21st Century Compliance: Data-Driven Solutions for Decarbonization and Equity

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ABSTRACT

California's Energy Code, Title 24 Part 6, is complex and the compliance forms can be burdensome. There is a concerted effort underway to make the code compliance process faster and easier for those who design, construct, and verify compliance. This is especially important for under-resourced projects and building departments struggling to meet heavy workloads. Easing the compliance process through data-driven solutions can help all Californians realize the full benefit of the Energy Code including persistent energy savings and decarbonization.

The Statewide Compliance Improvement (CI) Team developed a compliance tool, called the Virtual Compliance Assistant (VCA), and other components of an electronic infrastructure to enhance, simplify, and speed the compliance process. CI built the VCA using IDEO's Human Centered Design method and is offering the VCA to the building industry for free. VCA is currently the most widely used method to document mandatory and prescriptive compliance for commercial buildings in California. This paper describes the VCA tool, electronic infrastructure development process, and how the electronic infrastructure could be replicated in other jurisdictions.

California's VCA is making it faster and easier for the building industry to comply with California's complex Energy Code while capturing data that is informing future code requirements and Codes and Standards Program success. Code developers and program evaluators now have access to ample permit and installation data indicating the types of projects built and products installed throughout California. The VCA is highlighting areas for compliance improvement and shaping upcoming code initiatives while streamlining verification processes and saving energy.

Introduction

For more than 25 years, California's investor-owned utilities (IOUs) have supported the California Energy Commission (CEC) in strengthening the State's building Energy Code and appliance efficiency standards. Former Commissioner, Art Rosenfeld, taught us the value codes can have in keeping our per capita energy use flat compared to the rest of the nation as shown in Figure 1 below. As a result of California's Codes and Standards, California's energy consumption per capita is 31 percent less than the rest of the United States.

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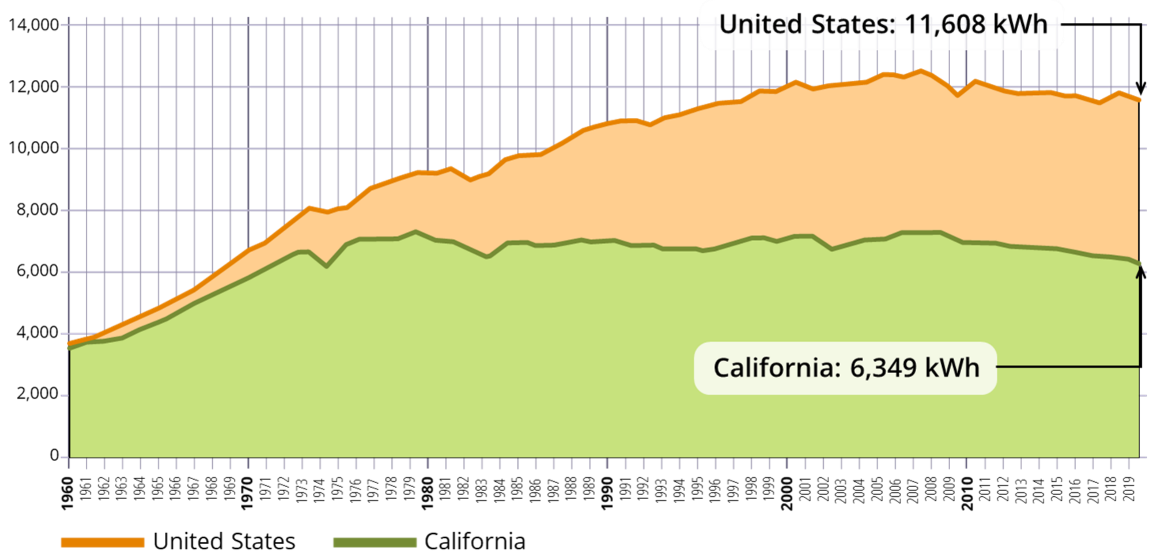

Figure 1. Annual electricity consumption per capita in United States and California. *Source:* 2022 Building Energy Efficiency Standards Summary; California Energy Commission; August 2021

Pat Eilert, Manager of the Statewide Codes and Standard (C&S) Program for the IOUs for the past twenty years, taught us that we can gain even more energy savings and environmental benefits if we maximize code compliance, gather data to guide our efforts, continually innovate, and err on the side of action. One of the impacts that Pat's vision and leadership style has had on California's codes and standards is a robust Statewide C&S Program with interlocking subprograms including:

- Advocacy that responds to all opportunities for significant savings through new codes and standards (i.e., local reach codes, state, and federal)
- Technical assistance to local governments that increases the adoption of local reach codes which support the development and adoption of statewide and national code changes
- Compliance improvement activities that strive to maintain high compliance margins for buildings constructed or altered within the Title 24, Part 6 compliance process and improve compliance margins for selected, high-importance building code measures and appliance standards
- Code readiness activities that aim to introduce promising building systems and appliances to actors within building industry supply chains to determine their readiness for codification to Prior Program Cycles

Within this model, the Compliance Improvement Subprogram (CI or Energy Code Ace) strives to maximize compliance with existing and newly adopted building energy efficiency standards (Title 24, Part 6 or Energy Code) and appliance regulations (Title 20) in order to meet California's energy efficiency and carbon reduction goals. As the figure below illustrates, CI has a bearing on the amount of savings the C&S Program realizes due to the fact that the Compliance Adjustment Factor is an inherent part of the Statewide C&S Program's savings attribution methodology as shown in Figure 2 below.

