey and comparison with historical aerial photographs to determine the unpermitted activity, showing approximately 22% in Bainbridge Island and 56% in San Juan Islands did not have permit and suggesting unpermitted shoreline construction activities may be an issue in Puget Sound area.

Unpermitted construction activities data and rates are especially important to labor groups and contractors who noted the primary reason to not pursue a permit is due to fear of losing the bid to others who can propose lower cost to perform the work without going through the

⁵⁰ Center for Sustainable Energy. 2016. Residential HVAC Alteration Compliance Baseline Analysis – Data Solicitation Activities and Lessons Learned. For California Energy Commission.

⁵¹ McCrudden, Charlie. 2018. "[Improving Energy Compliance of Central Air-Conditioning and Heat Pump Systems](https://efiling.energy.ca.gov/GetDocument.aspx?tn=224434&DocumentContentId=54710)." Daikin. CEC Docket # 17-EBP-01. TN 224434. Available at <https://efiling.energy.ca.gov/GetDocument.aspx?tn=224434&DocumentContentId=54710>.

⁵² Wiseman, Bob, Casey Bigelow, Russ King, Erik Emblem, and Nehemiah Stone. 2013. "Tracking Sales and Permit Volume". Statewide C&S Program Compliance Improvement. Compliance Improvement Advisory Group.

⁵³ Wegmann, Jake and Bell, Jonathan P. 2016. "[The invisibility of code enforcement in planning praxis: The case of informal housing in southern California](https://digitalcommons.calpoly.edu/focus/vol13/iss1/10)." *Focus*. Vol. 13: ISS. 1, Article 10. Available at <https://digitalcommons.calpoly.edu/focus/vol13/iss1/10>.

⁵⁴ Issues in Brief. 2016. "[Illegal Shoreline Armoring](https://www.eopugetsound.org/sites/default/files/features/resources/IssueBrief_IllegalArmoring.pdf)." Puget Sound Institute. Available at https://www.eopugetsound.org/sites/default/files/features/resources/IssueBrief_IllegalArmoring.pdf.

⁵⁵ Quinn, Timonthy. 2014. "[A Pilot Study to Estimate Levels of Unpermitted Construction Activity Along Marine Shoreline in Puget Sound](https://cedar.wvu.edu/ssec/2014ssec/Day2/15/)." Salish Sea Ecosystem Conference. Available at <https://cedar.wvu.edu/ssec/2014ssec/Day2/15/>.

appropriate permitting and compliance processes.⁵⁶ Numerous interested parties have called for greater enforcement and indicated unpermitted activities endanger quality worker programs and livelihood as well as implicitly negatively impacting compliance.

There is an acknowledgement of unpermitted work activities in residential buildings, specifically called out in AB758 Action Plan⁵⁷, SB1414, SB1164, and other CEC reports.^{58 59} The Final 2021 Integrated Energy Policy Report outlined comprehensive strategies to combat unpermitted HVAC work through enhanced enforcement mechanism, including expanding contractor licensing board authority with higher penalties, linking warranties to permit numbers, requiring distributors to report to CEC number of equipment units that are sold, and streamlining permitting processes to encourage compliance. Serial number tracking has been in discussion since 2007 from the plan to increase energy efficiency of air conditioners per AB2021 (Levine 2006). The WHPA published a white paper that describes the multiple perspectives of serial number tracking.⁶⁰ The CEC continued to work on establishing relationships and rulemaking to support HVAC sales data collection while strategically figuring out solutions to overcome cost and stakeholder acceptance barriers.

Compliance data for unpermitted construction is even more rare or frankly non-existent. While the DNV GL 2017 HVAC Assessment study indicated that the efficiency performance of unpermitted projects may not be completely bad due to other external factors such as Title 20 regulations, demanding a minimum efficiency for certain equipment to be sold in California.

In the next sections, staff explored any existing and accessible data sources as well as potential data sources, not limited to addressing compliance, but also unpermitted rates as well.

GAP# 16. Unclear level of compliance in unpermitted projects. Due to the lack of data and gaps in the literature, there is no empirical evidence on the level of compliance with unpermitted projects. By assuming that unpermitted projects have no Energy Code savings, this can lead to an overstatement of non-compliance savings.

3.2 The Existing Accessible Data Sources

⁵⁶ Heinemeier, Kristin. 2012. "[Contractors Walk on the Wild Side... Why?](https://wcec.ucdavis.edu/wp-content/uploads/2012/05/Kristin-Heinemeier-ACEEE-2012.pdf)" ACEEE Summer Study on Energy Efficiency in Buildings. Available at <https://wcec.ucdavis.edu/wp-content/uploads/2012/05/Kristin-Heinemeier-ACEEE-2012.pdf>.

⁵⁷ CEC. CA Draft Action Plan for the Comprehensive Energy Efficiency Program for Existing Buildings. June 2013. CEC - 400 - 2013 - 006 - D. p.23.

⁵⁸ Michael Messenger. 2008. Strategic Plan to Reduce the Energy Impact of Air Conditioners, California Energy Commission Report. CEC - 400 - 2008 - 010, p. 7 - 8. Available at <http://www.energy.ca.gov/2008publications/CEC-400-2008-010/CEC-400-2008-010.PDF>

⁵⁹ Kravitz, Raquel. 2022. [Final 2021 Integrated Energy Policy Report Volume 1, Building Decarbonization, Page 183](https://efiling.energy.ca.gov/GetDocument.aspx?tn=241599). California Energy Commission. Docket Number: 21-IEPR-01. Available at <https://efiling.energy.ca.gov/GetDocument.aspx?tn=241599>.

⁶⁰ WHPA. 2015. Serial Number Tracking: A Multi-Perspective Review.

Most direct compliance rates are derived from survey studies that collect on-site data against code requirements. There have been a few studies that try to calculate unpermitted rates specific to HVAC changeouts or to detached ADU construction activities. These studies only capture a specific portion of the building construction activities and do not capture unpermitted rates for the entire building construction activities portfolio.

A strong case can be made for using data-driven approaches to establish compliance rate proxies. Field studies are expensive and require significant resources to provide only a single snapshot in time. In contrast, data-driven methods are less costly to replicate. They also offer the advantage of ongoing tracking over time.

Using streamlined approaches means using existing data sets that are continually being updated from its source in a reliable manner to help determine an approximate compliance rate. This means the methodologies relating to streamlined methods may not be able to replicate the same level of accuracy as a field survey, but the outcome can still provide some value to understanding compliance in the State. For instance, attendance rates in education are a proxy for student engagement and likelihood of academic success. Similarly, monitoring the rates of unpermitted work can reveal areas with low process-based compliance and unknown quality of installation.

The trade-off for a less accurate measurement is time and cost because the ideal ways to measure compliance rates directly are challenging and can be impractical. Staff assessed the existing accessible data sources and potential streamlined approaches to measure proxy compliance rates.

Commission Compliance Document Repository (CCDR): The CEC receives all registered compliance documents including Certificate of Compliance (CF1R) forms, Certificate of Installation (CF2R) forms, and Certificate of Field Verification and Diagnostic Testing (CF3R) forms from registry Providers annually. The current version of the CCDR only contains residential project data and does not include non-registered forms. Currently, the CEC is working on improving the data engineering pipeline to extract, load, and transform raw data into a compliance database within a Snowflake database automatically. The current limitations with the existing sources are that only documents registered between 2017 to 2021 are parsed into the compliance database while additional registered projects are in the queue to be parsed.

GAP# 17. Lack of supporting data for nonresidential building category. In the nonresidential building categories, there are less accessible supporting data available to support compliance rates understanding. CEC compliance data warehouse is still undergoing development. Compliance investigation into nonresidential types will rely 100% on data collection with the AHJ.

Permit data: As discussed in section 1.2.2, CEC staff currently has access to the U.S. Census data and CIRB data. Due to the voluntary nature in the data collection for these data sources, there are limitations to the accuracy to the true population of construction activities. However, these may not be the best data sources available.

Building Permit Survey by the U.S. Census Bureau / California Department of

Finance Construction Permits Data: The California Department of Finance utilized the (free) Building Permit Survey to estimate construction permits in California. DOF estimates that in 2023, approximately 58,500 new single-family home permits and 53,000 multifamily home unit permits were issued in 2023.⁴⁰ This data focuses on residential and multifamily buildings, not nonresidential or industrial types.

- **Construction Industry Research Board (CIRB) Data:** The California Homebuilding Foundation provides building permit data through CIRB, covering both nonresidential and residential building production from most jurisdictions in California. The California Energy Commission subscribes annually to access detailed permit-level data from 2023 onward and aggregated city-level data prior to 2023. CIRB ended their services on May 30, 2025.

GAP# 18. Need for higher quality permit data. Current accessible permit databases (CIRB, Census) are limited by missing data, data quality, and other issues. While permitting data exists and provides insight into building construction activities, it is important to note that the data sources for permit data are not perfect. Additionally, non-standardized fields and data points between permit data sources make analysis difficult. Further data validation between all the permit data sources will be required to better enhance the precision of rates.

HVAC sales data. Using HVAC sales data and comparing to permitting data is a strong indicator for unpermitted activities. These are the existing sources for HVAC sales data:

- **Manufacturer Shipment Data:** is a monthly report published for free by AHRI that tracks U.S. manufactured shipment of central air conditioning, air-source heat pumps systems, gas and oil furnaces, and gas and electric tank water heaters. AHRI collects information from manufacturers that voluntarily provide shipment information. AHRI does not disclose the shipment volumes data at a state level or more granular level due to their agreement with the manufacturers. Typically, this data set is being used to validate other methods that estimate HVAC sales.

GAP# 19. Limited availability of HVAC sales tracking data. HVAC sales data is difficult to obtain because interested parties (manufacturers, distributors, installers, etc.) in the market are hesitant to share the information publicly. In addition, the efforts to collect such data are time consuming and intensive. The best available alternative to estimate HVAC sales depends on existing building stock data and End-of-Useful-Life data. This method still requires periodic empirical data to validate its credibility.

Other possible relevant data sources are listed below with a brief description and how the data source may be pertinent to compliance rates calculation.

- **Dodge Analytics Construction Data Projections:** Used in the CEC Integrated Energy Policy Report process and Building Standards Impact Analysis; Dodge Analytics provides projection of construction data for the next 30 years. This data source is not analogous to

the permit data from the Census Bureau and CIRB. This data source might be useful for calculating future or projected noncompliance cost.

- **Database for Energy Efficient Resources (DEER):** is a comprehensive resource maintained by the CPUC to support energy efficiency programs. It provides data on energy savings, cost-effectiveness, and performance parameters for a wide range of energy-efficient technologies and measures. Effective useful lifetimes (EUL) of HVAC equipment from this database in combination with other data sources can be used to estimate annual residential HVAC unit installations in both existing and new homes. This method is directly cited from the 2017 DNV GL HVAC Assessment study.
- **Residential Appliance Saturation Survey (RASS)** collects data on energy usage patterns, appliance ownership, and household characteristics in California homes. Conducted periodically by the California Energy Commission (CEC), it provides detailed insights into residential energy consumption. The 2017 DNV GL HVAC Assessment study used RASS data as a starting point to estimate equipment saturation overtime and combined with the changes in housing stock over time to extrapolate the equipment stock and mix of equipment vintages.

Based on the data sources listed above, there can be several ways that proxy compliance rates can be determined as described in **Table 10** below.

Table 10: Example of Proxy Rates

Example of Proxy Rates	Implications	Limitations
Proxy rate of enforcement = # of compliance forms (CF2R or CF3R) from CCDR / # of issued or completed permits for existing residential from CIRB	Ideally, the number of units that contain CF2R (installed) or CF3R (field verified) forms should match the number of units permitted. If there is a lack of compliance forms where there are change-out permits (i.e. if the rate is closer to 0%) then it can suggest people are not registering the forms as they are supposed to or possibly under-enforcement issues. On the other hand, if the number of CF forms exceeds the number of permits, it can highlight issues with the data collection or availability.	This analysis is limited to part of the existing residential category (HVAC changeout specifically, some alterations/additions). CCDR development is underway and efforts to clean BOTH registry data and permit data are in place, CEC can calculate this proxy in the future. A live proxy rate cannot be established now due to current on-going development.
Proxy rate of unpermitted work = # HVAC sales shipment from a new direct data source/ # of issued permits from CIRB data	Ideally, this rate should be closer to 1 to indicate approximately equal number of units installed for HVAC to the number of units being permitted. If the proxy rate is higher than 1 in multiple folds, this indicates that there is a higher amount of work that is unpermitted than permitted. On the other hand, if the rates are closer to 0, then it can mean that there are a lot of other permits being pulled compared to HVAC changeouts.	This analysis is not possible currently due to the lack of HVAC sales data available for the State or at a more granular level. Typically, an issued permit comes before HVAC sales occur, so there are some assumptions made that the HVAC sales occur within reasonable time close to the year of issued permit. In the permitting database, there is a category specifically for HVAC changeouts. However, HVAC sales can also occur in new construction and other permitting types like alteration or additions. Some jurisdictions may not require separate permits for a single scope of work whereas others may require electrical and plumbing permits to be submitted separately for the same scope of work.

Example of Proxy Rates	Implications	Limitations
Proxy rates of unpermitted work = HVAC sales estimates from using Census, RASS, and DEER database / # of issued permits from CIRB	This proxy rate logic is the same as above. The key difference is how the HVAC sales data are derived, whether they're through a direct source or through an estimation method based on other pertinent available data.	This analysis would replicate one of the approaches in the 2017 DNV GL HVAC Assessment. This analysis is effort-intensive and currently cannot be replicated by CEC staff due to current resources available and expertise. The key assumption is that the HVAC sales estimates assume the accuracy of the housing census data, assume that replacement happens at End-of-Useful-Life, and disregard scenarios where HVAC changeouts occur before end of useful life.

3.3 Potential Data Sources

CEC staff developed a high-level list of potential data sources and their accessibility for use in streamlined compliance evaluation approaches. There is **no in-depth analysis** on how these data sources can be used to estimate compliance rates or proxy rates. A more in-dept analysis would be the next step if the technological gap is prioritized and valued by interested parties. These methods are mostly untested, with the exception a few.

The list below describes the potential data sources in the following format: Source Name – Describe what it is. Describe accessibility and cost, if known. Describe its relevancy to estimating compliance rates or other proxy indicators.

1. **Project Data from Dodge Analytics** - Dodge Analytics provides detailed information on construction projects, including project size, type, and timeline. These projects may be a small portion of the entire construction activities in California. Accessibility typically requires a subscription or fee. The alternative to this data source is reaching out to local jurisdictions and asking for project information. It is relevant to Energy Code compliance rates evaluation by identifying project information, which can be cross-referenced with compliance metrics.
2. **Permit Data from ATTOM, BuildZoom, Shovels** - These sources aggregate building permit data, offering insights into construction activity, permitting trends, and project characteristics. Accessibility and cost vary, with some requiring subscriptions or licensing agreements. This data helps evaluate compliance rates by determining whether projects are obtaining permits that align with Energy Code requirements.
3. **Real Estate or Assessor Data from Zillow Bridge API** – Zillow’s Bridge API provides property-level data, including sales history, property features, and valuations. It is accessible through an application process, and costs may apply. This data is relevant for Energy Code compliance by linking property improvements or changes to compliance with energy efficiency standards.
4. **Satellite Data for Computer Vision Models to Track Unpermitted Construction** – Satellite imagery and computer vision models can identify physical changes to properties that might indicate unpermitted construction. Accessibility may require partnerships with satellite data providers or specialized services. This data source is valuable for compliance evaluation by identifying construction projects potentially bypassing permitting and Energy Code requirements.
5. **Other Equipment Sales Data such as HARDI (Heating, Air-conditioning & Refrigeration Distributors International) Shipment Data** – HARDI through Co-Metrics provides sales data for HVAC equipment from distributors, including product types and shipment volumes. The market share of the data source may be 40% of the market share and slowly increasing in the future from a conversation with CoMetrics and CEC Staff in 2024Q3. Access typically requires membership or subscription fees that are not readily available to purchase yet. This data aids compliance evaluation by tracking the adoption of energy-efficient equipment and comparing it to compliance standards.

