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BUILDING ENERGY EFFICIENCY MEASURE PROPOSAL TO THE

CALIFORNIA ENERGY COMMISSION

FOR THE 2022 UPDATE TO THE

CALIFORNIA ENERGY CODE, TITLE 24, PART 6

BUILDING ENERGY EFFICIENCY STANDARDS

RESIDENTIAL ELECTRIC BASELINE

Residential HVAC and Residential Water Heating

Prepared by California Energy Commission   May 2021

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Executive Summary

Introduction

This report and the code change proposal presented herein provide technical and cost-effectiveness information for proposed regulations on building energy efficiency design practices and technologies.

The overall goal of this Report is to propose a code change for prescriptive residential heat pump space heating and heat pump water heating and performance baselines. The report contains pertinent information that justifies the code change.

Measure Description

This report proposes changes to the prescriptive requirements for space heating and water heating systems for energy and greenhouse gas (GHG) emissions savings in residential single-family buildings. The Energy Commission investigated heat pump space heating and water heating requirements across all climate zones and proposes one or the other for each climate zone, dependent on cost-effectiveness, GHG and market impacts. In select climate zones, additional energy measures are needed to meet time dependent valuation (TDV) equivalence with existing natural gas baselines. These include compact water heating design in Climate Zones 1 and 16 and drain water heat recovery in Climate Zone 16. The performance standard design would match the proposed prescriptive requirements, replacing the dual baseline strategy.

Background Information

The heat pump space heating and heat pump water heating measures build on the 2019 Title 24, Part 6 Standards that include a dual baseline strategy wherein electrically space-heated and water-heated buildings are compared to a code minimum electrically space- heated and water-heated building, whereas natural gas-based systems for space heating and water heating are compared to code minimum natural gas-based systems.

Energy Commission presentations during the 2019 Title 24, Part 6 pre-rulemaking and rulemaking process show that all-electric buildings would generate less overall carbon than mixed-fuel buildings. However, the all-electric buildings use more TDV energy than mixed fuel under the 2019 Title 24, Part 6 Standards because 2019 TDV values electricity use higher than natural gas/propane during peak periods. Thus, the goals of cost effectiveness (using TDV) and overall carbon reductions are currently in conflict even with the improvements in the 2019 Title 24, Part 6. Improved TDV values for the 2022 Title

24, Part 6 code cycle, make all-electric buildings more feasible than under the 2019 TDV metric.

Proposed Code Change

This proposal would modify Subsection 150.1(c) Prescriptive Standards/ Components Package. The proposed code change would prescriptively require:

- Heat pump space conditioning system in Climate Zones 3, 4, 10, 13 and 14.
- Heat pump water heating in Climate Zones 1, 2, 5, 6, 7, 8, 9, 11, 12, 15, and 16.
- Compact hot water distribution in Climate Zones 1 and 16
- A drain water heat recovery system in Climate Zone 16

The change would also require updates to the Residential Alternative Calculation Method (ACM) Reference Manual, Residential Compliance Manual, and compliance documents.

Scope of Code Change Proposal

Table 1 summarizes the scope of the proposed changes and which sections of the Standards, Reference Appendices, ACM Reference Manual, and compliance documents that would be modified as a result of the proposed change(s).

Table 1: Scope of Code Change Proposal

Measure Name	Type of Requirement	Modified Section(s) of Title 24, Part 6	Modified Title 24, Part 6 Appendices	Would Compliance Software Be Modified	Modified Compliance Document(s)
Heat Pump Space Heating	Performance Path Baseline System Prescriptive Requirement	150.1(c)7	N/A	Yes	N/A
Heat Pump Water Heating	Performance Path Baseline System Prescriptive Requirement	150.1(c)8	N/A	Yes	CF2R-PLB-02a CF2R-PLB-22a

Market Analysis and Regulatory Assessment

Heat pump space heating and heat pump water heating are established technologies and readily available in the market. Including prescriptive requirement for either heat pump space heating or heat pump water heating by climate zone, rather than the same requirement across all climate zones, will allow heat pump equipment manufacturers to keep pace with increased demand and mediate dramatic reduction in demand for gas appliances.

Cost Effectiveness

Cost-effectiveness analyses results on a per-unit basis are presented in Table 2 and Table 3 for the 2,100 ft^2 and 2,700 ft^2 single family prototypes respectively. The benefit-to-cost (B/C) ratio is the incremental TDV Energy Costs Savings divided by the Total Incremental Costs. When the B/C ratio is greater than 1.0, the added cost of the measure is more than offset by the discounted energy cost savings and the measure is deemed to be cost effective.