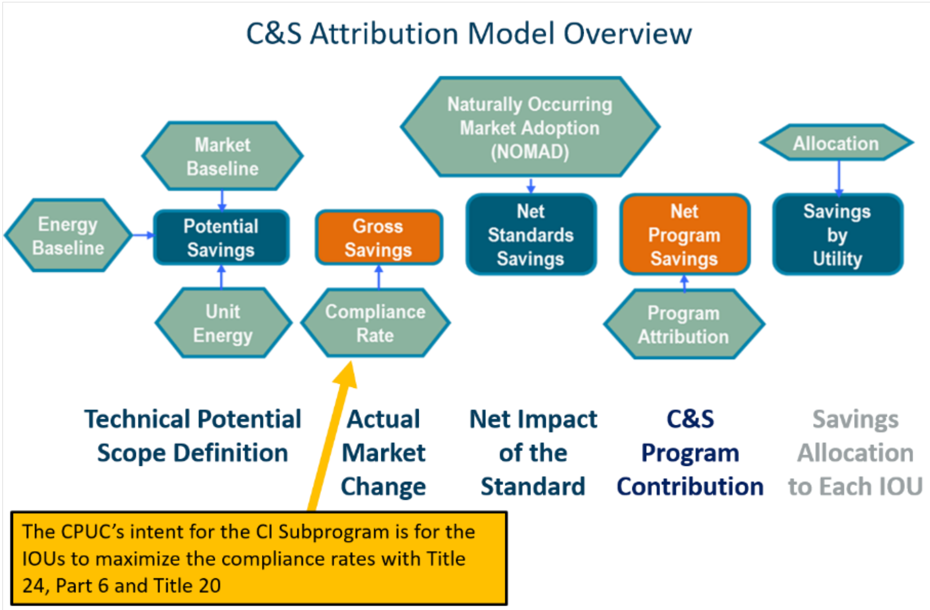

Figure 2. Codes and Standards Attribution Model Overview. *Source:* Eilert, 2015

Empowering market actors with the knowledge and tools they need to perform their compliance-related tasks quickly and effectively can help drive compliance rates higher thereby maximizing savings achieved by the Statewide C&S Program. CI's success hinges on understanding market actors' unique workflows, the barriers they face, and collaborating with users and the CEC to develop and implement the appropriate solutions. CI develops performance solutions with users and code experts and works with the CEC to vet all offerings. Performance solutions come in the following forms:

- Outreach to increase awareness of code requirements and benefits and to motivate people to comply
- Training to further increase awareness and motivation and provide the knowledge and skills needed to comply
- Tools and Resources to empower people to take the desired action

Once the proper performance solutions have been identified, CI employs a user-centered design approach by developing minimum viable products (MVP), iterating with 'users' and then working with users to implement the solutions within their workgroups and industry organizations. The CI Advisory Group (CIAG), which was comprised of representatives from each market actor group responsible for implementing California's C&S, helped us realize the need for simplification through automation. In short, when asked what the CI could do to improve compliance, the CIAG said you shouldn't have to be an Energy Code subject matter expert in order to effectively complete the compliance forms just like you shouldn't have to be a tax code subject matter expert to effectively complete tax forms. Per the CIAG, "When the prescriptive path is used, as is common with additions, alterations, tenant improvements, shell compliance, or occupancy change, the permit applicant must determine which code requirements apply, which forms those requirements trigger, which fields within the forms are required and which are not, and if exceptions apply and how to properly document them. This is where the complexity and perceived complexity compound to create an environment of potential bad will and non-compliance. A similar situation exists with the tax code. As it became increasingly complex, it became nearly impossible for an individual tax filer to navigate the forms. Even those using the short form must answer questions that have tax implications, either good or bad. In response to this complexity, we developed online tools and applications that help the filer navigate the system and produce a customized set of forms based on their individual situation. This filtering logic also applies to the Energy Code so that permit applicants only have to see and respond to those questions and requirements that apply to their individual permit application and project scope. By creating a user interface that guides the applicant via a series of questions about their design, users only need see requirements to which they must pay attention." (Bachand, Benningfield, and Heinemeier 2012). This insight formed the basis of CI's Virtual Compliance Assistant (VCA).

Automating the compliance process with a digital tool is not only helping more people comply with the Energy Code it is also helping California collect data that informs future code development efforts and track progress toward meeting emission reduction goals. "There is an incredible amount of project data related to Title 24, Part 6 compliance that is being captured on compliance forms used to obtain building permits. In most of the 580 building departments across the state, this project data is not being catalogued or aggregated electronically for data analysis. However, this data could be integral to moving the state towards ZNE building codes by better supporting market transformation, quality assurance and code readiness." (Blair 2015).

Compliance Process Intervention

Utilizing tools to automate tasks in the code compliance process requires intimate understanding of the targeted roles and beneficial points of intervention in each role's typical workflow. The VCA supports compliance documentation and verification tasks performed by designers, energy consultants, plans examiners, installers, and inspectors.

Compliance with the Energy Code requires the use of CEC-issued forms to complete the permitting process with local Authorities Having Jurisdiction (AHJs). The forms must document compliance at key points during design and construction, such as:

- Certificates of Compliance document project designs
- Certificates of Installation document installed products
- Certificates of Verification document compliant field verifications
- Certificates of Acceptance document compliant start-up and controls[1]

Used statewide, these compliance forms create consistency at scale and document mandatory, prescriptive and performance compliance. Consistency is important because it allows for statewide deployment of support resources such as training and plans examiner's checklists, a more efficient use of taxpayer and ratepayer funds.

In 2016, the California Building Officials (CALBO) CEC Advisory Committee drafted a letter to the CEC detailing concerns around "the complexity of the Energy Code and the amount of paperwork required to demonstrate compliance" (Mahoney 2016). Instead of thinking of the forms as burdensome paperwork that provides little value, CI envisioned their use as tools to

[1] Title 24, Part 6, Section 10-103 – Permit, Certificate, Informational, and Enforcement Requirements for Designers, Installers, Builders, Manufacturers, and Suppliers. https://energycodeace.com/content/10-103-permit-certificate-informational-and-enforcement-r

help users more easily and accurately complete their required permitting tasks. In addition to automating tasks, forms can collect data in aggregate showing how real projects throughout the State comply with Energy Code requirements (Blair 2015). Based on the needs to reduce complexity, cost, and time spent on permitting, CI discussed redesigning and condensing the forms with the CEC and electronically applying the "rulesets" of mandatory and prescriptive code requirements. The CEC already automated application of the performance rulesets through its CBECC compliance modeling software and agreed to partner with CI in developing new mandatory and prescriptive compliance forms. Although an existing tool in California's market did already automate rulesets and produce PDFs of compliance forms, the ruleset validation was not occurring, and consistent application of rules is imperative as more tools automating compliance tasks become available.

