



TITLE 24, PART 6

2028 CODE CYCLE

HVAC Fault Detection and Diagnostics

Codes and Standards Enhancement (CASE) Proposal
Nonresidential | HVAC Controls

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Code Change Description

- Code Change Proposal
- Benefits
- Background Information



Proposed Code Change

Mandatory requirement:

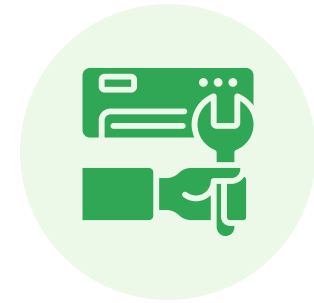
- Add HVAC Fault Detection and Diagnostics (FDD) as a mandatory measure for new HVAC systems with (equipment with) design heating or cooling capacity of 300,000 kBtu/hr or larger, installed in new construction or alterations of buildings 100,000 square feet or larger.
- Baseline functional requirements such as using rule- or model-based analysis, minimum performance data trending and storage, and reporting.

Defining:

- Fault – a deviation from intended operation that prevents the system from performing its intended function efficiently.
- Fault Detection and Diagnostics – an automated process to identify faults in building systems using sensors and data analytics to monitor system performance, determine potential solutions, and communicate findings.

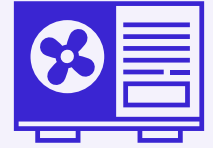
Benefits of the Proposed Change

- We recommend this change because it will save energy and simplify operations by enabling continuous monitoring of system operation and performance.
- FDD provides building operators with a proactive way to maintain and optimize their systems by collecting and reporting operational data that can provide actionable insights.
- FDD can also sustain other HVAC efficiency measures by monitoring their performance and identifying repairs.



Background Information

- 2013 Title 24 introduced a mandatory requirement to include economizer FDD for air-cooled DX systems with cooling capacity equal to or greater than 54,000 Btu/h.
- Manufacturers must certify the FDD systems to the Energy Commission.
- 2019 Title 24 expanded mandatory economizer FDD requirements to cover built-up systems.
- 2022 Title 24 lowered the trigger threshold for economizers and FDD down to 33,000 Btu/hr (from 54,000 Btu/hr).



Marked-up Code Language

See Title24stakeholders.com for marked-up code language

Title 24, Part 1

- No changes

Title 24, Part 6

- Definitions
- Section 120.2
- Section 120.5

Reference Appendices

- NA7.5

Poll

What is your role in the industry? Pick the option that best describes your role.

- a. Building owner
- b. Building operator
- c. HVAC Designer
- d. HVAC Contractor
- e. Controls contractor
- f. FDD provider
- g. Commissioning agent
- h. HVAC or controls manufacturer
- i. Building official (plan checker, inspector, etc.)
- j. Other (FILL IN)



Market and Technical Considerations

- Current Conditions and Trends
- Potential Barriers and Solutions
- Technical feasibility

Current Market Conditions

Prevalence of HVAC faults in nonresidential buildings:
40% of air handling units and 30% of air terminal units reported fault daily in a study of over 60,000 pieces of HVAC equipment (Crowe et al., 2023).

This study and input from HVAC designers and building operators indicate a market need for FDD, which would evolve quickly with code adoption.



Crowe, E., Chen, Y., Reeve, H., Yuill, D., Ebrahimifakhar, A., Chen, Y., ... Granderson, J. (2023). Empirical analysis of the prevalence of HVAC faults in commercial buildings. *Science and Technology for the Built Environment*, 29(10), 1027–1038. <https://doi.org/10.1080/23744731.2023.2263324>

Market Barriers and Solutions

Market Barriers

1. Every building is unique, making FDD hard to consistently implement
2. FDD provider options vary in terms of functionality
3. Proper training for FDD end users



Potential Solutions

1. Provide minimum baseline FDD functionality for easier adoption while still seeing savings
2. Code language broad enough to allow flexibility
3. Identify training barriers and solutions to communicate to end users

Current Market Penetration

The Statewide CASE Team has not found any studies on the prevalence of HVAC FDD in California nonresidential buildings and will continue literature review for quantitative data.