Table 2: Cost-effectiveness Summary – 2,100 ft² Prototype

Climate Zone	Benefit: TDV Energy Cost Savings (2023 PV$)	Cost: Total Incremental First Cost and Maintenance Cost (2023 PV$)	Planned Benefit to Cost (B/C) Ratio
Climate Zone 1	$418	($1,113)	>1
Climate Zone 2	$1,428	($1,113)	>1
Climate Zone 3	$1,497	($482)	>1
Climate Zone 4	$1,235	($482	>1
Climate Zone 5	$1,355	($1,113)	>1
Climate Zone 6	$2,231	($1,113)	>1
Climate Zone 7	$2,329	($1,113)	>1
Climate Zone 8	$2,583	($1,113)	>1
Climate Zone 9	$2,500	($1,113)	>1
Climate Zone 10	$392	($482	>1
Climate Zone 11	$1,602	($1,113)	>1
Climate Zone 12	$1,540	($1,113)	>1
Climate Zone 13	$1,206	($482	>1
Climate Zone 14	$530	($482	>1
Climate Zone 15	$2,550	($1,113)	>1
Climate Zone 16	$752	($342)	>1

Table 3: Cost-effectiveness Summary – 2,700 ft² Prototype

Climate Zone	Benefit: TDV Energy Cost Savings (2023 PV$)	Cost: Total Incremental First Cost and Maintenance Cost (2023 PV$)	Planned Benefit to Cost (B/C) Ratio
Climate Zone 1	$565	($1,113)	>1
Climate Zone 2	$1,803	($1,113)	>1
Climate Zone 3	$1,495	($482)	>1
Climate Zone 4	$1,523	($482	>1
Climate Zone 5	$1,369	($1,113)	>1
Climate Zone 6	$2,541	($1,113)	>1
Climate Zone 7	$2,476	($1,113)	>1
Climate Zone 8	$2,915	($1,113)	>1
Climate Zone 9	$2,910	($1,113)	>1
Climate Zone 10	$584	($482	>1
Climate Zone 11	$1,938	($1,113)	>1
Climate Zone 12	$1,924	($1,113)	>1
Climate Zone 13	$1,630	($482	>1
Climate Zone 14	$986	($482	>1
Climate Zone 15	$2,854	($1,113)	>1
Climate Zone 16	$1,266	($342)	>1

Section 5.1 discusses the methodology and Section 5.2 shows the results of the cost-effectiveness analysis.

Statewide Energy Impacts: Energy, Water and GHG Emissions Impacts

Table 4 shows the estimated energy savings over the first twelve months of implementation of the heat pump space heating and heat pump water heating measures. Note that electricity savings (GWh) and power demand reduction (MW) are negative and indicate increased use. MMtherms and overall TDV savings are positive.

Table 4: Statewide Estimated First-Year Energy Savings

	First-Year Statewide Savings			First-Year Statewide TDV Savings	
	Electricity Savings (GWh)	Power Demand Reduction (MW)	Natural Gas Savings (MMtherms)	TDV Electricity Savings (Million kBTU)	TDV Natural Gas Savings (Million kBTU)
Heat Pump Space Heating	(40.11)	-	3.86	(1,133)	1,618
Heat Pump Water Heating	(74.54)	(4.52)	7.83	(1,890)	2,769
TOTAL	(114.65)	(4.52)	11.69	(3,024)	4,387

Section 4.2 discusses the methodology and Section 4.3 shows the results for the per-unit energy impact analysis.

Greenhouse Gas Impacts

Table 5 presents the estimated avoided GHG emissions of the proposed code change for the first year the standards are in effect. Assumptions used in developing the GHG savings are provided in Section 6.2 and Appendix C of this report.

The monetary value of avoided GHG emissions is included in TDV cost factors (TDV $) and is thus included in the cost-effectiveness analysis prepared for this report.

Table 5: Estimated Statewide Greenhouse Gas Emissions Impacts

	First-Year Statewide	
	Avoided GHG Emissions ($MTCO_2e$/yr)	Monetary Value of Avoided GHG Emissions ($2023)
Heat Pump Space Heating	12,047	$1,279,447
Heat Pump Water Heating	34,644	$3,679,176
TOTAL	46,691	$4,958,622

Water Use and Water Quality Impacts

The proposed measure is not expected to have any impacts on water use or water quality.