Automatically applying mandatory and prescriptive requirements to a project's unique scope and design helps energy consultants and designers understand what requirements apply and whether their current design complies. If their design does not comply with prescriptive requirements, designers can understand this before plan check and either alter the design or pursue performance path compliance. This allows designers to be confident their designs will pass plan check as long as the construction documents match the project data entered into the compliance forms. Determining compliance prior to submitting for plan check can save designers the cost of redesigning to rectify correction comments and time required to resubmit corrected plans. This can be especially helpful for projects trying to make project budgets work for affordable housing, community buildings, and other projects supporting under-resourced communities.

The automation of mandatory and prescriptive rulesets also benefits plans examiners because determining what Energy Code requirements apply and whether the project complies is a main cause of complexity and use of their time. If the project data entered into the form has already been determined compliant, plans examiners can spend their limited time making sure the construction documents reflect the data featured in the forms, illustrated in Figure 3. State validation of ruleset application and consistency between tools also benefits plans examiners because they can be confident in the accuracy of the application of requirements regardless of the tool used to complete forms. Decreasing review time while increasing accuracy of compliance verification helps resource-constrained AHJs and brings the energy and carbon savings benefits to their communities.

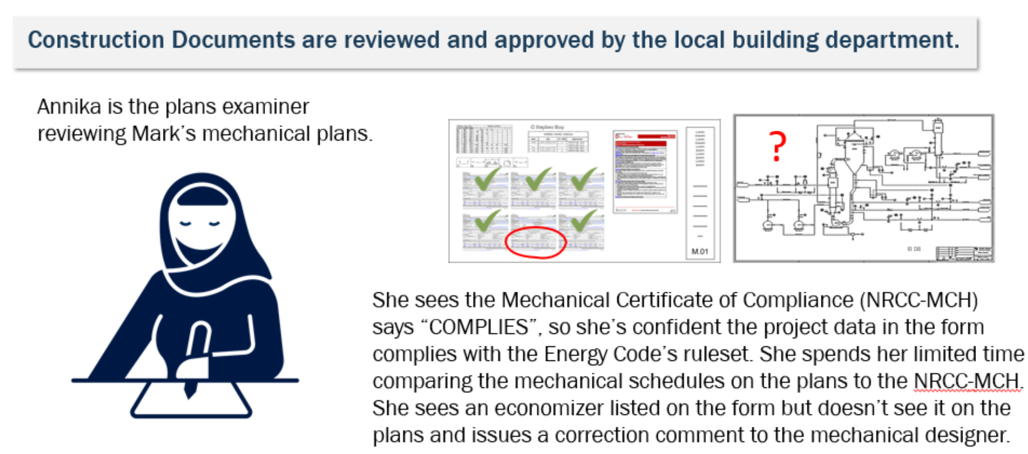

Figure 3. Vision for automating compliance status for the plans examiner using compliance forms with built in rulesets. *Source*: Weinkle, K. Energy Code Ace Virtual Compliance Assistant Storyboard, updated 2020.

Installers need to understand which aspects of their scope impact compliance so they can accurately bid. Navigating the Energy Code, and even the somewhat complex Certificates of Compliance, is difficult for installers because their expertise is in installation and not design calculations required to demonstrate compliant designs. Utilizing Certificates of Installation as tools to narrow what aspects of their materials and installations need to meet minimum performance requirements reduces complexity and saves time. The Certificates of Installation also communicate what field verifications have been identified as applicable so installers are aware of the coordination that will be necessary in the field. Installers also need to determine if field changes such as simple substitutions comply without revising designs and going back through plan check. Including a ruleset in the Certificates of Installation that determines whether the substitution is equal or better than the permitted project helps installers to quickly determine if their substitution complies while easily documenting as-built conditions.

Inspectors have very limited time during site visits and reviewing paperwork provides little value to building owners. Certificates of Installation clearly documenting as-built conditions and automating the determination of whether the condition is equal to or better than the permitted design reduces the time and cognitive load for the inspector. This automation allows the inspector to spend their limited time verifying installations against documented as-built conditions.

Electronic Infrastructure Components

To bring our vision to life, we implemented three core components: The client application, the schemas, and the report generator. These three components combine to make up the electronic infrastructure that supports designers, energy consultants, plans examiners, installers, and inspectors in demonstrating and verifying compliance with the Energy Code.

The VCA functions as a client application, providing a user-friendly graphical interface for permit applicants to interact with. It is one of several client applications available, offering users the flexibility to choose the interface that best suits their needs as shown in Figure 4 below. VCA's approach to developing a user interface prioritizes support for under-served portions of the market. This user-friendly design ensures the system is accessible to individuals who may not be Energy Code experts, lack the resources to hire an energy consultant, or struggle to demonstrate compliance due to limited resources. The VCA's user base consists of building owners, design professionals, energy consultants, installers, and general contractors which we will refer to as the permit applicant.

The VCA prompts the permit applicant with a series of questions about their project, curating future questions based on previous questions' answers. The VCA then uses the collected information to populate a Certificate of Compliance or Certificate of Installation necessary for permitting with the AHJ. The VCA interacts with other components of the electronic infrastructure including the schemas and report generator to produce completed compliance documentation.

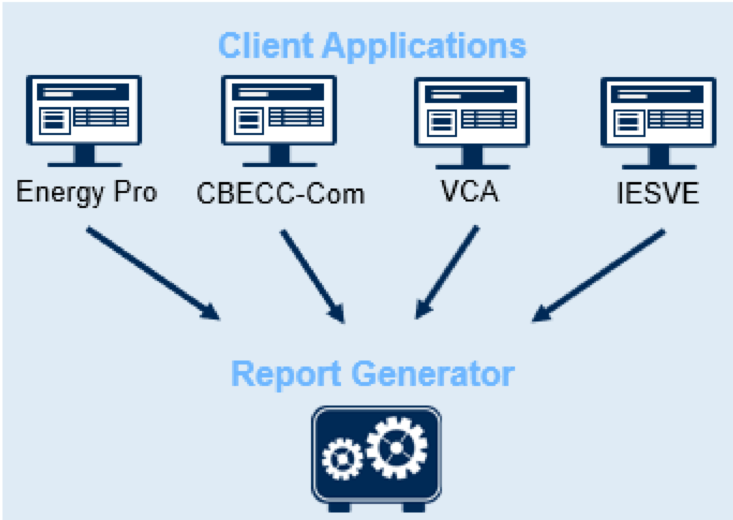

Figure 4. Electronic Infrastructure Components. *Source*: Weinkle, K. Energy Code Ace Electronic Infrastructure in Title 24, Part 6 Compliance Process, updated 2024.