6. **Other Equipment Sales Data: ENERGY STAR Shipment Data** – ENERGY STAR Shipment Data tracks the distribution of ENERGY STAR-certified products, reflecting trends in energy-efficient technology adoption. Accessibility may be free. It supports compliance evaluation by providing a benchmark for equipment performance compared to code requirements.
7. **Other Equipment Sales Data: IRS Form 5695** – IRS Form 5695 reports residential energy credits claimed for energy-efficient property improvements (including solar and other renewable system installations, insulation improvements, windows replacement, and HVAC systems replacements). The data availability is promising in the next few years, but the public data is not yet available. This data can be relevant for proxy compliance rates for understanding market penetration of energy efficient products and homeowners' compliance with the Energy Code.
8. **Data from Rental Inspection Programs**⁶¹ - Rental inspection data in California refers to information collected during inspections of rental properties to ensure compliance with health, safety, and building codes, designed to protect tenant rights and ensure safe living conditions. The data typically includes property details (e.g., address, owner, and unit type), inspection findings (e.g., code violations or deficiencies), and actions taken to address non-compliance. Accessibility varies by jurisdiction, with some data publicly available, while others require requests or have restricted access. While this data is useful for identifying trends in rental property compliance, it is not comprehensive enough to assess compliance with the previously defined building scope. This limitation arises from the fact that rental inspection programs are few, unevenly distributed, and insufficiently widespread across jurisdictions.
9. **Data from Interval Metered Data (IMD)** - Interval metered data refers to energy usage data recorded at regular intervals (e.g., hourly or sub-hourly) by smart meters or other advanced metering infrastructure. It provides detailed insights into energy consumption patterns for residential, nonresidential, and industrial buildings. Due to the data volume, and potential for this data to contain personally identifiable information (PII), it is very difficult to gain access, work directly with, or even create an environment for third parties outside of the CEC to gain access to this data without first taking necessary safety precautions. While interval metered data can help estimate unpermitted rates by identifying energy trends that align with permit data, it can also serve as a proxy to understand operational efficiency and verifying performance against modeled predictions in compliance evaluations. The use-case with IMD data can vary widely. Nevertheless, the logistics challenges such as access, technical skills, and large volume of data may be difficult to overcome to create a meaningful proxy compliance evaluation product.

⁶¹ Some examples of Rental Inspections Program include: City of Arcata (Available at <https://www.cityofarcata.org/973/Residential-Rental-Inspection-Program>), Sacramento County (Available at <https://www.sacounty.gov/services/Pages/Rental-Housing-Inspection-Program.aspx>), City of Hayward (Available at <https://www.hayward-ca.gov/your-government/programs/residential-rental-inspection-program-rrip>), and more.

10. **Certified Appliance Recycler (CAR) Program from the California Department of Toxic Substances Control (DTSC)** provides an annual report of major appliances that requires special handling. This program also includes identification of abandoned appliances, documenting details such as type, quantity, and associated hazardous materials. This data is part of DTSC's effort to monitor and manage hazardous waste from appliances like refrigerators, air conditioners, and other household or nonresidential units. The data may be available through DTSC records, subject to public information requests. Accessibility can vary, and there may be administrative costs for obtaining detailed datasets. This data can be relevant to evaluating compliance with regulations regarding appliance recycling, disposal, and hazardous material handling. It may also serve as a proxy for estimating broader compliance trends in sectors involving regulated appliances, particularly in alignment with environmental and waste management codes.
11. **Technology and Equipment for Clean Heating (TECH) Working Data Sets** – includes anonymous data gathered from incentive applications submitted by the TECH participating contractors. This data set is specifically unique to the installation of a heat pump water heater or a heat pump air conditioner equipment.

3.4 Sampling Techniques

In any energy code compliance analysis specifically via field studies, understanding sampling is crucial. Proper sampling allows researchers to efficiently access large building populations with representative samples without inspecting every single structure.

By choosing the appropriate sampling methods, researchers can maintain scientific rigor, reduce potential errors, and generate reliable findings that can be generalized. Most importantly, the sampling design plays a key role in the project's scope and cost.

Appendix C provides an in-depth analysis of sampling techniques and background. This section aims to discuss highlights.

Key background knowledge includes:

The standard formula for determining an appropriate sample size is

$$\text{Sample Size} = \frac{\frac{[z^2 * p(1 - p)]}{e^2}}{1 + \frac{[z^2 * p(1 - p)]}{e^2 * N}}$$

Where, N = population size, z = z-score, e = margin of error, and p = standard deviation. The population size (N) is the construction activities within a building category. Standard deviation (p) is 0.5 if unknown. Z-score (z) and margin of error (e) are dependent on the target confidence level (80% to 99%).

Probability Proportional to Size (PPS) is the most common method to select the appropriate number of samples that is proportional to its population by size measure. For example, larger buildings (by square footage) may have a higher probability of selection than smaller ones if they represent a greater portion of the total building population in a region.

Key takeaways from the literature reviews, specifically for field studies methods, include:

- When designing a sampling plan for field studies, researchers can choose random sampling, non-random or a combination of both. Past field studies in California consistently utilized multistage sampling which contains aspects of both forms. Multistage sampling approach involves sample points proportionally allocated by regions and building types. Municipalities within each region are then randomly selected and ordered using a proportional-to-size sampling method. Staff then contact building departments to develop a population list of recently issued permits under the desired code cycle. This list is then validated per the goals of the study. This process is repeatable depending on the scope of a study and the measures being evaluated.
- Per the CPUC California Protocol Framework (2004), the minimum standard for accuracy is 90% confidence with 30% uncertainty. Based on the other field studies conducted from the DOE protocols, the best practice is 90% confidence with 10% uncertainty. In addition, this protocol also suggests dividing the 16 California climate zones into 5 distinct regions. Lowering the stratification from 16 climate zones to 5 regions reduces the overall required number of samples and saves cost. The minimum number of samples required per the protocol is 300.
- Sampling design for building permits, codes, and standards evaluations are rife with challenges. Each study is unique and problem solving for design challenges is critical in the overall sampling plan. Common barriers include scope, funding, time, and data/personnel accessibility. Field studies are of special note because they are impacted by all three.
- Key consistent barriers include self-selection bias and data quality from samples. Self-selection bias indicates that projects that are likely to be compliant are more likely to participate in the study, thus skewing the results and overestimating compliance levels across the population. Additionally, samples in past studies were omitted due to lack of data quality, ineligibility due to external factors, lower quantity of samples than the initial target amount, and bias detected in the sample acquisition.

GAP# 20. Sampling challenges lead to uncertainty. The effort to acquire truly random representative samples is high. Modern compliance evaluations that seek to develop robust studies frequently use multistage sampling that combines both random and non-random sampling techniques. Inherent to the volunteer nature of data collection, self-selection bias is likely and can increase the uncertainty of the results.

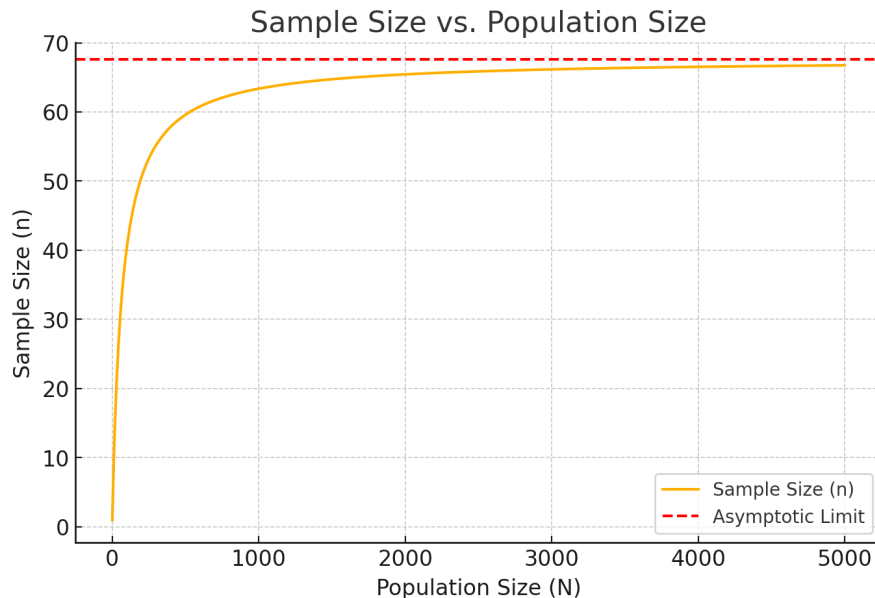
Given the background and best practices from the literature review, CEC staff attempted to calculate how many samples are needed for scoping purposes. The assumptions are as follows:

- CEC staff use the number of units of data from the permit database as the population (N).
- A 90% confidence is used to determine the Z-score, and target margin of error is 10%.
- The standard deviation is set to 0.5 because it is undetermined from the permit data.

Thus, the resulting number of samples per strata is **68 samples**. This is aligned with the DOE field studies protocols that dictate that the minimum samples to 63.

To further illustrate how sample size can change based on the population (N), CEC staff graphed the standard equation in **Figure 3-6**. This reveals that for a population size above 3,000, the sample size plateau to about 68 samples based on the above assumptions.

Figure 3-6: Sample Size Correlation to Population Size Using the Standard Equation



Source: CEC staff

While the number of samples can be calculated through textbook formulas, stakeholder acceptance upon the appropriate number of samples that are representative of the studied population is critical to the credibility of future state-wide study.

A stratum (plural: strata) is a distinct subgroup of a population. The number of strata can include various building categories and 5 climate regions. This is specifically relevant for multifamily and nonresidential buildings where building types have very distinct characteristics. For example, in nonresidential buildings, an office building and a high-rise hotel are very different building types that would warrant different compliance investigations and survey design.

Using this base knowledge, CEC staff use the minimum of samples and appropriate strata by building categories to estimate the scope and cost of proposed solutions in Chapter 5.

CHAPTER 4:

Gap Analysis

The purpose of this gap analysis is to enable interested parties to provide input and help staff identify the priorities set by interested parties in sequential work. CEC staff inventoried and summarized the observed gaps from literature reviews. To prioritize the identified gaps and design a study with a limited scope, CEC staff developed a gap framework to rank and score these gaps. This approach incorporates input from key interested parties to guide the study's direction and facilitates prioritizing future actions.

The risk management framework will be the tool to be used during future project execution within the project team. A risk register is a project management tool that provides project sponsors and project team with a summary of issues that can impact the scope, schedule, and cost of the study. The work in the gap analysis will guide the initial development of the risk register to inventory potential risks, particularly from the challenges identified with field studies and data-driven methods.

4.1 Gaps Inventory

This gaps inventory is a comprehensive assessment that identifies shortcomings, inconsistencies, and areas needing improvement in how compliance is measured and understood. The inventory categorizes the gaps into different types as defined in **Table D-1** of Appendix D: Types of Gaps.

Gap types provide a structured approach to highlight the root causes of issues and avoid conflating unrelated problems. It also allows for targeted recommendations and solutions as each gap type may require a different strategy to address. For instance, a policy gap may not be addressable in a compliance rate study that's more suitable to address the data gaps. This distinction still ensures a comprehensive analysis, enabling policymakers and interested parties to prioritize efforts and allocate resources effectively.

Table 11 simply describes the gap name and gap type as identified. The numbering **does not** reflect priority or importance. The next section discusses the gap framework to rank and score the gaps accordingly. Appendix E shows the detailed gap inventory and scoring.

Table 11: Gaps Inventory

# As Identified	Gap Name	Gap Type
1	Manual data collection from AHJs	Practical-Application Gap
2	High scope and costs for nonresidential and multifamily categories	Practical-Application Gap
3	Variability in compliance definitions	Literature Gap
4	No single methodology to quantify compliance rates	Literature Gap
5	Voluntary participation for field data collection	Policy Alignment Gap
6	Field studies only provide a snapshot of compliance in time	Temporal Gap
7	Increase coordination with CPUC's C&S program evaluations	Data Gap
8	Challenges and costs of whole-building compliance assessments	Data Gap
9	Limited compliance investigation coverage in rural service areas	Data Gap
10	Poor data quality in the compliance process	Data Gap
11	Diverse building categories necessitate multiple analytical methods	Data Gap
12	Prioritize existing single-family residential buildings	Practical-Application Gap
13	Prioritizing newly constructed multifamily over existing	Practical-Application Gap
14	Prioritize new construction nonresidential buildings over existing	Practical-Application Gap
15	Lower priority for covered process	Practical-Application Gap
16	Unclear level of energy compliance in unpermitted projects	Data Gap
17	Lack of supporting data for nonresidential building categories	Data Gap
18	Need for higher quality permit data	Data Gap
19	Limited availability of HVAC sales tracking data	Data Gap
20	Sampling challenges lead to uncertainty	Data Gap

4.2 Gaps Framework

The gap framework includes four primary criteria: transparency, alignment, feasibility, and market coverage. The key attributes are essential in a structured framework to evaluate effectiveness and limitation of current methodologies. These criteria help parse and prioritize the gaps based on their severity, relevance, and feasibility, ensuring that resources are directed toward the most critical issues. These criteria are intended to create a common language for interested parties, facilitating meaningful input and collaboration to help shape the study direction and address gaps comprehensively.

Transparency evaluates whether mitigating the gap in the compliance rate methodologies provides sufficient clarity to build trust, facilitate informed decision-making, and reduce the risk of misinterpretation. Essentially, are the assumptions, inputs, and calculations used in the compliance methodology clearly documented and easily understood by all interested parties, including non-technical users? The scoring criteria are as follows:

1 = Low Transparency: The gap currently has low transparency and requires mitigation effort to increase transparency significantly. Many underlying assumptions are difficult to understand and expected to be easily understood by all, especially nontechnical users. Efforts to address or communicate assumptions would lead to significant scope creep or added cost.

2 = Medium Transparency: The gap currently has medium transparency and requires some mitigation effort to increase transparency. Some assumptions are expected to be difficult to understand, but they can be addressed through the study design and do not increase cost significantly.

3 = High Transparency: The gap currently has high transparency. Most assumptions are easily understood even by nontechnical users. Additional costs to ensure added transparency are not required.

Advocacy groups and the public are the key interested parties most concerned with this criterion and should lead the inputs or scoring of the gap. Gaps with high transparency create more value for the public by enabling better oversight and accountability. Gaps with lower transparency will require more resources to build trust between institutions and communities.

Alignment evaluates whether mitigating gaps address the overarching objective of the Energy Code compliance across all categories rather than focusing solely on a narrow aspect of compliance. Essentially, does the gap effectively reflect the intent of the Energy Code and research goals of the CEC? Does addressing the gap ultimately help the State to understand the root causes of noncompliance and enable actionable solutions? The scoring criteria are as follows:

1 = Low Alignment: Gap focuses on basic compliance concerns but not broader objectives.

2 = Moderate Alignment: Gap supports compliance and energy efficiency objectives but lack potential specific and actionable outcome.

3 = High Alignment: Gap has a high impact on the broad Energy Code goals and highlight high-impact opportunities for policymakers to implement far-reaching beneficial changes.

CEC project sponsors and leadership would be the key interested parties to provide input and speak to the alignment of the overall Energy Code goals. Without alignment, even technically sophisticated methods or mitigation might fail to achieve the meaningful progress toward real-world performance. Gaps with high alignment value demonstrate weight in the strategic direction that the study should address.

Feasibility evaluates the cost, time, and effort required to mitigate the gap within a future study. The scoring criteria are as follows:

1 = Low Feasibility: Closing the gap requires significant cost, time, and effort, making it impractical or resource intensive.

2 = Medium Feasibility: Closing the gap requires moderate resources, with a manageable balance of cost, time, and effort.

3 = High Feasibility: Closing the gap is cost-effective, quick, and requires reasonable effort, making it highly achievable.

The CEC project team and other subject matter experts such as consultants would be the key interested parties to provide input and speak to potential cost, effort, and complexity. Gaps with highly feasible mitigation(s) are more likely to be low-hanging fruits to resolve.

Market Coverage evaluates how the gap can be applied to different project sizes and types in the overall building market. This attribute provides a quantification of market impact based on either the percentage of unit or permit or valuation. The scoring criteria are as follows:

1 = Low Market Coverage: The gap applies to only a small segment of the market, typically around 30% or less of the market.

2 = Medium Market Coverage: The gap applies to a significant portion of the market, typically affecting 30-70% of the market.

3 = High Market Coverage: The gap applies to most of the market, typically 70% or more.

The CEC project team and other subject matter experts such as consultants would be the key interested parties to provide the estimates and expert opinion. Gaps with higher market coverage will lead to higher overall impact.

4.3 Gap Analysis

CEC staff input the initial scoring for criteria in **Table 12** based on the gap inventory and framework. **Table E-1** in Appendix E: Detailed Gap Inventory and Scoring shows the comprehensive list of gaps, including long description, sorted by its ranked order.