Compliance and Enforcement

Compliance and enforcement, including applicable field verification and diagnostic testing, would remain the same for heating, ventilation, and air conditioning and water heating designs.

1. Introduction

The overall goal of this Report is to propose a code change for prescriptive residential heat pump space heating and heat pump water heating and performance baselines. The report contains pertinent information that justifies the code change.

Section 2 of this Report provides a description of the measure, measure history, and how the measure helps achieve the state's zero net energy and greenhouse gas (GHG) emissions reductions goals. This section presents how the proposed code change would be enforced and the expected compliance rates.

Section 3 presents the market analysis, including a review of the current market structure, a discussion of product availability, and the useful life and persistence of the proposed measure. This section offers an overview of how the proposed standard will impact various stakeholders including builders, building designers, building occupants, equipment retailers (including manufacturers and distributors), energy consultants, and building inspectors.

Section 4 describes the key assumptions used in the energy savings analysis, the energy savings methodology and provides the per-unit energy impacts and energy savings results.

Sections 5 includes a discussion and presents analysis of the materials and labor required to implement the measure and a quantification of the incremental cost. It also includes estimates of incremental maintenance costs, i.e., equipment lifetime and various periodic costs associated with replacement and maintenance during the period of analysis.

Section 6 presents the statewide energy savings and environmental impacts of the proposed code change for the first year after the 2022 code takes effect. This includes the amount of energy that would be saved by California building owners and tenants and impacts (increases or reductions) on material with emphasis placed on any materials that are considered toxic by the State of California.

Section 7 of the report concludes with specific recommendations for language for the Standards, Appendices, Alternate Calculation Manual (ACM) Reference Manual and Compliance Forms.

Section 8 – Bibliography presents the resources that the Report Authors used when developing this report.

Appendix A: Statewide Savings Methodology presents the methodology and assumptions used to calculate statewide energy impacts.

Appendix B: Embedded Electricity in Water Methodology presents the methodology and assumptions used to calculate the electricity embedded in water use (e.g., electricity used to draw, move, or treat water) and the energy savings resulting from reduced water use.

Appendix C: Environmental Impacts Methodology presents the methodologies and assumptions used to calculate impacts on GHG emissions and water use and quality.

Appendix D: California Building Energy Code Compliance (CBECC) Software Specification presents relevant proposed changes to the compliance software (if any).

Appendix E: Impacts of Compliance Process on Market Actors presents how the recommended compliance process could impact identified market actors.

Appendix F: Summary of Stakeholder Engagement documents the efforts made to engage and collaborate with market actors and experts.

Appendix G: Heat pump product availability analysis provides analysis of heat pump products available in the market and how they relate to federal and California appliance standards.

Appendix H: Nominal Savings Tables presents the energy cost savings in nominal dollars by climate zone.

2. MEASURE DESCRIPTION

2.1 Measure Overview

This Report proposes changes to the prescriptive requirements for space heating and water heating systems for energy and GHG emissions savings in residential single family buildings. These measures build on the 2019 Title 24, Part 6 Standards that include a dual baseline strategy wherein electrically space-heated and water-heated buildings are compared to a code minimum electrically space-heated and water-heated building, whereas natural gas-based systems for space heating and water heating are compared to code minimum natural gas-based systems. The Energy Commission investigated heat pump space heating and water heating requirements across all climate zones and proposes one or the other for each climate zone, to allow for industry transition. In select climate zones, additional energy measures are needed to meet time dependent valuation (TDV) equivalence with existing natural gas baselines. These include compact water heating design in Climate Zones 1 and 16 and drain water heat recovery in Climate Zone 16. The performance standard design would match the proposed prescriptive requirements, replacing the dual baseline strategy. The proposed measure does not apply to alterations.

2.2 Measure History

Local jurisdictions and efficiency advocates, including building decarbonizations groups, are increasingly proposing all-electric buildings in California. As of January 2021, approximately 42 local jurisdictions have adopted or proposed local ordinances that exceed the 2019 Title 24, Part 6 Standards with a specific goal of promoting decarbonization through building electrification (Building Decarbonization Coalition, 2020). These ordinances address the need to adjust energy policies and building construction practices with the state's desire to lower greenhouse gas and carbon emissions from buildings. Decarbonization is now the stated policy goal for the state as enshrined in Assembly Bill 32 (AB-3232 Zero-emissions buildings and sources of heat energy 2018), Senate Bill 350 (Clean Energy and Pollution Reduction Act - SB 350 2019) and the 2019 Integrated Energy Policy Report (IEPR) (CEC 2019). Whereas the previous iterations of IEPR primarily supported zero net energy goals for buildings to meet the state's energy targets, the recent IEPR makes a direct connection to building decarbonization as the means to meet the state's overall climate change mitigation goals. Several local, regional, national, and international organizations, including the Natural Resources Defense Council, have embraced decarbonization strategies and through their grassroots and policy advocacy work have supported building electrification efforts across the state. Designers and engineers are increasingly adopting and supporting building electrification. 2020 CALCERTS data shows that heat pumps are increasingly the system of choice for space heating and water heating in single family new construction (CalCERTS, 2021).