A national study using the Smart Energy Analytics Campaign collected data from 104 commercial organizations with over 567 million square feet and more than 6,500 buildings.

63% of participants were using some form of FDD

(Kramer et al., 2020)

- This shows FDD market penetration in organizations with large building portfolios.



Kramer, H., Lin, G., Curtin, C., Crowe, E., and Granderson, J. *Proving the Business Case for Building Analytics*. Lawrence Berkeley National Laboratory, October 2020. <https://doi.org/10.20357/B7G022>

Poll

What do you believe the current market penetration of HVAC FDD for buildings over 100,000 square feet? In your experience, select a percentage of large buildings in California currently have HVAC FDD.

- a. 0%
- b. Up to 25%
- c. 25% - 50%
- d. 50% - 75%
- e. Over 75%
- f. I don't know

Poll

What building types are currently implementing HVAC FDD?

In your experience, select which building types have had FDD added to their systems.

- | | |
|----------------------------|--------------------------|
| a. Offices | f. Universities |
| b. Retail | g. K-12 School buildings |
| c. Assembly* | h. Warehouse |
| d. Hospitals | i. Other (FILL IN BLANK) |
| e. Non-hospital Healthcare | j. I don't know |

* Includes events and exhibit buildings, performing arts theater, motion picture theater, gymnasium, museum, library, religious worship

Poll

What HVAC system types should be implementing FDD?

Select which system types have high energy savings opportunities from using FDD.

- a. Multi-zone air handling units
- b. Single-zone air handling units
- c. Rooftop units
- d. Heat pumps
- e. Fan coil units
- f. Chilled water plant
- g. Hot water plant
- h. Other (FILL IN BLANK)
- i. I don't know

Technical Considerations

Current Practice: Designers specify projects with standard sequences, points lists, and alarming requirements.