Table 12: Gaps Scores and Ranking

#	Gap Name	Gap Type	Market Coverage	Feasibility	Transparency	Alignment	Total Weighted Score	Rank
3	Variability in compliance definitions	Literature Gap	3	3	3	3	12	1
4	No single methodology to quantify compliance rates	Literature Gap	3	3	3	2	11	2
12	Prioritize existing single-family residential buildings	Practical-Application Gap	2	3	3	3	11	2
18	Need for higher quality permit data	Data Gap	2	3	3	3	11	2
10	Poor data quality in the compliance process	Data Gap	3	2	2	3	10	5
1	Manual data collection from AHJs	Practical-Application Gap	3	2	2	2	9	6
5	Voluntary participation for field data collection	Policy Alignment Gap	3	1	3	2	9	6
6	Field studies only provide a snapshot of compliance in time	Temporal Gap	3	1	2	2	8	8
11	Diverse building categories necessitate multiple analytical methods	Data Gap	2	1	2	3	8	8
13	Prioritizing newly constructed multifamily over existing	Practical-Application Gap	2	2	2	2	8	8
14	Prioritize new construction nonresidential buildings over existing	Practical-Application Gap	2	2	2	2	8	8
7	Increase coordination with CPUC's C&S program evaluations	Data Gap	2	3	1	1	7	12
8	Challenges and costs of whole-building compliance assessments	Data Gap	3	1	1	2	7	12
16	Unclear level of energy compliance in unpermitted projects	Data Gap	2	1	1	3	7	12
17	Lack of supporting data for nonresidential building categories	Data Gap	1	2	2	2	7	12

#	Gap Name	Gap Type	Market Coverage	Feasibility	Transparency	Alignment	Total Weighted Score	Rank
19	Limited availability of HVAC sales tracking data	Data Gap	1	1	2	3	7	12
20	Sampling challenges lead to uncertainty	Data Gap	3	1	1	2	7	12
15	Lower priority for covered process	Practical-Application Gap	1	1	1	3	6	18
2	High scope and costs for nonresidential and multifamily categories	Practical-Application Gap	2	1	1	1	5	19
9	Limited compliance investigation coverage in rural service areas	Data Gap	1	2	1	1	5	19

Gaps Categories

By categorizing gaps into types such as Literature, Practical-Application, Data, Policy Alignment, and Temporal, interested parties can pinpoint where the most significant barriers to effective compliance lie. For instance, literature gaps might suggest a need for standardization in terminology or methodologies, which can be addressed through academic and regulatory collaboration. Practical-application gaps indicate where procedural or study design is, potentially through better data management or training. Data gaps highlight deficiencies in information availability or quality, guiding initiatives towards data collection and quality assurance. Policy alignment gaps reveal where regulatory frameworks might need adjustment to enforce or encourage better compliance practices. Lastly, temporal gaps emphasize the need for ongoing, updated studies to keep pace with changes in technology, policy, or building practices. This structured understanding allows for targeted interventions, efficient use of resources, and ultimately, more effective strategies to increase compliance rates and achieve energy efficiency goals.

The data gaps category includes 10 gaps. The list below shows the list of gaps within the category and its ranking in parentheses.

- Higher quality permit data is required. (#2)
- Data quality from the compliance process is likely low, making it more difficult to fully assess compliance. (#5)
- Further investigation into unpermitted rates is needed to evaluate compliance risks. (#8)
- HVAC sales data to track unpermitted work is not available. (#12)
- Unclear the level of compliance in unpermitted projects. (#12)
- Increased coordination needed with CPUC C&S program evaluations in looking at energy - based compliance. (#12)
- Whole building compliance assessment is resource-intensive and presents challenges in transparency (due to the amount of data) and uncertainty. (#12)
- In the nonresidential building categories, there are less accessible supporting data available to support compliance rates understanding. (#12)
- Sampling challenges are significant risks to uncertainty results and credibility. (#12)
- Opportunity to expand compliance investigations in rural service territories. (#19)

The practical-application gaps category includes 6 gaps.

- Prioritizing the existing single-family residential building category. (#2)
- CEC must collect data manually from AHJs to assess comprehensive compliance rates. (#6)
- Prioritizing newly constructed multifamily over existing. (#8)
- Prioritize new construction nonresidential buildings over existing. (#8)
- Lower priority for covered processes. (#18)
- Nonresidential and multifamily scope can vary and require additional subcategories that increases cost and scope. (#19)

The literature gaps category includes 2 gaps.

- Variability in Compliance Definitions. (#1)
- No single methodology to calculate compliance rates. (#2)

The policy alignment gaps category includes 1 gap.

- Field data collection requires voluntary participation from building owners and local jurisdictions. (#6)

The temporal gaps category includes 1 gap.

- Field studies only provide a snapshot of compliance in time. (#8)

Some gaps can be addressed directly through the study design and can be defined through the stakeholder vetting and public workshop process. For example, the gap ranked #1 (variability in compliance definitions) can be addressed through the study design with the CEC staff defining what full compliance means. Gap ranked #2 (no single methodology to calculate compliance rate) can also be mitigated by CEC staff through the technical menus in Chapter 5. Interested parties, particularly the project sponsors and other interest groups, can confirm the path going forward if it differs from CEC staff recommendations.

Gaps Trends

The analysis of gaps in building Energy Code compliance reveals several key trends across different categories.

Clear objectives and definitions. There's a notable pattern of inconsistency and variability of how compliance is defined and measured. The top-ranked gap points to a lack of standardized definitions for compliance, which creates confusion and affects the credibility of compliance studies across the market. This issue is particularly acute in literature where terms are often assumed or defined variably, impacting both new and existing buildings.

Need to prioritize building categories. Another prominent trend involves the practical application gaps, especially concerning data collection and categorization. For instance, the prioritization of existing single-family homes over multifamily or nonresidential buildings due to data aggregation issues in permit databases like CIRB data suggests a need for more precise data segmentation. This not only affects the accuracy of compliance rates but also the strategic focus on which building types to study for maximum impact.

Need for enhanced data collection. Data quality and availability also emerge as a repeated theme. Multiple gaps highlight the challenges with current data sources, including the CIRB and Census data, which are not comprehensive or accurate enough for detailed compliance analysis. There's a call for higher quality, more granular permit data to enable better compliance assessments. Similarly, the lack of data on unpermitted work, particularly in HVAC sales, underscores a broader need for enhanced data collection methodologies, potentially through new regulations or incentives for data sharing.

Addressing the gaps requires strategic planning. The feasibility of addressing these gaps varies, with some being relatively straightforward to tackle if resources are allocated properly, like improving data transparency and standardization. However, others, such as those requiring voluntary participation or dealing with complex building types like

nonresidential structures, pose significant challenges due to resource intensity or policy barriers. This points to a need for strategic planning in compliance studies, focusing on where interventions can yield the most significant improvements with the least resistance.

Addressing gaps in order. Lastly, there's a noticeable trend in the alignment of these gaps with overarching Energy Code goals. High alignment gaps, like those concerning definitions and methodologies, directly support the intent to enhance energy efficiency through better compliance. However, gaps with lower alignment scores indicate areas where current practices or data do not fully serve the comprehensive objectives of energy policy, suggesting a need for realignment or reevaluation of priorities in future compliance strategies.

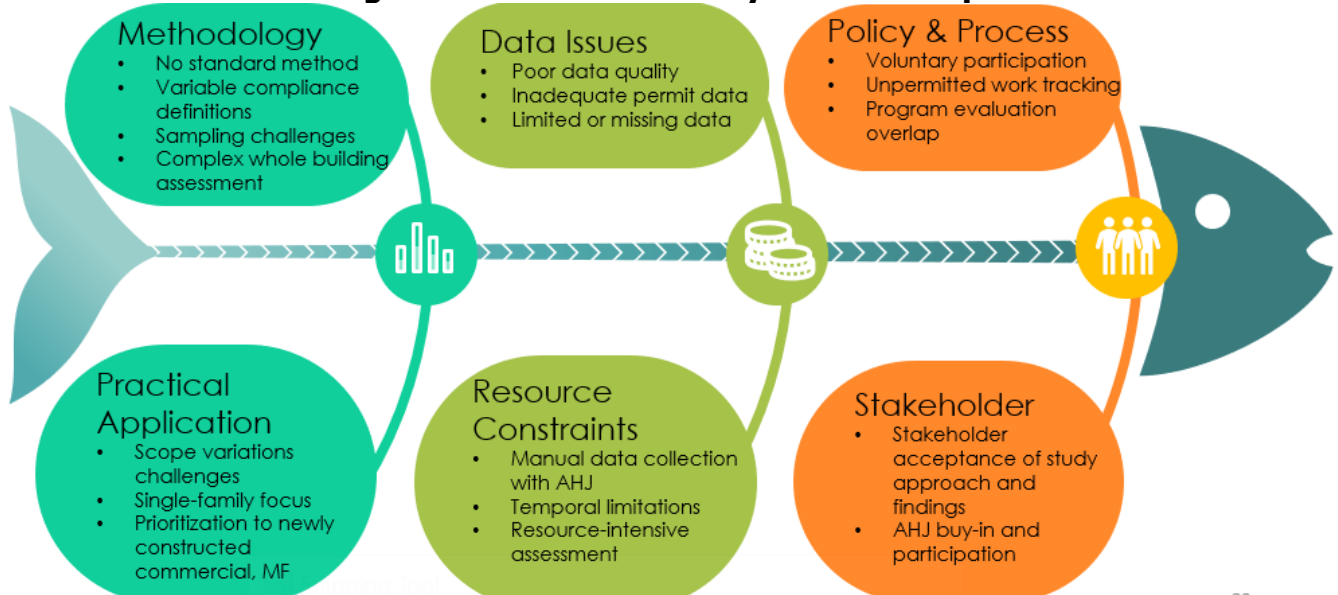
Addressing gaps with interested parties. Some gaps, such as variation in compliance definitions and the absence of a standardized compliance rate methodology, can be addressed through internal discussions within the CEC to determine the most appropriate approach. More complex issues—such as prioritizing building categories, evaluating the inclusion of unpermitted projects, and developing whole-building energy-based compliance metrics—would benefit from input and discussion with subject matter experts, consultants, and local jurisdictions to identify the most impactful and feasible solutions.

Gap Analysis

Employing techniques like the Fishbone Diagram and Pareto Analysis enriches discussions with interested parties about the gaps. The Fishbone Diagram visually maps out the causes of each gap, organizing them into categories that reveal the multifaceted nature of the problem, thus facilitating discussions by breakout rooms. Pareto Analysis then prioritizes these gaps by identifying which ones yield the most significant impact, allowing interested parties to concentrate resources on the most critical issues, often adhering to the principle that a few causes account for most of the effect. Other gap analysis techniques such as SWOT analysis are not used here. Together, these tools foster a more structured, evidence-based dialogue that can lead to actionable strategies for improving compliance and achieving energy efficiency objectives.

Figure 4-1 uses a fish-shaped structure where the "head" represents the main outcome or problem being analyzed, while the "bones" branching off the central spine represent different categories of factors contributing to that outcome. For example, the study methodology or design ties to practical application priorities. Data issues are often limited by resource constraints. The policy and process that influence the study approach are linked to stakeholder general tolerance of uncertainty and willingness to participate. The fishbone diagram effectively shows how various factors contribute to challenges in building an assessment or evaluation, pinpointing the complexity and interconnectedness of the issues at hand.

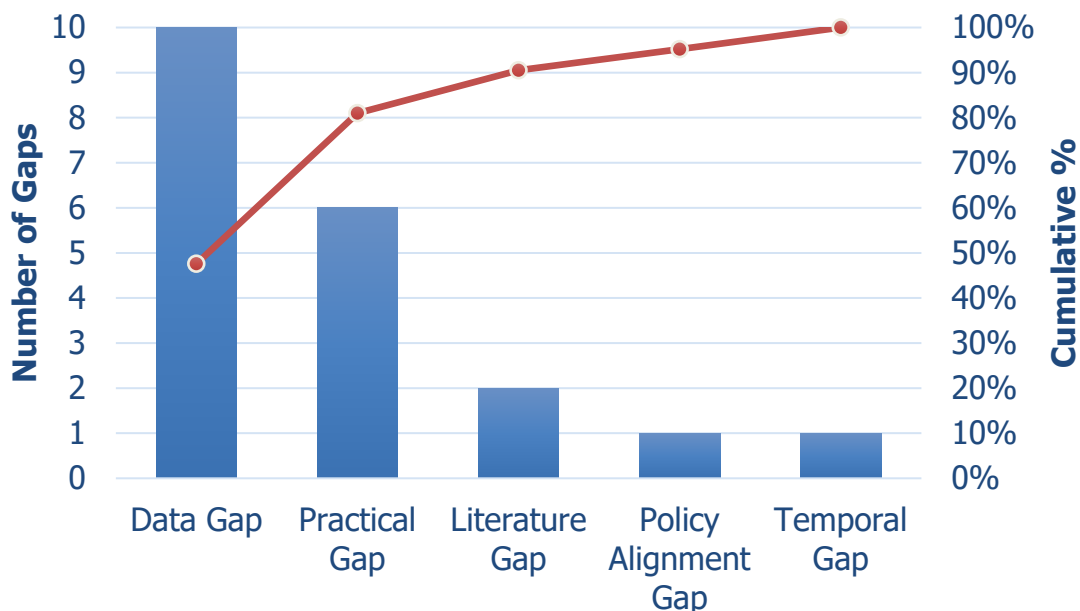
Figure 4-1. Fishbone Analysis of the Gaps



Source: CEC staff

Figure 4-2 shows a Pareto Analysis. On the x-axis, list the categories in descending order of their impact by gaps category. On the y-axis, plot both the individual impact percentages and the cumulative percentage. Typically, the cumulative line should rise steeply, illustrating the 80/20 principle (where 80% of the effects come from 20% of the causes). By using this process, CEC staff can identify which categories or causes contribute the most to the total impact, allowing you to focus your efforts on the most significant issues. While the fishbone diagram shows interconnected issues - Pareto analysis would help determine which connections are most crucial to address first for maximum impact on overall compliance rate study effectiveness.

Figure 4-2. Pareto Analysis of Gaps



Source: CEC staff

The Pareto analysis shows a few categories (Data and Practical-Application gaps) contribute to most of the issues, while the remaining categories (Literature, Policy Alignment, and Temporal) make up the remaining 20%.

Interested Parties Feedback

CEC staff have taken the initiative to develop a comprehensive gaps framework, identifying and scoring gaps, and perform basic gap analysis. This initial scoring provides a foundational understanding of where the most significant challenges lie in terms of compliance rates. However, recognizing the value of diverse perspectives, CEC staff are keen on enhancing this scoring and prioritization process through stakeholder feedback. Engaging interested parties is crucial because it allows for the validation or refinement of the assumptions made during the initial gap analysis. By incorporating feedback from consultants, project teams, advocacy groups, public interested parties, and the CEC project sponsors, the staff hopes that the prioritization of gaps reflects the practical insights and experiences of those directly involved or affected by these compliance issues.

This collaborative approach is expected to culminate into refined research questions to address the most pressing compliance rate issues effectively. It will serve as a roadmap for the State's strategy in improving compliance rates intelligence. With the feedback from interested parties, CEC staff can understand different perspectives. This process ensures that the efforts to enhance Energy Code compliance are both strategic and inclusive, leveraging collective knowledge to drive meaningful changes in code implementation practices across the state.

4.4 Risk Management

Many of the gaps listed should remain on the risk register for future projects to evaluate compliance rates. Projects further downstream will be subject to time, cost, and practicality constraints. Thus, the feedback from the gap analysis may be interpreted as how risk owners would perceive the risks: Accept, Avoid, Mitigate, and Escalate.

The perceived actions are defined below:

- **Accept** – Acknowledge the risk and take no immediate action, often used when the impact is minor or unavoidable.
- **Avoid** – Eliminate the risk entirely by changing the project plan or approach.
- **Mitigate** – Reduce the likelihood or impact of the risk through proactive measures.
- **Escalate** – Transfer the risk to higher authority when it exceeds the project team's control or responsibility.

The inputs from interested parties from public workshops may influence the ranking of the gaps and help the project team understand the important priorities. Given constraints pertaining to cost, time, and scope may come up, the project team will reference the gap analysis and interested parties' feedback to develop mitigation plans and move forward under the project sponsors' watch.

CHAPTER 5:

Menu of Technical Approaches

CEC staff developed a menu of approaches including those from both past literature and new ideas. The intent of the menu is to identify all known methods and consider cost as well as ease of implementation.