The schemas are a centralized framework used to enforce the ruleset of the Energy Code on client applications such as the VCA. Schemas also ensure that client applications provide all information required to determine compliance and in the correct format. Once the client application has collected all relevant information from the permit applicant, it packages that information in the structure defined by the schema and passes it to the report generator. The report generator compares the data sent by the client application to the data requirements from the schema in an attempt to "validate" the project data. The project data validates if all required data is provided in the format defined by the schema. In addition to providing the framework for data validation, the schema also includes pseudo code that communicates the Energy Code ruleset for implementation by the client application developer. As more client applications become available, it is important to have consistently formatted data and consistent application of the ruleset, regardless of the client application used by the permit applicant. If each client application developer uses the schema, consistency will be achieved regardless of client application used.

The report generator is a centralized reporting service that formats the project data and produces a populated PDF compliance form for permit submittal. The report generator receives the project information collected by the client application and determines validation status per the schema. If the project information is incomplete or in an incorrect format the project does not validate, and the report generator returns the PDF compliance form with a watermark saying, "Not usable for compliance." This serves as a safeguard to prevent the submission of incomplete reports, ensuring corrections occur before permit submittal. Figure 5 below illustrates the system components and data flow that was originally designed by RASENT Solutions, LLC and L'Monte Information Services for the California Energy Commission.

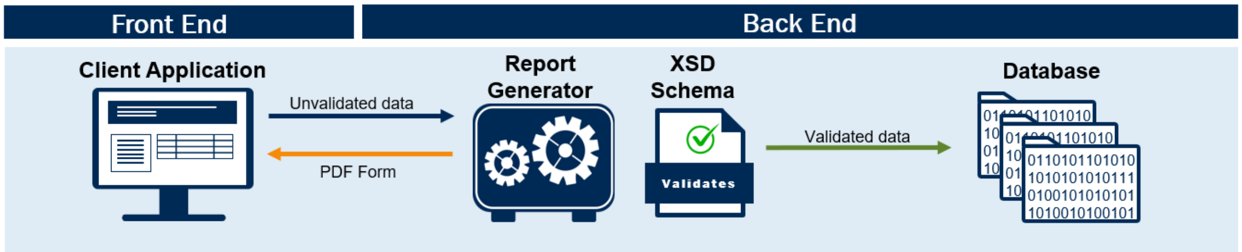

Figure 5. Electronic Infrastructure Components. *Source*: Weinkle, K. Energy Code Ace Electronic Infrastructure in Title 24, Part 6 Compliance Process, updated 2024.

To understand how these components contribute to a cutting-edge compliance system, we need to unpack each component and explore how they interact with each other.

Virtual Compliance Assistant – Designing A Tool With Intention

Permit applicants navigating the world of code compliance can leverage a diverse ecosystem of client applications. These software tools, each with a unique user interface and design philosophy, empower applicants to choose the solution that best aligns with their experience level and project needs. For instance, the VCA application is ideal for those with limited experience, or those who lack the resources to hire an energy consultant, while other applications may cater towards more advanced users. In addition to design philosophy, each software tool offers the ability to complete different compliance forms. Some applications might focus on core residential forms, while others might offer a wider range of forms suited for complex commercial projects. This variety ensures there's a suitable tool for each applicant, fostering a more efficient and user-centric approach to the compliance process. The VCA enables users to complete both the Certificate of Compliance and the Certificate of Installation. Designing the user interface with a user-centric approach ensures the tool supports all targeted roles and integrates seamlessly into their existing workflows. The VCA uses natural language in a conversational style when asking questions to ensure clarity and reduce user overload. The VCA utilizes conditional branching, a control flow structure, to dynamically determine the information required for Energy Code compliance. This approach ensures that permit applicants only answer questions applicable to their project scope and chosen compliance pathway. This approach streamlines the documentation process and eliminates the need to understand when an Energy Code requirement is applicable. The VCA also provides the user with additional context via customized tool tips. These tool tips help explain the requirement, why it applies, and what the prompt is asking for using links to internal resources such as fact sheets and checklists as well as external resources such as the Energy Code Standards language, compliance manuals, and reference appendices. See Figure 6 for an example of natural language and tool tips.

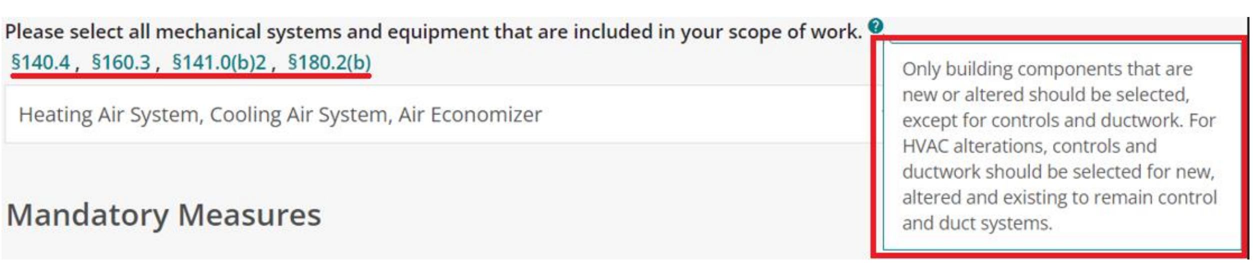

Figure 6. Virtual Compliance Assistant Certificate of Compliance User Interface. *Source*: Lalor, B. Virtual Compliance Assistant, 2024.