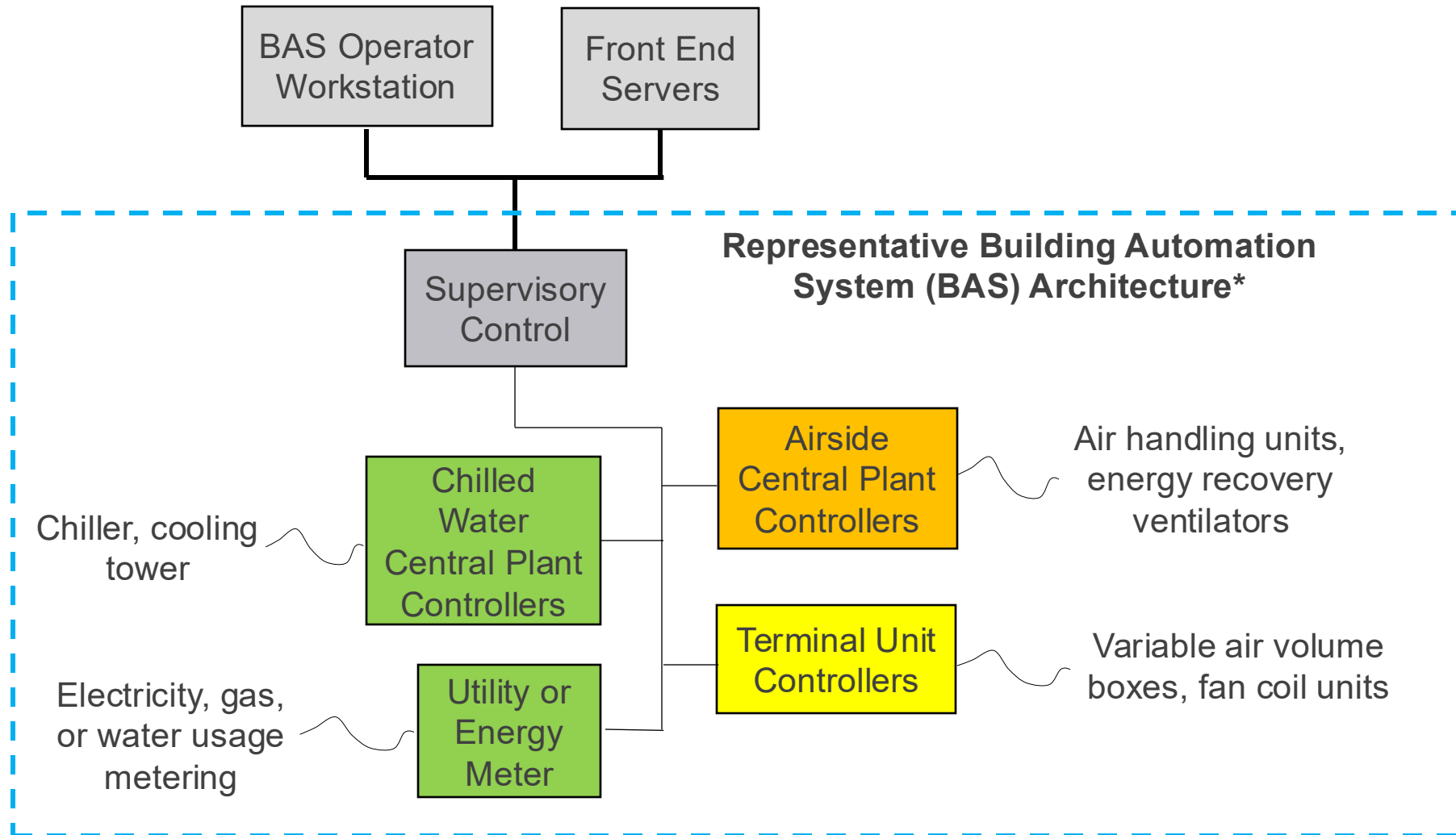
Controls contractors install control systems based on the specifications. They design the control system architecture as well as install their building automation frontend along with system integration and configuring control inputs and outputs.

Proposed code change:

- Designers specify and design HVAC FDD functionality.
- Controls contractors install with HVAC FDD as a requirement.
- Long-term system performance will improve through building life cycle through FDD information and facility manager actions.