5.1 Field Survey Methods

Most energy code compliance studies use a field surveying method – which includes a statistical analysis of representative sample data collected in the field to verify whether they match the compliance documentation and the intent of the energy code. The variations are derived from data sources, sampling design, and the study design. Field work typically contains some form of checklist where evaluators gather data and rate the compliance score for specific code requirements. All the requirements are then weighed and analyzed to capture the overall compliance rate for a specific building category or measure.

To divide the scope into manageable chunks, CEC staff split the scope by compliance definitions (process-based and energy-based) and building categories (the seven building categories).

Cost Difference Between Process-Based versus Energy-Based Definitions

Each element of the permitting process is essentially part of the stratum of process-based compliance. The evaluation team must increase the number of random samples at various stages of the project due to temporal gaps and practical considerations of how long a project takes from plan check to completion. Therefore, the cost for process-based compliance increases due to the number of strata and samples.

On the other hand, energy-based compliance typically only requires a single visit at a minimum to capture all the requirements that are needed to simulate a whole building model to be compared against projected code minimum model. Energy models require many inputs typically requiring evaluation teams to gather data outside the field visit and use complex techniques to ensure accuracy. Therefore, the approximate cost for analysis under the energy-based compliance checks are higher even if it requires less samples.

CEC staff put together **Table 13** to illustrate potential cost, using some arbitrary estimates of cost per sample to understand the magnitude differences of each chunk. Drawing on anecdotal observations, data, identified gaps, and robust public input, CEC staff aim to help the state advance the field of energy code compliance.

Cost Difference Between the Seven Buildings Categories

The major difference between building categories is the various useful stratifications and wisely differentiating the subpopulations for sampling to minimize inconsistent results. Nonresidential buildings pose a challenge because they encompass many building types where compliance rates may vary drastically by type. Stratifying by building type will increase the number of samples required; this leads to increases in necessary resources which make

achieving rigorous results difficult. In addition, with more complex and larger buildings, the evaluation effort exponentially increases and requires expertise as well as accessible and complete information from the sample selected. Therefore, **Table 13** provides an initial recommendation for stratifying each building category.

While there are arguable flaws in the arbitrary guesses to cost per sample, this approach is an attempt to estimate a manageable scope. The total cost is likely not a conservative number, but a minimum cost. The risks associated with the study are likely increasing uncertainty and potential cost.

Note that field evaluation study captures a snapshot of the compliance rates. Thus, to track compliance over time, the study will need to be performed ideally every code cycle and toward the end of the code cycle to capture the bulk of construction activities in that code cycle. Due to its high cost and various barriers - including but not limited to sampling bias, building recruitment, discourse on approaches, and data quality, it is resource intensive and moderately difficult to implement.

Table 13: Menu of Field Survey Methods for Full Compliance Assessment

#	Building Categories	Stratification	Number of Strata	Min # of Samples	Flat Cost Per Sample	Energy-Based Analysis Cost Per Sample	# Samples for Process-Based	Process-based Analysis Cost Per Sample	Estimated Total Cost Per Sample	Estimated Total Cost (mil)
	Notes	1	2	3	4	5	6	7	8	9
1	New construction single-family residential	5 Climate Region	5	340	\$1,000	\$1,500	680	\$1,000	\$5,500	\$1.9
2	Existing single-family residential	5 Climate Region, 2 Project Types (Addition or Alteration, HVAC Changeouts)	10	680	\$1,000	\$1,500	1360	\$1,000	\$5,500	\$3.7
3	New construction multifamily	5 Climate Regions, 2 Project Types (Low to midrise, Highrise)	10	680	\$2,000	\$3,000	1360	\$1,500	\$9,500	\$6.5
4	Existing multifamily	5 CR, 2 Build Types (Low to midrise, Highrise), 2 Project Types (Addition or Alteration, HVAC Changeouts)	20	1360	\$2,000	\$3,000	2720	\$1,500	\$9,500	\$12.9
5	New construction nonresidential	5 Climate Regions	5	340	\$3,000	\$5,000	680	\$2,500	\$15,500	\$5.3
6	Existing nonresidential	5 Climate Regions, 1 Project Type (Tenant Improvements)	5	340	\$3,000	\$5,000	680	\$2,500	\$15,500	\$5.3
7	Process	By-measures (assume top 5)	5	340	\$5,000	\$5,000	680	\$2,500	\$17,500	\$6.0

Notes:

1. Stratification refers to dividing a population into different groups based on specific characteristics to ensure better presentation and analysis. The California Evaluation Protocols for Evaluators (2006) used five climate thermal zones used for assessing Energy Code compliance. The CPUC's prior evaluations also divided the data collection by the five climate regions. Additional stratification that makes sense in the separation of analysis includes project type, generally renovation and remodeling observed from the construction activity characteristics.

2. The total number of stratifications is the product of all strata categories. For example:

$$5 \text{ (climate regions)} * 2 \text{ (project types)} = 10 \text{ (Total Number of Strata)}$$

3. The minimum samples per strata for a population over 1,000 are at least 63 samples, per DOE field studies protocol.

$$\text{Minimum Number of Samples} = 63 \frac{\text{samples}}{\text{strata}} * \text{Total Number of Strata}$$

4. Assumed the minimum flat cost per sample for recruitment, and administrative logistics to acquire a data sample. The cost increased based on building categories and assumed difficulty obtaining samples.
5. Assumed the minimum energy-based compliance analysis per sample cost based on the estimated efforts to perform energy simulation work and/or other calculations to process field collected data to noncompliance potential savings.
6. Process-based compliance requires additional sampling for 3 stages of permitting: design, inspection, and completion. When conducting energy-based compliance, the evaluation team would already be collecting data in the completion phase. Therefore, additional samples for design and inspection stages are needed.

$$\text{Required Addition Number of Samples for Process Based} = \text{Total Number of Samples} * 2$$

7. Estimated Total Cost Per Sample is the total cost per sample to conduct both process-based and energy-based compliance.

$$\text{Estimated Total Cost / Sample} = (\text{Flat cost/sample} + \text{Energy-based analysis cost/sample}) + (\text{Process-based analysis cost/sample}) * 3$$

- Estimated Total Cost is rounded to the largest hundred thousand dollars.

$$\text{Estimated Total Cost (\$Million)} = (\text{Flat cost/sample} + \text{Energy-Based analysis cost/sample}) * \text{Min. \# of samples} + \text{Process-based analysis cost/sample} * (\text{Min. \# of samples} + \text{\# Samples for process-based})$$

5.2 Data-driven Methods

Data-driven methods use large datasets to estimate rates. These methods rely on automated analysis, standardized inputs, and predictive algorithms, offering scalability and efficiency but potentially lacking in granularity in site-specific conditions or specific compliance issues.

Data driven methods are expected to have a high first cost and lower reoccurring cost once these methods have been established. The key advantage of a data driven method is tracking the same key performances indicator (KPI) over time. There's still a tremendous amount of work that needs to be done to be able to track compliance systematically at a highly accurate level for all building types. Therefore, this section is particularly focused on feasible options based on existing accessible data rather than the ideal compliance tracking system.

The basis for cost estimation with the data-driven methods contains higher uncertainty due to staff's limited experience. CEC staff discussed possible costs with Stanford RegLab researchers who conducted the Informal ADU study and DNV GL who conducted the HVAC Assessment study to develop the basis for cost estimation in **Table 14**.

Most data-driven methods require data engineers and data scientists to assemble aggregated data, perform training if needed, and create an analytical model to provide meaningful results. The cost basis is largely composed of skilled personnel cost (whether contracted or in-house). Other costs may include data tools and acquisition costs.

For instance, here is the breakdown for the data method for the highly complex approaches, including using computer vision with satellite data to automatically detect unpermitted work and using Interval Metered Data (IMD) to detect unpermitted HVAC changeouts. Estimated First Cost includes personnel cost (assumes 4 data scientists working on this for two years, $\$300k * 4 \text{ people} * 2 \text{ years} = \2.4 million), third party labeling cost (\$1 million), and other data acquisition or administrative costs (~\$500k), summing to be approximately \$4 million dollars. Given the uncertainty of approximately 30%, the cost can range from \$3 to 5 million dollars. Staff assumed the data acquisition, administrative cost, and personnel would be \$500k for reoccurring cost.

Staff assumed similar ballpark cost for other comparable machine learning approaches to estimate proxy rates for unpermitted work.

To estimate the cost for replicating the DNV GL HVAC Assessment study, historical study cost was used, which was around \$1.5 million dollars in 2014-2017. Through discussions with the DNV project manager, staff learned the consultant team was comprised of approximately 10 statisticians and scientists on day-to-day work. Given inflation and other economic escalation rates, the cost to replicate the study may range from \$2 to \$3 million dollars depending on the scope.

The CEC is working on developing the compliance registry data pipeline on a separate project. Hence, the estimated costs are not applicable. Once the project's milestones are achieved, efforts to develop dashboard and analysis will likely require at least one staff member to lead and continually refine the analysis.

High-level rough cost estimates were prepared by staff for initial and recurring expenditures. First costs are categorized as low (<\$3 million), medium (\$3-5 million), and high (>\$5 million).

Recurring costs, which include personnel and data requirements, are estimated as low (<\$500,000), medium (~\$500,000) and high (>\$1 million). The 'level of difficulty' metric is subjective to staff's assessment at the time drafting this report and incorporates factors such as methodological familiarity, necessary skillsets, data volume, and the challenges associated with acquiring and integrating clean data. Although the scoring represents preliminary assessments, the objective is to comprehensively evaluate all proposed solutions and provide a broad overview of their associated potential cost. **Table 14** below provides a summary of all the viable methods. **Table F-1** in Appendix F: Detailed Menu of Data Driven Approaches contains additional information on data methods.

Table 14: Menu for Data Methods

Data Methods Menu	Building Categories	How	Estimated First Cost	Estimated Reoccurring Cost	Estimated Difficulty to Implement
Detect unpermitted work using computer vision with satellite images	New construction: residential and nonresidential (new footprint only)	Partner and provide funding with academic researchers.	Medium	Medium	High
Detect unpermitted HVAC change-out using Interval Metered Data (IMD) data.	Existing residential	Provide additional resources with existing relationships with Stanford researchers.	Medium	Medium	High
Detect unpermitted HVAC change-out from population/building stock data and End-of-Useful-Life analysis (DEER, RASS) to replicate probable HVAC sales data (re-doing the DNV GL 2017 HVAC Assessment study)	Existing residential	Solicit a contract to update work or add capacity to develop expertise in-house.	Low	Unknown	Low
Detect unpermitted HVAC changeout from comparing HVAC sales data directly with permit data	Existing residential, MF, and nonresidential	Get HVAC sales data from HARDI/Co-Metrics OR CEC to establish rulemaking and collect data directly from market players	Medium-High	Medium	High
Detect unpermitted work/compliance levels by comparing the number of registered forms and permitting the database to understand potential gaps in enforcement	New construction: residential and (some) existing residential	Residential registry development is already in-progress per another project. Can invest more resources here to add capacity or contract out IT challenges.	N/A	N/A	Medium
Estimate unpermitted work based on the real estate listings through natural language processing or cross check assessor records	Existing residential	Solicit a contract or partner with institutional researchers with expertise in data science.	Medium	Low-Medium	High

CHAPTER 6:

Recommendations & Next Steps

Tracking Energy Code compliance in a scientifically rigorous and defensible way can be difficult, complex, and highly resource intensive. Therefore, staff recommend using this gap analysis to establish a foundational understanding of progress in this field to date, gather critical stakeholder feedback, and ultimately prioritize the scope of future state investments. To conduct the most comprehensive and impactful compliance rates study, the CEC needs to solidify prioritizing expenditures for both process-based and energy-based compliance.

To better understand compliance rates in California, staff recommends focusing on conducting comprehensive field studies across building categories first.

Field Study

To establish a comprehensive baseline, staff recommends the CEC conduct a highly targeted, limited scope, and tailored field study using the traditional approach to calculate compliance rates. This study would help the State better investigate process-based compliance and energy-based compliance at a high level. This study should reflect similar elements to the BayREN Prop Report conducted in 2015 and Quantec Process Evaluation Report on Noncompliance Rates in 2007 in evaluating compliance rates for different processes. The outcome can provide feedback to inform and improve existing compliance programs. Energy-based compliance evaluations would also be within the scope of the field study. However, the stringency and depth of energy-based compliance evaluations will be a secondary priority depending on budget constraints, the broader range of variables involved, and additional coordination needed across various parties. Although limited in scope, such a study will provide a high-quality, statewide baseline or snapshot of overall compliance rates at an unprecedented level of detail. This study would also provide greater clarity around the root causes of noncompliance and identify actionable improvements that the State can take to improve compliance rates.

Prioritization Option 1 – Order by Practicality

CEC staff recommend dividing the field studies scope by building categories per the analysis done in Chapter 3.1. Staff considered cost, complexity, feasibility, and potential savings impacts to prioritize each building category which is listed from highest to lowest priority:

- Existing Single Family Residential
- Newly Constructed Single Family Residential
- Newly Constructed Nonresidential
- Existing Nonresidential
- Newly Constructed Multifamily
- Existing Multifamily

- Covered Process

The analysis in Chapter 3.1 prioritized existing residential buildings over newly constructed (Gap 12), newly constructed nonresidential buildings over existing (Gap 14), newly constructed multifamily buildings over existing (Gap 13), and covered process (Gap 15).

The field study prioritization strategy begins with residential buildings, followed by nonresidential, multifamily, and covered processes. This sequence was chosen for practicality. Developing the evaluation protocol is complex and requires a lot of planning to develop data collection processes for each building category. Since there will be overlap in protocols between new and existing buildings within the same category, working on the same new construction and existing building category at the same time can provide some feasibility and cost benefits.

Prioritization Option 2 – Order by Greatest Impact

Based on the preceding discussions with interested parties and internally within the CEC, the following priority areas have been established for consideration:

- Existing Single Family Residential
- Newly Constructed Nonresidential
- Covered Process
- Existing Nonresidential
- Newly Constructed Multifamily
- Existing Multifamily
- Newly Constructed Residential

The rationale underlying this strategy reflects a deliberate balance between analyzing building categories with significant complexity—including unpermitted project implications, broad scope variability, and associated research challenges—and prioritizing studies that will yield the most impact on energy policy. Staff intend to engage interested parties to gather feedback on this prioritization strategy and to obtain perspective on which categories should be prioritized.

Data-driven Analysis

Creating a system to track compliance over time at a low replicable cost can provide significant value to Californians in the long run. However, the current data-driven methodologies identified in Chapter 5 mostly target quantifying unpermitted work. These data-driven methodologies are harder to achieve without more sophisticated solutions and will require substantial initial development with highly skilled data engineers and scientists.

Considering the CEC's current development of compliance infrastructure, such as the compliance data registry, less emphasis will be placed on the data-driven method(s) in subsequent steps. Data-driven approaches are unlikely to yield comprehensive compliance rates that can lead to actionable insights required for effective, real-world solutions. Upfront investments and ongoing maintenance for this work are expected to be significant.

In parallel, CEC should continue to explore other permit data options as permit data is still relevant to tailored field studies work. Other methods that utilize newer datasets (satellite

data, real estate and assessor records data, and IMD data) have pros and cons. These datasets can yield insightful results given the advancements in data science. However, no method alone provides a complete picture. Engaging with existing partnerships with academic research groups, forming new collaborations with academic institutions, and/or holding competitions such as hack-a-thons can provide new technical insights into innovative methods. CEC staff can continue to utilize existing datasets and other sources of best available data that have historically lacked the precision necessary to target specific interventions.

The Next Step

CEC staff plans to conduct public engagements on the topic of Energy Code compliance to present progress and findings to date, gather critical interested party feedback, identify data gaps more comprehensively, and incorporate input on how to prioritize those gaps. The goals of public engagements are to enable the public to help shape the prioritization and sequencing of future compliance improvement initiatives. At the same time, CEC staff is actively pursuing funding opportunities to support field studies and other compliance improvement initiatives.