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When designing the user interface for the Certificate of Installation, which supports installers and general contractors, we made sure to build a tool that helps installers/contractors determine compliance prior to making design or product substitutions in the field. To facilitate the comparison, the VCA automatically pulls design information from the Certificate of Compliance and prepopulates the Certificate of Installation with permitted design data. As shown in Figure 7, the user interface asks the installer if the installation matches the design. If they select yes, the install data is automatically prepopulated to match the design data.

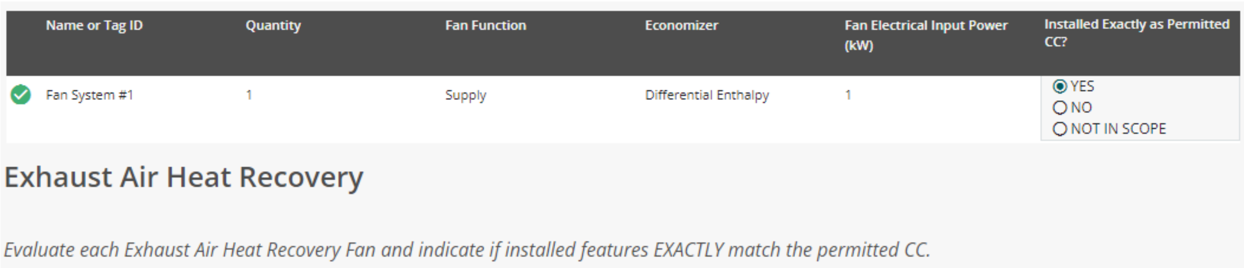

Figure 7. Virtual Compliance Assistant Certificate of Installation User Interface. *Source*: Lalor, B. Virtual Compliance Assistant, 2024.

If the installation does not exactly match the design, we ask the installer to indicate what is different using the same approach as the Certificate of Compliance – Natural language with added context via tool tips and links to supporting documentation as shown in Figure 8.

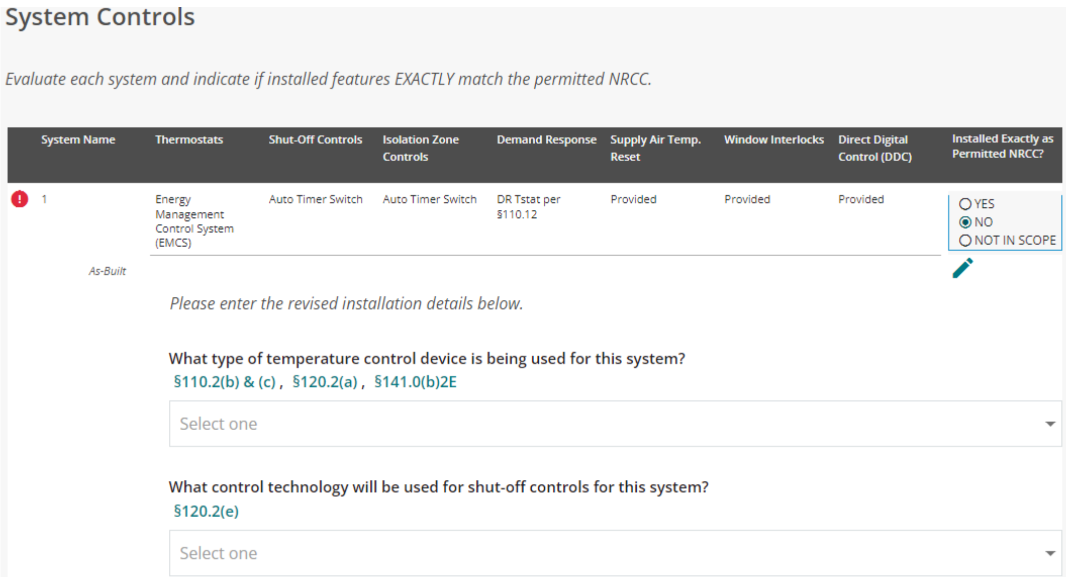

Figure 8. Virtual Compliance Assistant Certificate of Instllation User Interface. *Source*: Lalor, B. Virtual Compliance Assistant, 2024

By designing the user interface to support the specific role of the permit applicant, we simplify and streamline the compliance process for our users. Prompting the user with natural language, providing context, and linking to helpful resources make the VCA more accessible, allowing for people of various skills and experience to understand the applicable requirements and successfully demonstrate compliance with the Energy Code.

Once the client applications have collected all required project data, the system produces an XML file (Extensible Markup Language) and sends the file off for validation and report rendering.

Schemas – Enforcing the Rules

To ensure client applications are successfully enforcing the requirements of the Energy Code, we needed a centralized framework that could document the ruleset and validate the data collected by the client applications. Centralizing the schemas and the validation process is crucial to ensure that all client applications meet the same standard. CI chose the XSD (XML Schema Definition) as the framework to document the Energy Code ruleset given XSD's ability to define strict rules and constraints for XML documents.