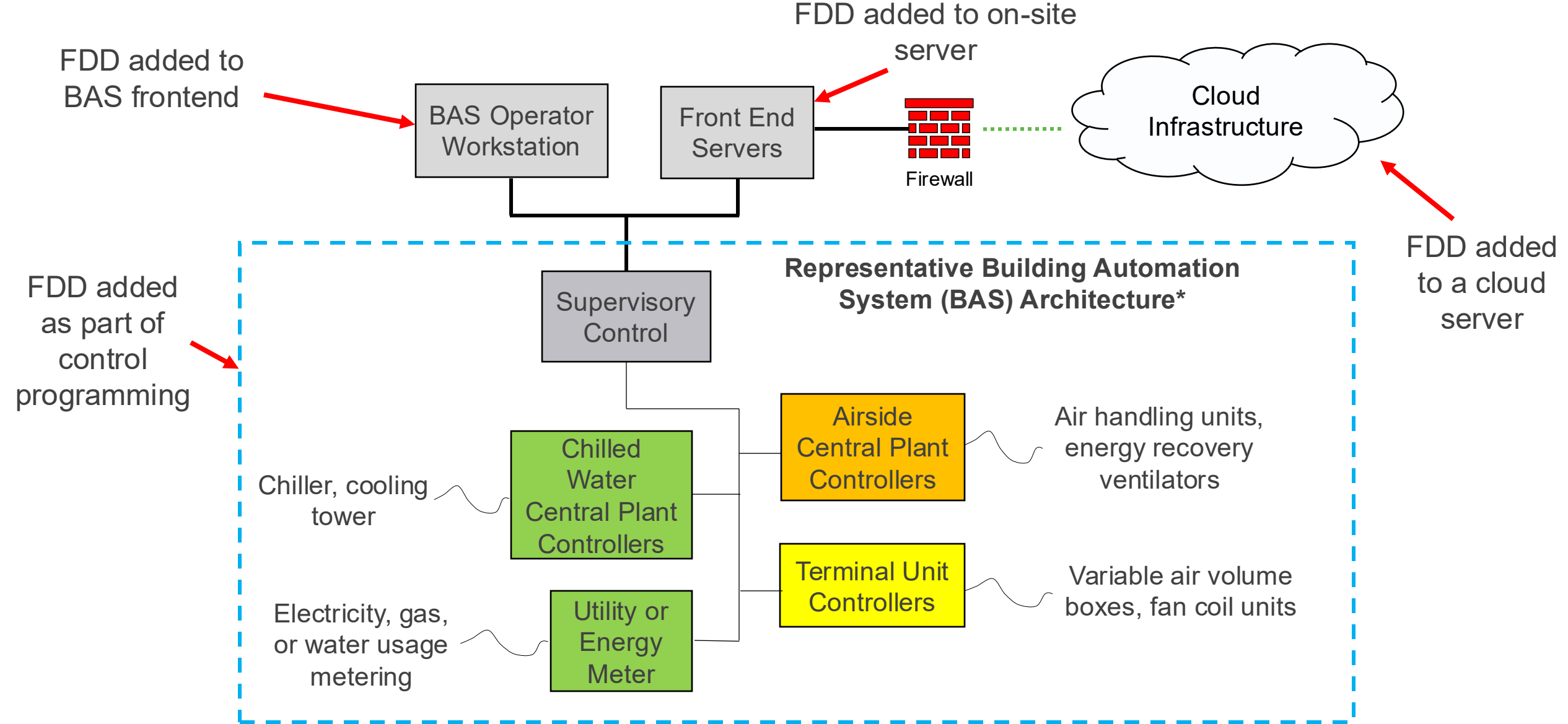


Technical Considerations – Current Standard



*Example of BAS architecture, every building will be different

Technical Considerations – Potential Options



*Example of BAS architecture, every building will be different

Poll



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Is there any potential FDD options that were missed? Briefly describe what other options that FDD can be used on a building.

Open ended response

Technical Barrers and Solutions

Technical Barriers

1. There is a broad range of HVAC FDD functionality
2. If cloud based, building owner cybersecurity approval may be needed



Potential Solutions

1. Defining HVAC FDD
2. Defining baseline functional requirements of an HVAC FDD system
3. Allowing onsite and cloud options to meet requirement

Poll

What is the range of HVAC energy savings that can be expected? Based on HVAC FDD usage, select the range of total HVAC energy savings that can be expected.

- a. < 5%
- b. 6% – 20%
- c. > 20%
- d. I don't know

Poll

If buildings are not seeing energy savings or sustained energy efficiency, why? Select all that apply from the list below on the most common reasons buildings would not see energy efficiency benefits from FDD.

- a. Inaccessibility to fault information
- b. Lack of staffing
- c. Lack of staff training
- d. Lack of resources
- e. Improper implementation
- f. System performance pre-install is already optimized.
- g. Other (FILL IN)
- h. I don't know

Poll

What else should we know?

Are there market or technical barriers or solutions we should consider?

Are there other faults and FDD requirements for large buildings that we should know about?

Open ended response

Per Unit Energy and Cost Impacts

Methodology and Assumptions

- Energy and Energy Cost Savings
- Incremental Costs



Energy and Energy Cost Savings Methodology

Per-sq ft energy and demand impacts:

- **Base case:** represents the non-FDD system:
 - reasonable system ongoing operation,
 - using identified common faults through literature review and SMEs and the assumption that common faults are not being resolved/repared
- **Proposed case:** represents the system with FDD:
 - common faults are being resolved/repared
- **2025 prototypes:** Large Office, Retail, School, and Grocery
- **Climate zones modeled:** All climate zones