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Glossary

Term	Definition
Assembly Bill (AB)	A legislative proposal originating from the California State Assembly. Once passed by both legislative houses and signed by the Governor, it becomes law.
American Community Survey (ACS)	An ongoing survey by the U.S. Census Bureau that provides vital information on a yearly basis about the nation and its people.
Accessory Dwelling Unit (ADU)	A secondary housing unit on a single-family residential lot, also known as a granny flat or in-law unit.
Authority Having Jurisdiction (AHJ)	An organization, office, or individual responsible for issuing building permits for newly constructed buildings or additions and alterations to existing buildings and enforcing the California Building Code (CBC), Title 24 of the California Code of Regulations in totality, including the Energy Code.
Artificial Intelligence (AI)	The simulation of human intelligence processes by machines, especially computer systems.
Acceptance Test Employer (ATE)	A person or entity who employs an Acceptance Test Technician and is certified by an authorized Acceptance Test Technician Certification Provider pursuant to the requirements of 10-103.1 or Section 10-103.2
Acceptance Test Technician (ATT)	A Field Technician as defined in Section 10-102 who is certified by an authorized Acceptance Test Technician Certification Provider to perform acceptance testing of either lighting controls or

Term	Definition
	mechanical systems pursuant to the requirement of Sections 10-103.1 or Section 10-103.2, respectively.
Acceptance Test Technician Certification Provider (ATTCP)	An agency, organization or entity approved by the CEC to train, certify and oversee ATTs and ATEs relating to either lighting controls or mechanical systems according to the requirements of Sections 10-103.1 or Section 10-103.2, respectively.
Building Energy Codes Program (BECP)	An office within Department of Energy that supports building energy code development, adoption, and implementation processes to achieve the maximum practicable, cost-effective improvements in energy efficiency while providing safe, healthy buildings for occupants.
Compliance Adjustment Factor (CAF)	A numeric value applied in building energy modeling or performance calculations to adjust for differences in compliance approaches, technologies, or assumptions, ensuring equitable comparisons and accurate energy savings estimates.
California Advanced Lighting Controls Training Program (CALCTP)	A program designed to educate and certify electricians in the proper installation and maintenance of advanced lighting control systems.
Codes and Standards Enhancement (CASE)	Initiatives aimed at improving building energy efficiency through updates to codes and standards.
Codes and Standards (C&S) Program	The statewide Codes and Standards (C&S) program are authorized under the California Public Utilities Commission (CPUC) to: 1) influence standards and code setting bodies (such as the California Energy Commission) to strengthen energy efficiency regulations, 2) improve compliance with existing codes and standards, 3) assist local government to develop ordinances that exceed statewide minimum requirements, and 4) coordinate with other programs

Term	Definition
	and entities to support the state’s ambitious policy goals. Codes & Standards program are typically executed by program administrators, selected through openly competitive processes, and include sub-programs such as Building Codes Advocacy, Appliance Standards Advocacy, Compliance Improvement, Reach Codes, Code Readiness, and Planning and Coordination.
California Building Standards Commission (CBSC)	This state agency is responsible for developing and implementing building codes and standards in California.
Commission Compliance Document Repository (CCDR)	An electronic database and document storage software application used for retention of registered electronic Compliance Documents generated by Data Registries and may also contain data and documentation relevant to other regulatory procedures administered by the California Energy Commission. The Commission Compliance Document Repository shall maintain these retained documents in accordance with Evidence Code sections 1530-1532 (in the custody of a public entity).
California Energy Commission (CEC)	The state's primary energy policy and planning agency, responsible for forecasting future energy needs and promoting energy efficiency.
Controlled Environment Horticulture (CEH) Space	A building space dedicated to plant production by manipulating indoor environmental conditions, such as through electric lighting, irrigation mechanical heating, mechanical cooling, or dehumidification. CEH space does not include building space where plants are grown solely to decorate that same space.
City Energy Project (CEP)	A \$20 million, multi-year initiative operated under Institute for Market Transformation that provided human and financial resources to major U.S. cities to

Term	Definition
	improve the energy efficiency of buildings and is a partner in the Bloomberg American Cities Climate Challenge, a \$70 million program funded by Bloomberg Philanthropies that supports bold climate action in 20+ U.S. cities. The Project worked collaboratively with each city to develop a tailored set of policies and programs to improve the energy performance of its building stock. The Project focused on large public and private-sector buildings, which together account for a disproportionate share of urban energy use and carbon pollution.
Compliance Form Report (CFR)	A standardized document generated through approved compliance software that demonstrates whether a building project meets the requirements of California’s Building Energy Efficiency Standards (Title 24, Part 6). The CFR summarizes key energy performance data and serves as part of the documentation submitted for plan review and permitting.
California Measurement Advisory Council (CALMAC)	An organization that provides guidance on measurement and evaluation of energy efficiency programs in California.
Certificate of Compliance (CF1R)	A document submitted to demonstrate that the project design and equipment complies with the Energy Code at the time of permit application.
Certificate of Installation (CF2R)	A document submitted to demonstrate installations are compliant with the Energy Code at the time of construction and should be submitted by the installer to the inspector.
Certificate of Verification (CF3R)	A document submitted to demonstrate field verification and/or diagnostic testing is compliant with the Energy Code at the time of construction and

Term	Definition
	should be submitted by the HERS Rater to the inspector.
California Public Utilities Commission (CPUC)	The regulatory agency in California that oversees privately owned electric, natural gas, telecommunications, water, and transportation companies.
Compliance Rate (CR)	The proportion of applicable building or appliance installations that fully meet the energy efficiency requirements specified in the adopted codes or standards. This metric is used to assess the effectiveness of code implementation and enforcement, and to estimate realized energy savings.
Database for Energy Efficiency Resources (DEER)	A comprehensive database that provides information on energy efficiency measures and their impacts.
Department of Energy (DOE)	A federal agency responsible for overseeing national energy policy and research.
Department of Finance (DOF)	A state agency responsible for ensuring the financial integrity of California's fiscal policies.
Department of Toxic Substances Control (DTSC)	A California state agency responsible for regulating hazardous waste and cleanup of contaminated sites.
Energy Code	This refers to a set of statewide regulations designed to improve energy efficiency in buildings. It is part of the California Code of Regulations, Title 24, Part 6. These standards establish minimum building requirements for energy-efficient design and construction, covering aspects such as insulation, windows, lighting, heating, ventilation, air

Term	Definition
	conditioning (HVAC), and renewable energy systems like solar panels.
Energy Code Ace	A public-funded resource that provides tools, training, and resources to help comply with California's Energy Code. Energy Code Ace strives to make it faster and easier for each market actor in the compliance supply chain to effectively comply with California's Energy Code (Title 24, Part 6) and appliance efficiency standards (Title 20) to help realize the full benefits of the statewide Codes and Standards program's advocacy efforts. The program is funded by California utility customers under the auspices of the California Public Utilities Commission and implemented by Pacific Gas and Electric Company, San Diego Gas and Electric and Southern California Edison in support of the California Energy Commission.
Energy Code Compliance (ECC) Program	Starting in the 2025 California Energy Code, the Energy Code Compliance program is the formal successor to the Home Energy Rating System (HERS) program. It oversees the training, certification, and monitoring of third-party verifiers—now known as Energy Code Compliance (ECC) Raters—who perform required field verification and diagnostic testing of installed energy measures. The ECC program ensures that residential buildings meet energy efficiency standards through verified compliance documentation and plays a critical role in upholding the integrity and effectiveness of California's Title 24, Part 6 requirements.
Energy Efficiency (EE)	The use of less energy to perform the same task or produce the same outcome. Energy efficiency measures reduce energy waste, lower utility bills, and decrease environmental impacts by improving the performance of buildings, appliances, equipment, and industrial processes without compromising service or comfort.

Term	Definition
Extensible Markup Language (XML) Format	A markup language designed to store and transport data in a structured, human-readable, and machine-readable format, using customizable tags to define elements and their relationships, widely used for data exchange across diverse systems and applications.
Energy Saving Adjustment Factor (ESAF)	A multiplier applied to estimated energy savings to account for factors such as installation quality, user behavior, or market trends that may affect actual performance. ESAF is used in energy efficiency program evaluations and compliance assessments to produce more accurate projections of realized energy savings from energy efficiency measures.
Effective Useful Life (EUL)	The estimated number of years that an energy efficiency measure or piece of equipment will remain in service and deliver energy savings under typical operating conditions. It is used in cost-effectiveness calculations and planning for energy efficiency programs.
Field-Verification and Diagnostic Testing (FV&DT)	A process required by the California Energy Code to confirm that certain energy efficiency measures have been properly installed and are functioning as intended. Conducted by certified third-party Raters, FV&DT includes visual inspections and performance tests—such as duct leakage or refrigerant charge testing—to ensure compliance with Title 24, Part 6 standards.
Gross Domestic Product (GDP)	The total monetary value of all finished goods and services produced within a country's borders in a specific period, serving as a broad measure of overall domestic production.

Term	Definition
Department of Housing and Community Development (HCD)	A state agency responsible for administering programs that provide safe and affordable housing and promote strong communities.
Home Energy Rating System (HERS)	Ensures that the various features of a home meet the California Building Energy Efficiency Standards (Energy Code). If work requires HERS testing, a rater will perform field verification and diagnostic testing on the appropriate features. If the system fails, the contractor is required to fix it.
Interval Metered Data (IMD)	Detailed energy consumption data recorded at regular intervals (e.g., every 15 minutes or hourly) by advanced metering systems. IMD provides granular insights into usage patterns, enabling more accurate energy analysis, demand response strategies, and performance evaluations of energy efficiency measures.
Internal Revenue Service (IRS)	The federal agency within the U.S. Department of the Treasury responsible for administering and enforcing the nation's tax laws, including the collection of taxes and the issuance of tax-related benefits such as energy efficiency tax credits and incentives.
Integrated Standards Savings Model (ISSM)	A CPUC-approved analytical tool used to estimate energy savings attributable to California's codes and standards efforts. The ISSM integrates data on building characteristics, compliance rates, measure adoption, and energy performance to provide consistent, statewide estimates of gross and net energy savings resulting from new or updated efficiency standards.
Joint Appendix 7 (JA7)	A section of the California Building Energy Efficiency Standards that provides guidelines for specific energy compliance measures.

Term	Definition
Key Performance Indicator (KPI)	A measurable value that demonstrates how effectively an individual, team, or organization is achieving key objectives.
Low-rise Multifamily Certificates (LMC)	A suite of compliance documentation required for low-rise multifamily residential buildings under California’s Building Energy Efficiency Standards. These include LMCCs, LMCIs, and LMCVs.
Low-rise Multifamily Certificate of Compliance (LMCC)	These document the energy compliance approach and performance results for a specific project. LMCCs must be registered if FD&DT is triggered. These certificates are typically generated and registered through approved compliance software and submitted to building departments as part of the project approval process.
Low-rise Multifamily Certificate of Installation (LMCI)	Completed by the installation contractor to verify that energy features were installed as specified. LMCIs that do not include numerals in the form number cannot be registered and those that do must be registered. These certificates are typically generated and registered through approved compliance software and submitted to building departments as part of the project approval process.
Low-rise Multifamily Certificate of Verification (LMCV)	Completed by a certified Energy Code Compliance (ECC) Rater to confirm that field-verified and diagnostically tested measures meet energy code requirements. LMCVs must be registered. These certificates are typically generated and registered through approved compliance software and submitted to building departments as part of the project approval process.

Term	Definition
Market Assessment & Evaluation (MA&E)	A study conducted by the California Public Utilities Commission to evaluate trends and challenges in implementing the Energy Code.
Nonresidential Lighting Controls Acceptance Test Technician Certification Provider (NLCAA)	An entity authorized to train and certify technicians who perform acceptance testing on nonresidential lighting controls.
Nonresidential Certificates (NRC)	A suite of compliance documentation required for nonresidential buildings, high-rise residential buildings, and hotels/motels under California's Building Energy Efficiency Standards. This includes NRCCs, NRCAs, and NRCIs.
Nonresidential Certificate of Acceptance (NRCA)	Forms completed by a field technician or Certified Acceptance Test Technician to verify compliance with acceptance testing requirements in the Energy Code, submitted to the inspector during construction.
Nonresidential Certificate of Compliance (NRCC)	Documents used to demonstrate that construction plans comply with the Energy Code at the time of permit application, outlining energy efficiency requirements for the building design.
Nonresidential Certificate of Installation (NRCI)	Certificates submitted by the installer to confirm that installed systems, components, or equipment match the specifications prescribed by the NRCC, ensuring compliance with the Energy Code at the time of construction.
Personally Identifiable Information (PII)	Information that can be used to identify an individual, such as name, social security number, or email address.

Term	Definition
Pacific Northwest National Laboratory (PNNL)	A U.S. Department of Energy national laboratory conducting research in areas like energy resilience and national security.
Probability Proportional to Size (PPS)	A statistical sampling technique where the probability of selecting a particular unit (e.g., a household, building, or entity) is proportional to its size, typically measured by a variable such as population, energy consumption, or another relevant metric. This method ensures that larger units have a higher chance of being included in the sample, improving the representativeness and efficiency of the sampling process for studies or surveys.
Program Year (PY)	A specified 12-month period during which a particular program's activities and budgets are planned and assessed.
Residential Appliance Saturation Survey (RASS)	A survey that is conducted to gather data on the prevalence and usage patterns of appliances in residential settings.
Regional Energy Networks (RENs)	A collection of localized organizations authorized by the California Public Utilities Commission to design and deliver energy efficiency programs tailored to the specific needs of their communities, often filling gaps left by investor-owned utility programs. These networks operate under regional governance, typically led by local government entities, to enhance energy savings, promote sustainability, and support equitable access to energy resources across diverse geographic areas in California.
Regional Housing Needs Assessment (RHNA)	A process that determines the number of housing units a region should plan for to meet future housing needs.

Term	Definition
Residential New Construction (RNC)	The process of designing and building new residential housing units.
Senate Bill (SB)	A legislative proposal introduced in the state senate, which must be passed by both legislative houses and signed by the Governor to become law.
Saving Estimate Spreadsheet (SES)	Developed by the Heschong Mahone Group in 2005, this spreadsheet documented the estimated savings for all building measures and its compliance rates used to calculate the savings by the utilities' energy efficiency programs.
Time Dependent Valuation (TDV)	A method of valuing energy savings based on the time of day and season, reflecting the changing costs and environmental impacts of energy use.

APPENDIX A:

Table of Field Methodologies

CEC staff have thoroughly examined studies across the United States that employ diverse methodologies to assess building energy code compliance. Key research methodologies include on-site building inspections, document review processes, statistical sampling techniques, and comparative analyses between jurisdictions. These methodologies typically involve detailed checklists, performance testing, and statistical extrapolation to provide a comprehensive understanding of energy code enforcement and implementation challenges at local, state, and regional levels.

A.1 Simulated Performance

Building Categories: All except process

How Compliance Rates are Measured: Compliance rates are evaluated based on the energy modeling output of the field survey buildings compared to its prescriptive minimum requirements.

Long Description: Standard analysis tools are usually code compliance or energy simulation software, especially seen in early 2000 evaluations. There is no standard software used nor standard data collection which makes cross comparison very difficult. This methodology uses data collected from the field, simulates energy models, and performs analysis to generate energy savings and compliance rates.

Particularly with residential evaluations, evaluators assess energy code compliance by comparing installed systems against minimum code requirements (prescriptive standard model) typically using REMRate (HERS Rating) and ResCheck software. Some studies only evaluated the thermal performance (UA analysis) or building components instead of whole-building analysis.

Newer methodologies such as the DOE BECP 2022 method also employed some simulation techniques and more advanced analysis such as Monte Carlo and Bayes Theorem that build off the work from this methodology.

Variations: Since only a certain amount of information can be collected during site visit, some studies employ Monte Carlo simulations to estimate the compliance rate.

Advantages:

- This method evaluates the overall savings, avoids double counting of savings between measures, and accounts for interactive effects.
- This method can limit the data collection to a single visit (post-occupancy or when the project is completed) that can save cost. However, the main challenge is that some improvements like insulation behind walls can't be easily checked once construction is done.

Disadvantages:

- Building an energy model through this methodology is data-intensive, requiring specialized auditors to collect and verify numerous variables. This process is time-consuming and susceptible to human errors and cumulative uncertainties.
- Critics note that the method overlooks mandatory measures not included in existing modeling software, assuming these measures are properly implemented in the field.
- This method will not address compliance changes throughout the permitting process.
- Prone to systematic errors to assess real energy savings from code implementation.⁶² This can overestimate heating use especially for homes with high heating energy intensity.
- The wide degree of uncertainty does not allow a simple analysis and can cause debates and confusion among interested parties.

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A.2 IMT/CEP Assessment

Building Categories: All except process

How Compliance Rates are Measured: Compliance rates are measured by measures of three building systems (lighting, envelope, and mechanical).