XSD schemas can define required data and the required data format. For example, XSD schemas can require furnace efficiency be provided via a decimal versus a percent. This ensures that the data shown on the compliance document is in a consistent format for the plans examiner. This also ensures that the ruleset can accurately determine compliance status when enforcing the requirement of *design efficiency > 0.90* where design efficiency is 0.92 and not 92%. The schemas can also define data types with predetermined enumerations, such as equipment type. Equipment type is defined in the schemas as *HvacSystemType* with associated enumerations, or options such as *UnitaryHeatPumps* with display text "Unitary Heat Pumps." This allows the schemas as shown in Figure 9 to predetermine the valid options for a question and determine the display text associated with each option that will show up in the generated PDF compliance document.

```
<xsd:simpleType name="HvacSystemType">
  <xsd:annotation>
    <xsd:appinfo source="displaytermType">
      <dtyp:displayterm>HVAC  System Type</dtyp:displayterm>
    </xsd:appinfo>
    <xsd:appinfo source="displayterm">
      <dtyp:displayterm value="ComputerRoomAC">Computer Room AC</dtyp:displayterm>
      <dtyp:displayterm value="CeilingCRAC">Ceiling Mounted Computer Room AC</dtyp:displayterm>
      <dtyp:displayterm value="DedicatedOAS">Dedicated Outside Air System</dtyp:displayterm>
      <dtyp:displayterm value="FurnaceAC">Furnace + AC</dtyp:displayterm>
      <dtyp:displayterm value="FurnaceUnitHeater">Furnace/ Unit Heater</dtyp:displayterm>
      <dtyp:displayterm value="HeatPumpAC">Sm. Commercial AC</dtyp:displayterm>
      <dtyp:displayterm value="HeatPumpDualFuel">Dual Fuel Heat Pump</dtyp:displayterm>
      <dtyp:displayterm value="PTAC_PTHP">PTAC/ PTHP</dtyp:displayterm>
      <dtyp:displayterm value="RoomAC_HP">Room AC/HP</dtyp:displayterm>
      <dtyp:displayterm value="SPV_ACHP">SPVAC/ SPVHP</dtyp:displayterm>
      <dtyp:displayterm value="UnitaryCondensersAC">Unitary AC/ Condensers</dtyp:displayterm>
      <dtyp:displayterm value="UnitaryCondensersAC_NoElectR">Unitary AC/ Cond. (no elec. resistance)</dtyp:displayterm>
      <dtyp:displayterm value="UnitaryHeatPumps">Unitary Heat Pumps</dtyp:displayterm>      DSPepetone, 2 years ago via
      <dtyp:displayterm value="UnitaryHeatPumpsNoElectR">Unitary Heat Pumps (no elec. resistance)</dtyp:displayterm>
      <dtyp:displayterm value="VariableRefrigerantFlow">Variable Refrigerant Flow</dtyp:displayterm>
    </xsd:appinfo>
```

Figure 9. 2022 NRCC-MCH XSD Schemas. *Source*: Lalor, B. Electronic Infrastructure, updated 2024.

XSD schemas can also include the ruleset that determines if the project data meets the requirements of the Energy Code. To include the ruleset in the schemas, CI translated the Energy Code Standards language into pseudo code. Once this translation was complete, CI added the pseudo code to the schema. For example, Title 24 Part 6 maximum fan power, or fan power allowance, is determined by looking at the ventilation system type, elevation, designed fan power and the components included in the designed ventilation system. The schema defines the rules for maximum fan power allowance (*H12_FanSystemPowerAllowance)* by referencing the

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schema fields that hold permit applicant provided data for ventilation system type (*H00d_SystemZoning*), elevation (*H00g_Elevation*), designed fan power (*H13_FanSystemInputPower*), and fan system components (*H04_FanPowerAllowanceDevice*). See Figure 10 for an example.

```
<xsd:element name="H12_FanSystemPowerAllowance" type="comp:FanSystemPowerAllowance" >
  <xsd:annotation>
    <xsd:documentation source="FieldText">Fan System Allowance (kW)[d:sup]3[/d:sup]</xsd:documentation>
    <xsd:documentation source="CalculationsAndRules">Calculated value:
If H13_FanSystemInputPower GTE 1.0
If H00d_SystemZoning != DOAS
If H00g_Elevation LTE 3,000 ft
result = ((H12a_SupplyFanBaseAllowance + H12b_ExhaustFanBaseAllowance + SUM ALL (H03_FanCount x H08_FanAllowance))  x  H00f_FanSystemFlowCapacity) / 1000
Else If H00g_Elevation GTE 3,000 ft And LT 4,000
result = 0.896  x (((H12a_SupplyFanBaseAllowance + H12b_ExhaustFanBaseAllowance + SUM ALL (H03_FanCount x H08_FanAllowance)) x  H00f_FanSystemFlowCapacity) / 1000)
Else If H00g_Elevation GTE 4,000 ft And LT 5,000
result = 0.864 x (((H12a_SupplyFanBaseAllowance + H12b_ExhaustFanBaseAllowance + SUM ALL (H03_FanCount x H08_FanAllowance)) x  H00f_FanSystemFlowCapacity) / 1000)
Else If H00g_Elevation GTE 5,000 ft And LT 6,000
result = 0.832 x (((H12a_SupplyFanBaseAllowance + H12b_ExhaustFanBaseAllowance + SUM ALL (H03_FanCount x H08_FanAllowance)) x  H00f_FanSystemFlowCapacity) / 1000)
Else If H00g_Elevation GTE 6,000 ft
result = 0.801 x (((H12a_SupplyFanBaseAllowance + H12b_ExhaustFanBaseAllowance + SUM ALL (H03_FanCount x H08_FanAllowance)) x  H00f_FanSystemFlowCapacity) / 1000)
End If
Else If H00d_SystemZoning == DOASZone
result = H00f_FanSystemFlowCapacity / 1000
End If
End If</xsd:documentation>
  </xsd:annotation>
</xsd:element>
```

Figure 10. 2022 NRCC-MCH XSD Schemas. *Source*: Lalor, B. Electronic Infrastructure, updated 2024.

Once the client application packages the project data into an XML file, the data is sent to be validated per the XSD schemas. The report generator uses the schemas to determine a validation status by enforcing the rules defined in the schema. Once the validation status has been determined, the XML file continues its journey to the report generator for compliance document rendering (i.e. generation of the PDF compliance form used for permitting).

Report Generator – Rendering Compliance Forms

The report generator receives data from the client application via an XML file. It uses XSLT (Extensible Stylesheet Language Transformation) to transform the XML data into a preformatted PDF compliance form used for permit application to the AHJ. The CEC assumes responsibility for approving the compliance form's layout, design, and content. Centralizing the report generator creates a client application agnostic reporting service that ensures PDF generation has a consistent design which enables both permit applicants and plans examiners to become knowledgeable on what to expect and improves report readability.

Prior to returning a PDF to the client application, the report generator compares the XML data to the data requirements in the schema in an attempt to "validate" the project data. If the project information is incomplete or formatted incorrectly, the project data does not validate, and the system returns the PDF compliance form with a watermark stating, "Not usable for compliance." This watermarking feature acts as a flag. It clearly signals to both permit applicants and plans examiners that the report is incomplete, preventing submission of invalid reports and prompting corrections before permit submittal.