Energy Modeling Assumptions

- Simulating using the following prototypical buildings and climate zones

Prototype Buildings

- Office Large
- Retail Large
- School Large
- Grocery

Climate Zones

- Simulating in 1 – 16

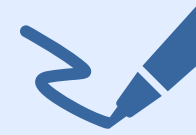
Assumptions for Standard and Proposed Designs



Baseline Case

System with common faults*, across the measure life such as:

- HVAC system scheduling
- simultaneous heating and cooling
- valve leak by (valve bypass)
- stuck damper/valve actuators
- low or high airflow
- rogue zone



Proposed Design

System with faults resolved

*Literature review will identify the most common and impactful faults

Incremental Cost Framework



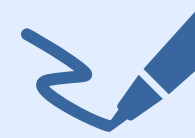
Baseline

First Cost

- System with no FDD

30-Year Maintenance Costs

- Regular maintenance and/or service agreements for system without FDD



Proposed

First Cost

- Fault detection and diagnostics software and installation

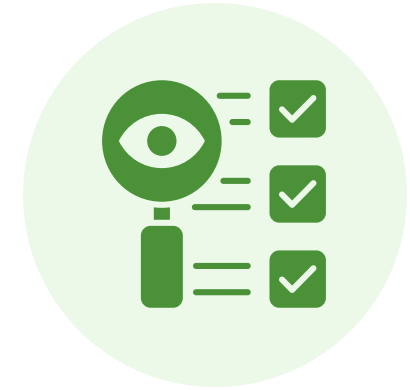
30-Year Maintenance Costs

- Regular FDD software update and/or service agreements

Approach for Gathering Costs

Literature review of cost of implementation

- Several research publications have costs included but more information is needed to help define proper FDD costs and benefits



FDD providers, we need your input!

How do you estimate costs for implementation?

How do you estimate ongoing costs?



Poll

FDD Providers: How do you estimate costs for implementation? Check all that apply

- a. Square footage
- b. Building type
- c. System type
- d. Hardware points
- e. Control or software points
- f. System age
- g. Other (Fill in)



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Poll

FDD Providers: How do you estimate costs for ongoing service or maintenance? Check all that apply

- a. Square footage
- b. Building type
- c. System type
- d. Hardware points
- e. Control or software points
- f. System age
- g. Flat regular fee
- h. No ongoing costs
- i. Other (Fill in)



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Poll

FDD Users: What approximate costs did you have for FDD implementation? You can either provide an answer here or email the measure lead with more details.

Open ended response

Poll

FDD Researchers: What unit costs have you seen in your research? Please let us know if you have any resources.

Open ended response



Compliance Verification

- Key Aspects of Compliance Verification
- Barriers and Solutions
- Revisions to Compliance Software

Key Aspects of Compliance Verification



- Design – Designers specify FDD in specifications, including hardware requirements, software requirements, and logic.
- Compliance forms will include checkboxes for designers to indicate whether FDD requirement is applicable and if the requirement is satisfied.



- Permit application
 - Plans examiner reviews FDD specifications and verifies they align with compliance forms.
- Construction
 - Contractor installs FDD to meet requirements.

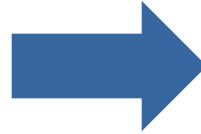


- Inspection
 - Acceptance test technician (ATT) performs required acceptance tests
 - Inspector reviews acceptance tests and compliance forms to verify FDD system meets minimum requirements.

Compliance Barriers and Solutions

Compliance Verification Barriers

1. Verification of control system capabilities is difficult and can be complex
2. Defining a compliant FDD system (“What right looks like”)
3. New acceptance tests for FDD system verification



Potential Solutions

1. Research of verification strategies from FDD providers
2. Clearly define minimum control capabilities code requirements
3. Develop clear instructions in NA7.5. Provide training to ATTs on FDD tests

Compliance Software Updates

Because this would be a mandatory change, there is no expected change in compliance software.

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More information on

[CEC's 2028 proceeding website.](#)

We want to hear from you!