Long Description: The City Energy Project (CEP), a collaboration between NRDC and IMT, developed a four-phase methodology in 2018 to assess energy code compliance:

1. Conduct stakeholder interviews
2. Review building department processes for completeness and issues
3. Sample permit data (limited, standard, or statistical)
4. Analyze findings to create compliance improvement plans and scores

The methodology was designed specifically for cities, counties, and local jurisdictions. It combines qualitative and quantitative assessments using a "building systems" approach that evaluates lighting, envelope, and mechanical components. Data collection occurs during specific construction stages when systems are accessible. This enables evaluators to assess multiple buildings' systems simultaneously rather than monitoring a single building throughout construction. For example, evaluators would collect data for a mechanical system for a project that would be undergoing mechanical inspections, and so that project would not contain ducts covered with sheetrock at the time of inspection. The approach applies to residential, multifamily, and nonresidential projects, with requirements varying by building type.

For quantitative compliance scoring, evaluators review pre-permit plans, create data collection forms to verify code compliance, and document discrepancies. They also conduct on-site inspections alongside field inspectors to evaluate energy inspection processes at different construction phases.

Variations: Sampling approaches include limited, standard, and statistical options for cities. Each option has a specific number of samples required where complexity and rigor vary with statistical option is the only one that will indicate statistical significance rigor.

This method suggests the use of energy modeling to support the compliance analysis as optional.

Advantages:

- Building systems approach simplifies the evaluation process, allowing local jurisdictions to pick and choose areas of concern applicable to their region.

Disadvantages:

- This methodology may not account for interactive effects and can present double counting or miscounting of the overall savings.

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A.3 DOE BECP 2010

Building Categories: All except process

How Compliance Rates are Measured: Compliance rates are measured from a checklist of 3 tiered weighted measures and statistical output from "yes/no" marking on each measure.

Long Description: This method provides two ways to score compliance:

- Binary yes/no checklist,
- 0-100% rating scale (though most states chose the binary option)

Code requirements are organized in three weighted tiers, with higher energy impact measures receiving greater weight. Compliance scoring varies by sector:

- Residential new construction: Total points received / total possible points
- Nonresidential new construction: Average individual scores weighted by building strata and construction activity projections (square footage)
- Renovations: Number of weighted compliant items / number of weighted items evaluated. Due to varying scopes and requirements, BECP 2010 lacks sufficient data for statistically rigorous conclusions about the renovations sub-populations.

Variations: Some studies added an "enhancement" by collecting more specific information during the field visit than just the simple "yes/no" to the compliance item. For instance, when looking at AC units, the evaluators also recorded an efficiency # instead of just simply "yes" to the field visit. This allows more in-depth analysis.

Advantages:

- Binary checklist simplifies the compliance evaluation process.
- Standardized methods across multiple states. Uniform data collection protocols enhance the reliability and replicability of results.
- On-site data collection provides direct evidence of compliance with energy codes, reducing reliance on self-reported data or assumptions.

- Field studies assess compliance at the measure level (e.g., insulation, window specifications, HVAC systems), enabling targeted recommendations for improvement. Identifies specific areas where compliance is high or low, facilitating focused interventions.

Disadvantages:

- Typically, the levels of compliance aren't assessed. Measures are either compliant or noncompliant. This quantitative analysis may not answer the level of compliance and indicate root causes to noncompliance.
- On-site data collection requires significant time, funding, and trained personnel, making it a costly approach compared to desk-based evaluations or simulations.
- Sample sizes are often limited due to resource constraints, which may reduce the statistical representativeness of findings. Some building types, such as multifamily or specialty nonresidential buildings, may be underrepresented due to sampling challenges.
- Field studies often focus on a subset of energy code measures (e.g., envelope insulation, air sealing), potentially overlooking broader aspects of code compliance. Interactions between measures, which impact overall building performance, may not be fully captured.
- DOE field studies often focus on technical compliance but may not account for market barriers, such as cost constraints or contractor resistance, that influence compliance behavior.

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A.4 DOE BECP 2022

Building Categories: All except process

How Compliance Rates are Measured: Compliance rates are measured by the top 8 key items (that has the highest impact of the energy code) and additional information is collected (not just yes/no) in the field to add energy modeling simulation in the analysis.

Long Description: Since 2010, the DOE-PNNL team leading the field studies methodology development has separated the methodology document into 4 major different categories: (1) residential, (2) nonresidential, (3) large nonresidential and complex buildings, and (4) multifamily.

For the updated 2022 residential methodology, DOE updated the sampling approach and evaluation checklist to focus on approximately 8 key items. The field data collection process also includes more context that is not necessarily relevant to the compliance item checklist but may help support the post-visit analysis. In addition to the compliance requirement being investigated as a measure of compliance, the authors utilize building energy simulation tools to do energy and savings analysis. For sampling, the approach added greater complexity of utilizing Delphi method and bootstrap sampling method to determine # of samples. In general, the number of minimum samples increased from 44 to 63 per key item.

Similarly for nonresidential buildings methodology, DOE recommends the key item approach. For low-rise multifamily, the approach is very similar to the residential methodology and focuses on key items particularly common areas around envelop, HVAC system, hot water, interior/exterior lighting. The differences between single-family homes and low-rise multifamily approaches are the number of samples as well as how the facilities are surveyed. Due to a lower number of low rise multifamily, the field survey is designed for the entire building vice parts of the building (or components).

Variations: The analysis and execution of this method were very consistent due to technical support by Pacific Northwest National Lab (PNNL) who helped create the sampling plan, documentation for data collection, and data analysis. The State's role was primarily data collection and perform other analysis as desired.

Advantages:

- Technical support from PNNL to create sampling plans, documentation for data collection, and data analysis.
- Method addresses overall energy savings from compliance through multiple approaches: measure-level analysis and whole building analysis.
- Nationally recognized methodology developed by the DOE.

Disadvantages:

- The methodology was designed to IECC and ASHRAE codes, not California Energy Codes.

- More complex methodology requires highly specialized expertise. Logistical challenges in scheduling and accessing multiple sites can increase project complexity.
- Higher cost due to the number of samples required to be collected (63 samples x 8 key measures = 504 data sets in addition to other data required for building simulation).
- Data quality depends heavily on field inspectors' expertise and consistency in applying protocols. Variability in construction practices and documentation across jurisdictions can complicate data collection and interpretation.

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A.5 Northwest

Building Categories: All except process

How Compliance Rates are Measured: Compliance rates are measured using significant items/measures of estimated savings and analyzed with the DOE BECP 2022 methodology and the support of PNNL.

Long Description: Northwest Energy Efficiency Alliance (NEEA) conducts field studies on behalf of the Northwestern states, including Washington, Idaho, Nebraska, Oregon, and Montana from the 1990s to present. Over time, it was observed that the methodology to measure energy code compliance evolved.

- **1990s:** Studies varied in design and rigor, emphasizing stakeholder interviews and compliance recommendations.
- **2008:** Shifted to building systems approach (envelope, lighting, mechanical) with random sampling using Census data and multiple aggregated sources.
- **2019-2022:** Adopted BECP 2010 methodology components, including three-phase approach and explicit statistical significance reporting.

CEC staff met with the project managers for NEEA residential and nonresidential field studies and discussed their 2024 ACEEE paper and lessons learned in conducting these evaluations. NEEA highlighted the use of multiple data sources, the challenges with rural jurisdictions data collection, the challenges with nonresidential buildings, and the cost in data collection in partnership with PNNL.

Variations: Earlier studies used binary pass/fail criteria while later ones employed weighted scoring or EUI to understand the percentage of homes meet or exceed the current code in compliance. Earlier studies focused on single-family homes whereas later studies expanded to multifamily units and diverse state-wide samples. The later studies include more data sources. The sampling frames are stratified by size or type versus broader multi-strata approaches. Statistical rigor increased with precision metrics improving from 80% confidence to 95% confidence level.

Advantages:

- Adapt compliance evaluation method to fit their research needs.
- Finding creative ways to collect data from multiple sources to lessen the burden on the field data collection.
- Leverage existing methodology laid out by DOE and relationship with PNNL to gain support for additional analysis.
- Leverage local market actors for recruitment.

Disadvantages:

- Many variations in the methodology to meet the regional needs that may not be applicable to California population and region.
- Do not evaluate compliance changes within the permitting process or address unpermitted rates.

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A.6 Delphi Panel

Building Categories: All except process

How Compliance Rates are Measured: Compliance rates are measured through an aggregation of compliance scores by interviewing experts through multiple rounds.

Long Description: A Delphi panel, or Delphi method, is a structured process for gathering expert opinion on a topic. It's often used in forecasting, decision-making, and policy analysis, especially when it comes to complex or uncertain issues. The method typically involves a panel of experts who participate in multiple rounds of questionnaires and interviews. In the compliance evaluation context, the compliance rate is an aggregation of compliance scores by experts through three or rounds of interviews.

Variations: The variations in this method lie in the number of experts and how the questions are asked to derive rates.

Advantages:

- To gather expert consensus, reduce group thought through anonymous participation, and allow experts to refine opinions through multiple rounds.
- For complex problems lacking clear data.

Disadvantages:

- Depend heavily on expert selection and panel composition.
- It can be expensive to coordinate and maintain expert engagement.
- Risk of oversimplifying complex issues to reach consensus.

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A.7 California

Building Categories: All except process

How Compliance Rates are Measured: Compliance rates are based on whole-building analysis and compared savings of sampled buildings to projected savings from code improvements. Compliance rates evaluation methodology does not look at the entirety of *Title 24 Part 6* requirements and are often limited to high-impact measures to calculate attribution savings. Compliance rates in this context are called compliance adjustment factors or energy saving adjustment factors.

Long Description: See Appendix B.

Variations: See Appendix B.

Advantages:

- ESAF enables evaluations to account for over-compliance. ESAF reflects real-world energy performance, capturing interactions among building systems and beyond simplistic pass/fail compliance.
- Incorporates on-site inspections, field verifications, building simulation modeling, surveys, and interviews to assess compliance comprehensively. Combines qualitative insights with quantitative data, offering rich context for understanding barriers and drivers of compliance.

Disadvantages:

- Whole-building analysis and ESAF calculations require significant resources, advanced tools, and expertise, making them time-consuming and costly.
- Different evaluators may apply methodologies differently, introducing variability and reducing reliability.
- Stratified sampling often excludes specific building types or regions, leading to incomplete representations of statewide compliance trends. Some interested parties argue that methodologies overly inflate compliance rates due to biased sampling or inconsistent application of criteria.
- Evaluations often underrepresent multifamily buildings and alterations, despite their share of the construction market. Site visits for multifamily projects are frequently omitted due to logistical difficulties.

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⁶³ Opinion Dynamics, Navigant, Market Logics. 2023. [PY 2016-2018 Building Codes Advocacy Program Evaluation: Volume 2 – Final Report](https://www.calmac.org/%5C/publications/C&S-Report_Del_13A_Vol2_FINAL_04-20-23.pdf). CPUC. CALMAC ID: CPUC0235.02. Available at https://www.calmac.org/%5C/publications/C&S-Report_Del_13A_Vol2_FINAL_04-20-23.pdf.

APPENDIX B:

CPUC IOU C&S Building Codes Advocacy Program Impact Evaluation Long Summary

This appendix summarizes relevant reports from the CPUC's oversight of IOU Codes & Standards (C&S) Building Codes Advocacy Program Impact Evaluations by program years. Other relevant reports as part of the energy efficiency program evaluation are also touched on.

B.1 IOU Statewide C&S Building Codes Advocacy Program Impact Evaluation Program Years (PY) 2006-2008

Building Categories Evaluated: Residential and Nonresidential

Cadmus partnered with KEMA (or later known as DNV) led research and evaluation efforts for the first official program impact evaluation study to examine the statewide C&S program using the California Protocols⁶⁴. Their research focused on 194 homes that hadn't participated in utility energy efficiency programs.

The study estimated whole building compliance rates by "using the ratio of the energy use of buildings built to just meet the 2001 Title 24 minus their consumption as built under the 2005 Title 24, divided by their energy use if built to just meet the 2001 Title 24 minus their consumption if built to just meet the 2005 Title 24."

The methods vary across building categories:

- **Newly constructed Residential:** Using MICROPAS to calculate the whole house compliance rates which takes the ratio between actual energy saved from 2001 Title 24 standard divided by expected savings from 2005 Title 24 updates.
- **Existing Residential:** Determined from surveys of building code officials and home occupants.
- **Newly constructed and Existing Nonresidential:** The author mentioned that whole building compliance analysis, like the newly constructed residential method, was ideal, but due to data collection challenges, they could not use the approach. Therefore, they use a measure-by-measure analysis "included in the SES spreadsheet".

Later evaluations in 2010-2012 noted gaps in documentation and methodology. The shift from whole-building to measure-specific analysis for nonresidential properties highlights the complexity of evaluating larger structures. These challenges continue to affect accurate compliance measurement in the nonresidential sector.

⁶⁴ Cadmus et al. 2010. *Codes & Standards (C&S) Programs Impact Evaluation California Investor-Owned Utilities' Codes and Standards Program Evaluation for Program Years 2006-2008*. CALMAC. Study ID: CPU0030.06. Available at https://www.calmac.org/publications/Codes_Standards_Vol_III_FinalEvaluationReportUpdated_04122010.pdf.

B.2 IOU Statewide C&S Building Codes Advocacy Program Impact Evaluation 2010-2012

Building Categories Evaluated: Nonresidential primarily, other categories including interior lighting alteration projects, envelope insulation projects, and cool roof projects

Based on the impact evaluation results from 2006-2008 program, Cadmus partnered with DNV GL looked at the high impact saving code categories and drove the selected categories of the studies.⁶⁵ The research priority for this cycle was focused on newly constructed and nonresidential buildings renovations, using field survey methods and building simulation to calculate savings, while compliance for residential construction relied on findings from the prior evaluation.

The team visited 68 newly constructed nonresidential buildings across four climate regions (the fifth climate zone was excluded due to low construction activity) and conducted 207 successful on-site surveys out of 272 planned. From 207 completed site surveys, 197 sites were used in the analysis. This highlights the challenges in the data collection process and quality issues that led to a smaller sample being analyzed than what was planned. The researchers used a two-stage sampling method. First, they selected building departments based on their size and activity, employing probability-proportional-to-size (PPS) sampling approach. Second, they gathered permit data from local authorities and construction databases.

Compliance rates started to be defined more clearly in this cycle where authors distinguished the definitions and methodology between “Compliance Rate” and “Compliance Adjustment Factor” (CAF) as show in **Figure B-1** below.

⁶⁵ DNV GL, Cadmus. 2014. *Statewide Codes and Standards Program Impact Evaluation Report for Program Years 2010-2012*. CALMAC. Study ID: CPU0070.03; CPUC WO 0031. Available at https://www.calmac.org/publications/CS_Evaluation_Report_FINAL_10052014-2.pdf.

Figure B-1: How C&S Evaluation PY 2010-2012 Defined Compliance Metrics

Term	Definition	Methods
Compliance Rate	A measurement of the total installed building measures or equipment that comply with current code requirements.	Appliances Ratio: (equipment that meets the current standard) / (total market volume) Buildings <i>Prescriptive</i> Ratio: (equipment that meets the current standard) / (total market volume) <i>Performance</i> Ratio: (annual energy consumption of building that just meets the current standard) / (annual energy consumption of building as built)
Compliance Adjustment Factor	Measurement used to adjust IOU savings claims	Appliances Ratio: (equipment that meets the current standard) / (total market volume) Buildings Ratio: (gross savings) / (potential savings) calculated as $CAF = \frac{(2005 - AsBuilt)}{(2005 - 2008)}$

Source: Cadmus, 2016.

Because compliance alone does not necessarily translate into achieving the intended energy savings, Compliance Adjustment Factors (CAF) intend to adjust projected savings to account for other factors. Real world conditions differ from ideal assumptions where measures are installed correctly and little variability in equipment performance versus user behavior. CAF ultimately looked at the total energy savings estimates accounting for possible interactive effects within measures.

This approach aligns with the evaluation's primary objective: quantifying program-attributable energy savings. Notably, the evaluation does not assess strict conformance to code requirements. In cases where specific compliance rates are unavailable, the evaluation defaults to IOU-determined percentages for savings calculations.

The findings do show high compliance in general with new nonresidential construction and less so for some alterations. The precision metrics for alterations were higher (i.e. less precise) than new construction.

B.3 IOU Statewide C&S Building Codes Advocacy Program Impact Evaluation 2013-2015

Building Categories Evaluated: Residential and Nonresidential; both newly constructed and alterations

DNV GL and Cadmus continued to do the evaluation in this program year cycle.⁶⁶ The key difference in this reporting cycle in the methodology is adjustments to determine gross savings.