The report generator adds a footer to each page of the report that includes crucial metadata to help identify and track the history of the report. Metadata fields include documentation software, Compliance ID, generation date and time, report and schema version, and Energy Code code cycle. The Compliance ID is the most critical metadata field rendered in the report footer. The Compliance ID is a unique identifier applied by the report generator that identifies a project and each iteration across a project's lifetime. When a permit applicant sends new project data to the report generator for the first time, the system applies a unique compliance

ID to that project and displays the ID in the footer of the PDF report. When a permit applicant updates existing project data, the report generator increments the previously applied compliance ID. This enables AHJs to identify each iteration to a project. They can also find the compliance document in the permitted plan set. Using this compliance ID approach also enables software developers to map the version of permitted design data to the associated Certificate of Installation. Other metadata fields such as documentation software, report and schema version, and generated date and time help software developers and AHJs trace the data to investigate any discrepancies in the data validation or rendering processes and pinpoint the issue's origin.

Once the client application development is complete, the schemas are defined, and the report generation service is online, the system is ready to function. Client applications can collect project information, pass that data to the report generator for schema validation, and receive a formatted PDF form back. With this minimum functionality of each component, this represents the Minimum Viable Product (MVP) for a usable electronic infrastructure.

Database – Informing Decision Makers

After launching the MVP, the next step is to leverage the benefits of this modern, software-based system by collecting the design and installation data in aggregate. Comprehensive statewide building design and installation data can help inform policy decisions such as future versions of Title 24, Part 6, or other statewide programs.

To collect project data in aggregate, a virtual storage location is set up to store XML files. When a client application sends XML data, the XML file is scrubbed of personal identifiable information (PII) and saved to the storage location. Structuring the XML files in a hierarchical format that conforms to the predefined XSD schema enables CI to readily map the data into a SQL database for analysis. The database takes advantage of metadata fields such as the Compliance ID to help distinguish between iterations of project data and identifying new projects. Since the system scrubs PII prior to storage, Compliance ID serves as a substitute to uniquely identify projects and distinguish between iterations of existing project data and new projects. This is crucial to prevent duplication and ensure data integrity.

Impact and Expansion: Data-Driven Blueprint for Next Generation Energy Codes

As of March 2024, the VCA has generated compliance forms for more than 182,738 projects. The electronic infrastructure implemented by the CI is providing insight into how people are choosing to comply with the Energy Code and is guiding future code requirements. Certificates of Compliance collect design strategies, Certificates of Installation collect field changes and as-built conditions, and Certificates of Acceptance and Verification gather start-up functional performance testing results and other visual field verifications. Looking at this data in aggregate helps us understand how as-designed and as-built conditions compare and which materials, equipment, and construction techniques are employed throughout the State.

California's 2025 Energy Code rulemaking features an example of how CI is using the aggregated project data to inform future code requirements. Market actors had been calling for simplification, and the CEC was open to ideas on how to simplify the compliance process without changing the stringency of the requirements. CI queried indoor lighting data and determined how current projects were complying prescriptively and identified opportunities to simplify lighting requirements with minimal impact to projects. Figure 11 shows the statewide distribution of 12,520 indoor lighting projects included in the dataset, representing both new construction and alterations.

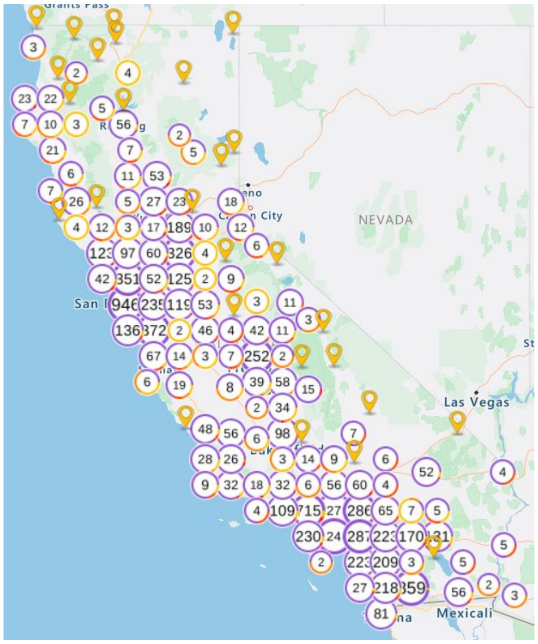

Figure 11. Statewide distribution of indoor lighting projects included in dataset used to develop 2025 code simplification proposal for Title 24, Part 6. *Source:* Blair, S. Lighting Language Cleanup, Utility sponsored stakeholder meeting. May 2023.

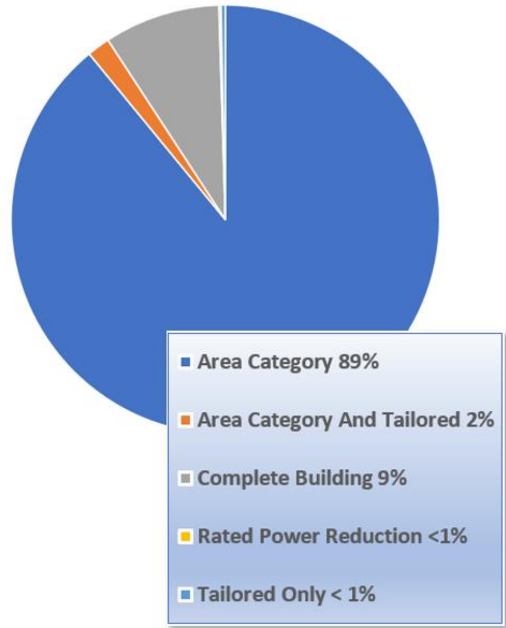

Figure 12. Data from indoor lighting projects showing 98% of projects used Area Category and Complete Building Methods and less than one percent used Tailored Method. *Source:* Blair, S. Lighting Language Cleanup, Utility sponsored stakeholder meeting. May 2023.