- (1) The savings from building codes are sometimes estimated based on energy consumption of whole new buildings and sometimes based on energy consumption of specific measures within a new building or construction project. The IOUs have historically used both approaches in their estimate, so there were questions about whether there are overlapping and overcounting of savings. The IOUs acknowledged that whole building savings and some measure level estimates were redundant, and they regard the whole building approach as more accurate than individual measures due to interactions between various measures within a building. Therefore, they try to use the whole building simulation approach to estimate savings for new construction projects and then reconcile the measure findings for alterations.
- (2) Cadmus pointed out that compliance definitions are noted as problematic because of the differences in definitions used by various interested parties. While CAF and CR is used in the appliance standards (not evaluated in this gap analysis), Cadmus proposed to use “Energy Savings Adjustment Factor” (ESAF) for Title 24 to evaluate the energy performance of construction projects rather than evaluation of strict conformance to regulatory requirements.

Using CEC, CIRB, and Dodge data, Cadmus developed a sampling plan around building types for nonresidential and by 5 climate regions. Cadmus evaluated a subset of standards, prioritizing selection based on the IOU estimate of potential savings for each standard and practical considerations for the analysis. Evaluated measures included 28 measures across three building categories (newly constructed nonresidential, alteration nonresidential, residential) and building systems (fenestration, lighting controls, and HVAC controls).

The authors pointed out significant differences between two approaches to measure savings: whole building analysis versus measure-level analysis. While measure-level analysis can be useful, this approach does not account for double-counting and other interactive effects within the building. On the other hand, the accuracy of whole building analysis is difficult to achieve due to difficulty with data collection and typically more time and resource intensive.

Cadmus cited incredible challenges in recruiting for site visits and had to decrease sample size to remain on schedule. In addition, the author noted that the existing analysis is not comprehensive (such as including all building types) enough to estimate Title 24 statewide impact. Thus, they recommend the IOUs, CPUC, and CEC to collaborate to develop an approach designed to quantify Title 24 savings using a consistent building simulation approach.

⁶⁶ DNV GL, Cadmus. 2017. *California Statewide Codes and Standards Program Impact Evaluation Phase Two, Volume Two: 2013 Title 24*. CALMAC. Study ID: CPU0170.01. Available at https://www.calmac.org/publications/CPUC_CS_Volume_2_Report_FINAL_R1_06232017.pdf.

Particularly to nonresidential study assessment, the lag time in construction poses a challenge to evaluate due to the natural timeline in nonresidential buildings from issue permit to project completion. Therefore, it may take longer than 1 year to complete evaluation for nonresidential projects. This presents a gap when a point-in-time or snapshot study should be conducted. If buildings are included in the study that were built under a prior code (and no information is available to determine what code they were built under), their level of compliance with the new code is likely to be less so their estimated savings would be less. On the other hand, assuming too short a time lag would mean that the estimated volume of buildings covered by the new code would be overstated.

B.4 IOU Statewide C&S Building Codes Advocacy Program Impact Evaluation PY 2016-2018

Building Categories Evaluated: Residential, Nonresidential and Low Rise (Residential) Multifamily

In a change of historic contracting practices, this impact evaluation was conducted by Opinion Dynamics, Guidehouse, and Market Logics. This study calculated attribution to savings and concluded about 97%+ compliance rates across the board for new construction and existing residential/nonresidential.

In addition, this report also defined compliance differently as how well the building's main energy use end uses conform to the building plans "as approved" by the local jurisdiction. This definition of compliance is somewhat different from the previous cycle. However, the technicality of how ESAF is calculated – through the whole building analysis – is still the same as previous cycle. This study took the assumption that buildings built to "as planned" meet the minimum compliance required by the Energy code. Some interested parties may criticize this approach because projects passing plan checks may not be fully compliant due to enforcement issues. However, from the perspective of the energy efficiency program, they didn't care about the compliance rates during the permitting process and essentially only looked at the whole building energy consumption at the end of the project.

While a few multifamily projects were included in the sampling plan, the actual multifamily family projects did not have site visits. Thus, the sampling data was not sufficient to reveal insights about multifamily compliance trends.

B.5 Process Evaluation Reports

Several relevant reports are highlighted below:

4. **2007 Statewide Codes and Standards Market Adoption and Noncompliance Rates⁶⁷:** Quantec conducted a study to refine the original estimates of noncompliance rates (30% for all measures) and other market related metrics and to test the process laid by the 2006 California Energy Efficiency Evaluation Protocols. This study was unlike the C&S evaluation studies in its methodology where it focused on understanding

⁶⁷ Khawaja, M. Sami, Allen. Lee and Michelle. Levy. 2007. [Statewide Codes and Standards Market Adoption and Noncompliance Rates](http://www.calmac.org/publications/Codes_and_Standards_Final_Report.pdf). Prepared for Southern California Edison. Portland, Ore.: Quantec, LLC. Available at http://www.calmac.org/publications/Codes_and_Standards_Final_Report.pdf.

compliance at each step of the permitting process and utilized a categorical scoring approach. The authors reviewed 418 records representing 437 measures for both residential and nonresidential building categories, finding noncompliance estimates to be between 30% to 100% for various measures.

5. **2016 Codes & Standards Compliance Improvement Program Year 2013-2014 Process Evaluation Final Report**²⁷: DNV GL conducted research to determine if the compliance improvement program activities are impactful to address barriers to Energy Code compliance and which components are effective in changing behaviors in effecting compliance through document review, telephone interviews, web surveys, and follow up telephone reviews. This qualitative process evaluation report further identified remaining barriers to energy compliance to be complexity of compliance, lack of incentives for permit compliance, quality installation is not addressed with the Energy Code, and lack of clarity of what are required to comply.
6. **2019 C&S Attribution Study**²⁸: TRC aimed to conduct a high-level process evaluation of the overall C&S attribution methodology, including compliance evaluation, and provide recommendations for improvement. This study summarizes the changes in compliance evaluation methodology in prior years and highlights that compliance findings can be inaccurate. Overall, the author did not agree with the binary approach to estimate compliance, recommends a whole building energy performance approach, noted opportunities to streamline compliance assessment to reduce cost and time, and improve transparency to understand estimated savings, especially with over-compliance in impact evaluations.

All in all, the TRC team also advised that “compliance margin” (CM) should be used as the metric to determine compliance status with Title 24⁶⁸ (i.e. whole building approach) and that “over-compliance” (or performance exceeding Title 24 requirements) should be included when calculating average compliance. However, standard level over-compliance from one code cycle could not be carried over to the subsequent code cycle.

One of the major findings and recommendations of the TRC Attribution study is that a more robust compliance assessment approach is needed. Standards with high-impact opportunity for savings merit *comprehensive* compliance studies. Simultaneously, code compliance evaluations will need to leverage data (economic, participatory, market, equipment saturation) from other utility and non-utility energy efficiency programs and activities.

⁶⁸ “Compliance Margin” (CM) is the amount of building energy use below Title 24 maximum thresholds, presented as a calculated percentage of the Title 24 energy budget and where a negative value shows non-compliance. Compliance margin is an indicator of energy or performance-based compliance.

APPENDIX C:

Preliminary Sampling Research

The tables below include core results from the 2023 CIRB analysis that were used to derive recommendations. The 2023 Annual Report and the 2023 Detailed Reports provide various insights into the variety of permits being submitted statewide. The data presented here is primarily sourced from the Annual Report as it provided a simplified view of permit categories. The sampling design is inherently linked to the size of each building category's population. Additionally, we've included an intro to sampling for clarity.

C.1 Sampling Background

The core of sampling revolves around four key concepts: populations, samples, sampling frames, and randomization.

- **Populations** are the groups of interest.
- The **sample** is the specific group(s) where data is collected.
- The **sample frame** is the list of individuals from which the sample is drawn.
- **Randomization** dictates the sampling technique applied to the study.

Sampling methods can be broken down into either probability sampling or non-probability sampling.

In **probability sampling**, random selections allow you to make statistical assumptions about a group. This is mainly used in quantitative research. Forms of probability sampling include simple random sampling (SRS), systematic sampling, stratified sampling, cluster sampling, and multistage sampling. In SRS you randomly select a subset of the population using a lottery or random number generator. This way each unit in the sample has equal chances of being selected. Systematic sampling is like SRS but without randomization; sampling is conducted at regular intervals. This leaves room for a lack of precision. In stratified and cluster sampling you divide the population into subgroups based on specific features. In regular stratified sampling, samples are created from these subgroups however in cluster sampling, the subgroups mirror the features of population. Multistage sampling involves using a combination of techniques; this often starts with a form of stratified sampling which is combined with other sampling methods based on resources. The goal of probability sampling is to yield higher precision and statistically significant estimates where generated samples can be repeatedly tested. These studies are typically complex and require access to ancillary information. Because of this they can require extensive time, cost, and effort.

Non-probability sampling is a non-random selection based on convenience or other criteria. This is often used in qualitative research. Forms of non-probability sampling include but are not limited to convenience sampling, purposive sampling, quota sampling, and snowball sampling. In convenience sampling you select the samples that are easiest to access; this is quick and cost effective when resources are readily available. In purposive sampling the researcher(s) utilize their expertise to select cases most relevant to the study. Quota sampling

ensures specific subgroups are represented in a study. In snowball sampling, participants help recruit others creating a growing sample network. Most non-probability sampling methods are not statistically significant and cannot be generalized to the entire population. They are best used for exploratory studies, when resources are limited, and when they can generate benefit to a more robust study in multistage sampling.

CEC staff identified two standard equations used to calculate the sample size.

First, **the standard formula** for determining an appropriate sample size is

$$\text{Sample Size} = \frac{\frac{[z^2 * p(1 - p)]}{e^2}}{1 + \frac{[z^2 * p(1 - p)]}{e^2 * N}}$$

Where, N = population size, z = z-score, e = margin of error, and p = standard deviation.

Second, another sample size formula is the **Slovin formula**.

$$\text{Sample Size} = N / (1 + Ne^2)$$

Utilizing the Slovin formula yields higher estimates than the standard formula. Slovin formula is preferable when you need a simplified approach and quick sample size estimate, know the population size, applicable to more finite population, working with 95% and above confidence level, and precision requirements are straightforward. On the other hand, the standard formula is more applicable to a population with an unknown variance, offering more control over confidence levels, and working with unknown or infinite population.

The Department of Energy field study protocols utilized the standard equation. Hence, CEC staff would also recommend using the same equation during our project planning and scoping phase to estimate the approximate sample size.

There are critical inputs to the standard formula. Generally, as the population gets larger, the number of samples plateau. Here are the inputs:

- The population size (N) is the construction activities within a building category.
- The Standard deviation (p) is 0.5 if unknown.
- The Z-score (z), **Table C-1**, is a set value based on the target accuracy (typically ranges from 80% to 99%).
- The margin of error (e) is based on the target uncertainty (typically it ranges from 1% to 30%).

Table C-1: Z-Score Based on Confidence Level Percentage

Confidence %	80%	85%	90%	95%	99%
Z-score	1.28	1.44	1.65	1.96	2.58

C.2 Estimating Sample Size

For field studies methodology, estimating sample size requires defining the study target population and identifying its trends.

For permitted projects, CEC staff use the permit information by building categories as the source input for population (N). The standard of deviation (p) depends on the variability of permit counts across different years.

For unpermitted projects, the population is unknown, assuming to be larger than 3,000 units in each category. The standard of deviation is also unknown, so 0.5 is used. Given a similar target, desired confidence level and uncertainty, CEC staff recommend that at least 68 samples are used per strata for unpermitted work. The Slovin formula yields about 100 samples. However, CEC staff opt to use the standard equation because it not only aligns with the DOE established field studies protocol but also because the true population size is unknown due to this being an unregulated market.

On the other hand, a data driven methodology that utilizes machine learning or other statistical methods on a large dataset requires a different perspective to sampling. Typically, the analysis would encompass the whole dataset. Sampling plays a role in computational efficiency, model performance, and reducing uncertainty. On a smaller scale, a subset of data may be used to train a model with a desired sample to speed up computation while maintaining accuracy. Based on the trained data, the machine learning algorithms or statistical method can perform the evaluation on the rest of the data to provide the final fitting and results. Generally, for large datasets (above 100,000 records) and fine-tuning model parameters, a typical split can be 60% for training, 20% for testing, and 20% for validation.

To derive the total construction activity per building category, CEC staff estimated the number of unpermitted units through a simple approach. Although these estimates may lack precision, they offer a useful starting hypothesis for gauging the population of unpermitted construction activity per building category. This is essential for scoping a study relating to unpermitted work and calculating an approximate study sample size.

The estimates shown in **Table C-2** below were derived from various sources including 2022-2023 data from US Census Bureau, construction data projections from the 2022 Impact Analysis, 2023 annual permit data from CIRB, and 2022 annual permit data from the Federal Reserve Economic Data (FRED). Staff used these sources to validate the analysis of the 2023 CIRB data and estimate permit populations per building category. In 2023, CIRB recorded 286K residential and multifamily permits and 38K nonresidential permits. Industrial processes were omitted due to low counts and classification discrepancies. Some data gaps in the CIRB data include lack of accurate data for the number of units for existing single-family and multifamily building categories and newly constructed multifamily units are higher 40% higher than Census data sources.

The estimated average annual unpermitted activity assumes a factor between 3-5 for existing residential and multifamily based on the key articles (DNV GL 2017 and Stanford RegLab 2024). These counts fall short of the total size of each market and highlight the need for assessing unpermitted construction activities.

Table C-2: Estimated Population Size

#	Building Category	Existing Building Stock	Annual Issued Permits Construction Activity ⁷⁰	Est. Average Annual Unpermitted Activity	Est. Total Annual Construction Activity
1	Newly constructed residential	59K Units ⁶⁹	55K Units	-	-
2	Existing residential	9.8M Units ⁷⁰	~70K Units*	~210K Units*	~280K Units
3	Newly constructed multifamily	53K Units ⁶⁹	75K Units	-	-
4	Existing multifamily	4.6M Units ⁷⁰	~70K Units*	-	-
5	Newly constructed nonresidential	163M SqFt. ⁷¹	8.3K Units	-	-
6	Existing nonresidential	7,790M SqFt. ⁷¹	27K Units	-	-
7	Process	-	-	-	-

Notes: Staff estimate a factor of 3 between unpermitted vs permitted work based on best available data from key articles. Staff also used the number of residential alterations and/or addition permits (roughly 140K) to estimate the existing number of units for single-family and multifamily because they are combined within one category. Staff assume a 1:1 ratio between existing single-family and multifamily to approximate the number of units.

In short, the overall true population is unknown if considering unpermitted activities. Hence, it makes sense to use the standard sampling size formula over the Slovin formula because there are still uncertainties and unknowns about the studied population.

C.3 Common Sampling Challenges

After conducting a literature review of compliance rate studies and evaluations, most limitations in sample design are derived from a combination of budget, schedule, and stakeholder acceptance. These determined the statistical significance of all the evaluated

⁶⁹ US Census Bureau. 2023. "[BPS – Permits by State](https://www.census.gov/construction/bps/statemonthly.html)." Available at <https://www.census.gov/construction/bps/statemonthly.html>

⁷⁰ US Census Bureau. 2022. "[DP04: Selected Housing Characteristics](https://data.census.gov/table/ACSDP1Y2022.DP04?q=american%20community%20survey&t=Homeownership%20Rate&q=040XX00US06)." Available at <https://data.census.gov/table/ACSDP1Y2022.DP04?q=american%20community%20survey&t=Homeownership%20Rate&q=040XX00US06>.

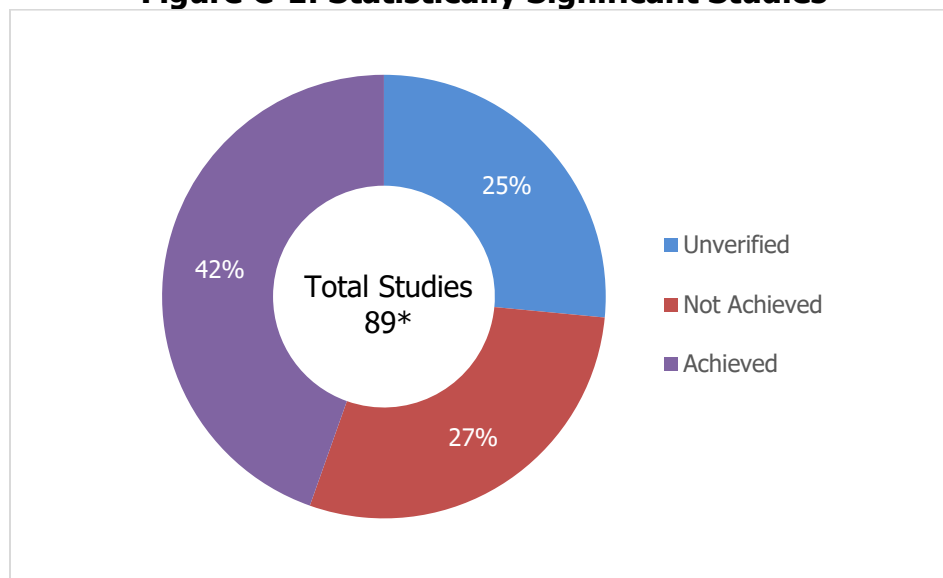
⁷¹ California Energy Commission Staff. 2023. [2022 Energy Code Impact Analysis](https://www.energy.ca.gov/publications/2023/impact-analysis-2022-update-california-energy-code). Publication Number: CEC-400-2023-008. Available at <https://www.energy.ca.gov/publications/2023/impact-analysis-2022-update-california-energy-code>.

reports. Common barriers from these include access to quality data, resource bandwidth, and sampling bias.