As illustrated above in Figure 12, the data showed that out of the five allowance calculation methods offered in the Energy Code, the Tailored Method was used by less than 1% of projects, while the two most popular methods, Area Category and Complete Building, were used by 98% of indoor lighting projects complying prescriptively (California Lighting Technology Center, University of California 2023). Digging further into the data revealed that Tailored Method was primarily being used in retail merchandise sales and dining areas. In addition, of the retail merchandise sales areas that complied prescriptively, 81% complied using Area Category and Complete Building methods, and only 19% used Tailored Method. Ninety-four percent of dining areas used Area Category and Complete Building methods and only 6% used Tailored Method as shown in Table 1. This clearly begged the question of whether the popular Area Category Method could accommodate these specialty retail merchandise sales and dining areas.

Removing Tailored Method from the Energy Code would result not only in less code language but would also result in a simplification of compliance forms used to document compliance, simplification of the Compliance Manual, simplification of the CBECC software maintained by the CEC to support performance compliance, and simplification of various compliance support resources such as plans examiner checklists, fact sheets, etc. published by CI. Maintaining all these various resources to accommodate so few projects does not make sense if the projects can comply using the Area Category Method.

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Table 1. Indoor Lighting Compliance Method

Space Function	Tailored	Area Category	Complete Building
Retail Merchandise Sales	409 (19%)	1517 (72%)	180 (9%)
Dining Area	62 (6%)	850 (80%)	152 (14%)
Multipurpose Area	18 (0.5%)	3025 (99.5%)	-
Exhibit Museum Area	12 (21%)	45 (79%)	-
Main Entry Lobby	7 (0.2%)	2798 (99.8%)	-
Conference Area	4	See Multipurpose	-
Showroom Area	3	-	-
Religious Worship Area	2	58	4
Grocery Store Area	2	272	6
Meeting Center Area	1	See Multipurpose	-
Auditorium Area	1	34	-

Table 1. Data showing the number of space function areas using Tailored, Area Category and Complete Building Methods for calculating prescriptive indoor lighting power allowances, 2023.

The data collected through the compliance forms were used for further data analysis to support a code simplification proposal developed with a group of lighting industry stakeholders, the CEC, and the C&S Program. The proposal includes adding specialty allowances to the Area Category Method to accommodate space types that utilized Tailored Method and to remove Tailored Method from the 2025 Energy Code, Compliance Manual, compliance forms, CBECC software, and other compliance support resources and materials.

Additionally, the data gathered through mechanical and plumbing compliance forms indicates that California all electric projects are trending up. When comparing mechanical and plumbing equipment trends between the 2019 and 2022 code cycles, data suggests the 2022 code cycle is seeing increased electrification. During the 2019 code cycle, 49% of new construction projects in the dataset were identified as all electric by the designer of record, compared to 61% during the 2022 code cycle, as shown in Figure 13 below.

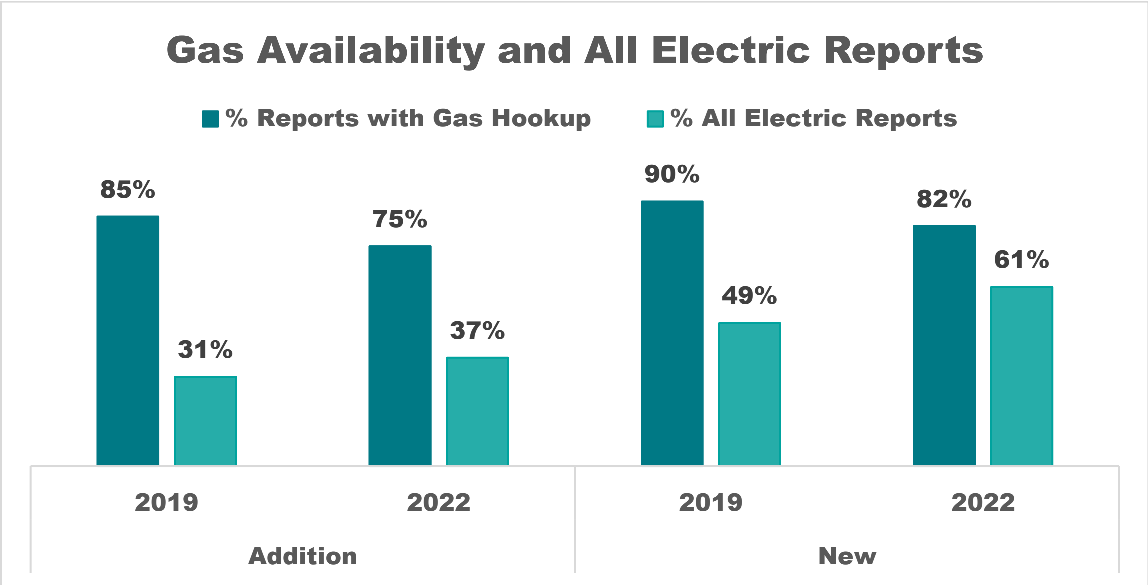

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Figure 13. Gas Availability and All Electric Reports: Trends Between Code Cycles Comparing 2019 and 2022 mechanical and plumbing data. *Source:* Virtual Compliance Assistant Database

In conclusion, the comprehensive approach developed in this paper offers a framework to improve compliance and inform policy decisions that can be implemented in any state or local jurisdiction. The framework consisting of several key components, including client applications, schemas, a report generator, and a database, each play a crucial role in facilitating data collection, reporting, and data analysis.

The versatility of the framework makes it adaptable to different compliance needs and policy contexts. Its modular design allows for customization based on specific requirements of the program, while its structure ensures consistency and interoperability. The framework could be utilized in local jurisdictions with both extremely simple or complex regulations, across various industries including environmental and others. The framework's standardized data formats and centralized, efficient report generation facilitate seamless integration into both new and existing systems. Whether starting from scratch or enhancing an established infrastructure, the framework not only accommodates diverse data structures but also enhances system efficiency. The framework demonstrates scalability through its utilization of automation and centralized services, accommodating the expansion of users or policy initiatives.

By leveraging its standardized processes, adaptable design, and scalable architecture, states can effectively address compliance challenges, improve regulatory outcomes, and advance their policy objectives. Ensuring equitable access to knowledge and tools for compliance supports the goals of the state's energy code, fostering fairness and inclusion across all segments of the market regardless of resource availability. As we move forward, collaboration and innovation will be key drivers in realizing the full potential of the framework to create a more sustainable and compliant future.

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