CEC staff recommend addressing self-selection bias from two critical perspectives. First, non-random data selection challenges data acquisition and validation, which impacts the study's statistical validity⁶⁵. Second, volunteer bias in field audits stems from stakeholder concerns about the noncompliance consequences, resulting in an overrepresentation of compliant samples and leading to compliance overestimation⁶⁵. Southwest Energy Efficiency Project (SWEET)⁷² has suggested overcoming this challenge through a very strategic engagement to promote the understanding of shared benefits and avoid placing blame. Other studies suggested to disguise the study under a different topic to increase participation and lessen the intimidation or negative connotation associated with compliance studies.

Figure C-1 represents the count of evaluations from the literature review that achieved statistical significance. Over half the evaluations failed to achieve this due to individual study constraints. Frequently this was due to sample recruitment⁶⁴ and self-selection bias that forced the entities to either omit data or shrink their sample sizes.

Figure C-1: Statistically Significant Studies



Note: *89 studies and methods were evaluated; six were omitted due to inapplicability in this category.
Source: CEC staff

In addition to these common barriers, California has additional challenges that impact study design including geographic size, population and building demographics, and complex building and Energy Codes considerations.⁶⁴ Recent California reports⁶³ take these into consideration and outline specific limitations including:

- the number and types of code represented

⁷² SWEET. 2019. *Best Practices for Conducting Energy Code Compliance Studies*. Colorado Code Consulting. Available at <https://www.swenergy.org/wp-content/uploads/best-practices-for-conducting-energy-code-compliance-studies.pdf>.

- the number and type of participants in each proceeding, and
- the types and degree of code changes being considered.

Given these challenges doing a comprehensive statewide study is inherently difficult. CEC staff recommend the above considerations in addition to:

- selecting a specific representative building sub/category for evaluation
- being wary of non-probability sampling and self-selection bias when combining sampling techniques, and
- recruiting large sample frames and sample populations

APPENDIX D:

Types of Gaps

This updated table includes a broader range of gaps, offering a comprehensive framework to identify and address areas of improvement in energy policy research.

Table D-1: Types of Gaps			
Type Name	Type Definition	Example	Mitigation Strategies
Temporal Gap	Outdated research that does not reflect recent developments or changing contexts.	Compliance studies exclude the impacts of recently introduced automated compliance verification tools.	Regularly update research methodologies and integrate new technologies into compliance evaluation studies.
Policy Alignment Gap	Disconnect between policies at various levels or between policy objectives and practical implementation.	Lack of alignment between state energy codes and municipal enforcement practices leads to inconsistent compliance.	Facilitate workshops to align interested parties, develop harmonized frameworks, and streamline enforcement across jurisdictions.
Behavioral Gap	Insufficient understanding of human behaviors and decision-making processes related to energy code compliance.	Lack of research on how contractor attitudes influence code compliance in residential buildings.	Conduct surveys and focus groups to study stakeholder behaviors and implement training programs addressing behavioral barriers.
Empirical Gap	Lack of sufficient data or studies to validate assumptions or measure outcomes.	Limited empirical evidence on the effectiveness of training programs for building inspectors.	Deploy pilot programs, collect field data, and assess the impact of training interventions to establish evidence-based practices.
Spatial Gap	Inadequate exploration of geographic differences in energy code compliance patterns or impacts.	Limited research on how rural and urban areas differ in code compliance rates due to varying resources and expertise.	Conduct region-specific evaluations, tailor compliance strategies to local conditions, and share best practices across regions.
Literature Gap	Missing, incomplete, or conflicting findings in existing literature, leaving unanswered questions.	Contradictory findings on the role of third-party inspections in improving compliance rates.	Perform meta-analyses, systematically review existing studies, and identify clear priority areas for additional research.
Knowledge Gap	Missing or incomplete understanding of a topic or phenomenon.	Lack of understanding about the barriers inspectors face when enforcing energy codes in small-scale projects.	Collaborate with enforcement agencies to document challenges and provide tailored support and solutions.
Evidence Gap	Insufficient empirical support to validate assumptions or practices.	Absence of comprehensive data linking stricter code enforcement to energy savings in nonresidential buildings.	Collect longitudinal data, conduct comparative studies, and use simulations to evaluate the impact of stricter enforcement.
Practical-Application Gap	Disconnect between theoretical knowledge and real-world implementation.	Difficulty in applying theoretical compliance benchmarks to on-site inspections in multifamily housing projects.	Develop practical tools and resources for inspectors and pilot solutions with feedback loops to bridge theoretical and practical gaps.
Conceptual Gap	Absence of exploration or integration of new ideas or interdisciplinary approaches.	Minimal exploration of integrating AI and machine learning to streamline energy code compliance evaluations.	Foster interdisciplinary collaborations, test AI-driven tools, and explore how technology can enhance compliance processes.

APPENDIX E:

Detailed Gap Inventory and Scoring

The detailed gap inventory is sorted by rank. CEC staff provided the initial scoring for all criteria.

Table E-1. Detailed Gap Inventory and Scoring

As Identified #	Gap Name	Gap Description	Gap Type	Market Coverage	Feasibility	Transparency	Alignment	Total Weighted Score	Rank
3	Variability in compliance definitions	Different use of “compliance” makes it confusing to understand. The definition of compliance is often omitted and assumed in various literatures. Compliance can be defined in different contexts, whether it’s complying with the regulatory processes or complying to the minimum performance requirements set by the Energy Code to meet intent. The research questions must be clear about compliance definitions that can affect the study design.	Literature Gap	3	3	3	3	12	1
4	No single methodology to quantify compliance rates	It is difficult to implement a comprehensive study that applies the “stringent” interpretation of the requirements. The variance in interpretation stringency, depth of investigation, and resources available add to the complexity of how a compliance rate study should be conducted. Past studies tried to simplify the study design to obtain actionable insights to improve compliance and did not check every requirement to the letter of the code. The extent of rigor and how the study is designed can be a source of confusion and point of debate with external interested parties.	Literature Gap	3	3	3	2	11	2
12	Prioritize existing single-family residential buildings	Permit data for existing single-family and multifamily are often grouped together. Lack of clarity in the CIRB permit database as to the number of units of existing single-family versus multifamily make it more difficult to quantify the studied population. Nevertheless, permitting in the existing single-family scope of work is a larger piece of the picture that may warrant priority in future studies.	Practical-Application Gap	2	3	3	3	11	2
18	Need for higher quality permit data	Current accessible permit databases (CIRB, Census) are limited by missing data, data quality, and other issues. While permitting data exists and provides insight into building construction activities, it is important to note that the data sources for permit data are not perfect. Additionally, non-standardized fields and data points between permit data sources make analysis difficult. Further data validation between all the permit data sources will be required to better enhance the precision of rates.	Data Gap	2	3	3	3	11	2
10	Poor data quality in the compliance process	Data quality in the compliance process is likely low, making it more difficult to fully assess compliance. The data quality (including omission and completeness) in the data collection process is likely going to be a barrier to quality analysis and a risk to scope and cost.	Data Gap	3	2	2	3	10	5
1	Manual data collection from AHJs	The CEC must collect data manually from AHJs to assess comprehensive compliance rates. The lack of project specific data will require the CEC to manually collect data from local jurisdictions.	Practical-Application Gap	3	2	2	2	9	6

As Identified #	Gap Name	Gap Description	Gap Type	Market Coverage	Feasibility	Transparency	Alignment	Total Weighted Score	Rank
5	Voluntary participation for field data collection	Field data collection requires voluntary participation from building owners and local jurisdictions. The United States, including California, does not have regulations to demand random and periodic audits of compliance with the Energy Code. Thus, data collection is dependent on building owner and local jurisdiction decision and willingness to share data access to the State’s evaluation team(s). This recruitment process differs from an obligation by law that all building owners must allow the State to conduct a compliance audit.	Policy Alignment Gap	3	1	3	2	9	6
6	Field studies only provide a snapshot of compliance in time	Comprehensive studies are expensive and time consuming, hence most experts recommend conducting a field study every 3 to 5 years. Even though by the time study is completed, findings may be outdated.	Temporal Gap	3	1	2	2	8	8
11	Diverse building categories necessitate multiple analytical methods	Quantifying unpermitted activity across diverse building categories may necessitate employing multiple data driven analytical methods to enhance detection accuracy. Analyzing unpermitted construction rates remains a critical area for understanding compliance risk comprehensively. Preliminary findings suggest that data techniques such as permit-to-project matching and anomaly detection are more effective at identifying unpermitted activity in new construction than in existing buildings, where data is often fragmented or incomplete. Unpermitted work may significantly affect compliance outcomes across multiple building categories, but limited and inconsistent data sources constrain quantification. Targeted research is needed to refine detection methods and assess the potential impact of unpermitted activity on compliance metrics and savings estimates.	Data Gap	2	1	2	3	8	8
13	Prioritizing newly constructed multifamily over existing	Newly constructed multifamily units are more prevalent in the permit market than they seem when only looking at permit data. This means from a permitting lens they could be grossly underrepresented. Existing multifamily faces several challenges that will make obtaining samples costly. Additionally, data for this subcategory is aggregated with other residential subcategories into the “alteration/addition” classification.	Practical-Application Gap	2	2	2	2	8	8
14	Prioritize new construction nonresidential buildings over existing	Although the number of permits for existing nonresidential construction exceeds those for new construction, assessing compliance in new buildings may be simpler due to their more standardized scope and rigorous documentation. In contrast, existing buildings present a wider range of complexities in the compliance process, the creation of a sampling plan, and stakeholder recruitment. Additionally, nonresidential projects often require multiple permits under different jurisdictions, making it difficult to determine the exact number of units based solely on permit data. As a result, the reported number of nonresidential units may be lower than the total number of permits issued.	Practical-Application Gap	2	2	2	2	8	8

As Identified #	Gap Name	Gap Description	Gap Type	Market Coverage	Feasibility	Transparency	Alignment	Total Weighted Score	Rank
7	Increase coordination with CPUC's C&S program evaluations	The methods employed in the CPUC's C&S evaluation leaned toward energy-based compliance definition and specific to certain measures under the IOUs programs. There are no cyclical studies that focused on process-based compliance rates although there were a few studies that tried to capture process-based compliance in the process evaluation reports. If CEC is to conduct studies to evaluate energy-based compliance, this may appear to have some overlap with the existing CPUC's scope in their energy efficiency program evaluation. Where practical, coordination between the CEC and CPUC can address potential overlapping research efforts and ensure complementary research approaches.	Data Gap	2	3	1	1	7	12
8	Challenges and costs of whole-building compliance assessments	Whole-building compliance assessment, while thorough, presents challenges in transparency and precision due to the amount of diverse data required and efforts to site verify. Prioritizing this method may present significant cost and technical risks.	Data Gap	3	1	1	2	7	12
16	Unclear level of energy compliance in unpermitted projects	Due to the lack of data and gaps in the literature, there is no empirical evidence on the level of compliance with unpermitted projects. By assuming that unpermitted projects have no Energy Code savings, this can lead to an overstatement of non-compliance savings.	Data Gap	2	1	1	3	7	12
17	Lack of supporting data for nonresidential building categories	In the nonresidential building categories, there are less accessible supporting data available to support compliance rates understanding. CEC compliance data warehouse is still undergoing development. Compliance investigation into nonresidential types will rely 100% on data collection with the AHJ.	Data Gap	1	2	2	2	7	12
19	Limited availability of HVAC sales tracking data	HVAC sales data is difficult to obtain because interested parties (manufacturers, distributors, installers, etc.) in the market are hesitant to share the information publicly. In addition, the efforts to collect such data are time consuming and intensive. The best available alternative to estimate HVAC sales depends on existing building stock data and End-of-Useful-Life data. This method still requires periodic empirical data to validate its credibility.	Data Gap	1	1	2	3	7	12
20	Sampling challenges lead to uncertainty	The effort to acquire truly random representative samples is high. Modern compliance evaluations that seek to develop robust studies frequently use multistage sampling that combines both random and non-random sampling techniques. Inherent to the volunteer nature of data collection, self-selection bias is likely and can increase the uncertainty of the results.	Data Gap	3	1	1	2	7	12
15	Lower priority for covered process	Unlike other building categories, covered process measures can be implemented across various nonresidential building types that are not easily identified in the existing data, making it difficult to define the studied population and generate sample size. Future evaluation for this category will likely demand specialized expertise.	Practical-Application Gap	1	1	1	3	6	18

As Identified #	Gap Name	Gap Description	Gap Type	Market Coverage	Feasibility	Transparency	Alignment	Total Weighted Score	Rank
2	High scope and costs for nonresidential and multifamily categories	Nonresidential and multifamily scopes vary and require additional subcategories that increase cost and scope. Compliance documentations for multifamily building categories vary because the scope and requirements differ significantly between a duplex and mixed-use high-rise, for example. With mixed use types, typically the ATTs are responsible for the nonresidential portion and ECC Raters are responsible for the dwelling scope. Thus, a future compliance study will need to consider additional subdivision within the multifamily categories to better capture the distinctive trends and to design the study efficiently. Similarly, nonresidential categories also include many building types that differ in characteristics (e.g., a church versus high-rise office building).	Practical-Application Gap	2	1	1	1	5	19
9	Limited compliance investigation coverage in rural service areas	The CPUC’s C&S evaluation reports serve to quantify savings attributable to each of the primary IOUs (PG&E, SDG&E, and SCE) programs. There is potential to enhance the data collection process by extending coverage to rural areas that may fall outside of traditional IOU program implementation zones. Since the data collection process largely depends on willing participants, expanding to rural areas may present unique recruitment challenges and require tailored approaches to obtain representative data.	Data Gap	1	2	1	1	5	19

APPENDIX F: Detailed Menu of Data Driven Approaches

Table F-1. Preliminary Cost Assumptions of Data Driven Approaches								
Data Methods Menu	Building Categories	How	Estimated Highly Skilled Personnel	Estimated Data Acquisition and Tools Cost	Estimated First Cost	Estimated Reoccurring Cost	Estimated Difficulty to Implement	Estimated Timeline (years)
Detect unpermitted work using computer vision with satellite images	New construction: residential and nonresidential (new footprint only)	Partner and provide funding with academic researchers.	3 to 4	\$1mil	Med	Med	High	2 to 5
Detect unpermitted HVAC change-out using Interval Metered Data (IMD) data.	Existing residential	Provide additional resources to academic researchers.	4 to 6	\$200k	Med	Med	High	2 to 5
Detect unpermitted HVAC change-out from population/building stock data and End-of-Useful-Life analysis (DEER, RASS) to replicate probable HVAC sales data (re-doing the DNV GL 2017 HVAC Assessment study)	Existing residential	Solicit a contract to update work or add capacity to develop expertise in-house.	2 to 4	\$200k	Low	Unknown	Low	2 to 3
Detect unpermitted HVAC changeout from comparing HVAC sales data directly with permit data	Existing residential, MF, and nonresidential	Obtain HVAC sales data from third party (ex: CoMetrics) OR CEC to establish rulemaking and collect data directly from market players	3 to 5	\$1mil+	Med - High	Med	High	3+ years
Detect unpermitted work/compliance levels by comparing the number of registered forms and permitting databases to understand potential gaps in enforcement	New construction: residential and (some) existing residential	Residential registry development is already in progress under another project. Can invest more resources here to add capacity to resolve challenges.	N/A	N/A	N/A	N/A	Med	1 to 3
Estimate unpermitted work based on the real estate listings through natural language processing or cross check assessor records	Existing residential	Solicit a contract or partner with institutional researchers with expertise in data science and/or steer internal resources to this effort	2 to 3	\$500k	Med	Low-Med	High	2 to 5