For the 2019 Title 24, Part 6 code cycle, the Energy Commission made significant progress toward achieving the decarbonization goal by increasing energy efficiency requirements, leveling the playing field for all-electric single family buildings that use individual water heating systems.

Presentations made by Energy Commission staff and their consultants during the 2019 Title 24, Part 6 pre-rulemaking and rulemaking events show that all-electric buildings would generate less overall carbon than mixed-fuel buildings. However, the all-electric buildings use more TDV energy than mixed fuel under the 2019 Title 24, Part 6 Standards because 2019 TDV values electricity use higher than natural gas/propane during peak periods. Thus, the goals of cost effectiveness (using TDV) and overall carbon reductions are currently in conflict even with the improvements in the 2019 Title 24, Part 6.

The Energy Commission has proposed alternatives and improvements to the 2022 code compliance metrics to address these issues and has re-evaluated the relative cost effectiveness and carbon reductions for heat pump space heating and water heating. The Energy Commission released a new set of TDV values for the 2022 Title 24, Part 6 code cycle, which make all-electric buildings more feasible than under the 2019 TDV metric.

In the following sub-sections, the authors present the measure history and background for the two submeasures in this report: heat pump space heating and heat pump water heating.

2.2.1 Heat Pump Space Heating

2019 Title 24, Part 6 provided an alternative pathway for electric space heating systems for residential buildings (three stories or less) in both the prescriptive and performance pathways. The Energy Commission changed low-rise residential heating, ventilation, and air conditioning (HVAC) baselines such that the baseline system fuel type is the same as the proposed system fuel type. For buildings with electric space heating, the baseline is a minimum efficiency heat pump system.

2.2.2 Heat Pump Water Heating

In the 2019 Title 24, Part 6, the low-rise residential standard design for water heating is a heat pump water heater (HPWH) when the proposed system is a heat pump or electric resistance. The prescriptive pathway allows either a HPWH meeting federally regulated efficiency levels along with additionally measures such as compact hot water distribution or drain water heat recovery or a Northwest Energy Efficiency Alliance (NEEA) Tier-III rated HPWH. NEEA Tier-III rated equipment represent the most efficient HPWHs available in the market that are rated to perform at outdoor conditions found in cold climate locations. The performance approach uses the federal minimum efficiency HPWH along with the associated measures as standard design when the proposed system is a heat pump or electric resistance system.

2.3 Summary of Proposed Changes to Code Documents

The sections below provide a summary of how each Title 24 document will be modified by the proposed change. See *Section 7* of this report for detailed proposed revisions to code language.

2.3.1 Summary of Changes to the Standards

This proposal would modify the following sections of the building energy efficiency standards as shown below. See *Section 7.1 Standards* of this report for the detailed proposed revisions to the standards language.

SECTION 150.1 PERFORMANCE AND PRESCRIPTIVE COMPLIANCE APPROACHES FOR LOW-RISE RESIDENTIAL BUILDINGS

Subsection 150.1(c) Prescriptive Standards/Components Package

The proposed code change would prescriptively require:

- Heat pump space conditioning system in Climate Zones 3, 4, 10, 13 and 14.
- Heat pump water heating in Climate Zones 1, 2, 5, 6, 7, 8, 9, 11, 12, 15, and 16.
- Compact hot water distribution in Climate Zones 1 and 16
- A drain water heat recovery system in Climate Zone 16

2.3.2 Summary of Changes to the Reference Appendices

There are no proposed changes to the Reference Appendices.

2.3.3 Summary of Changes to the Residential ACM Reference Manual

This proposal would modify the following sections of the Residential ACM Reference Manual as shown below.

Chapter 2 Proposed, Standard, and Reference Design

- **Section 2.4 Building Mechanical System**
Subsection 2.4.1 Heating Subsystems – the Standard Design is space heating heat pump in the case that the water heating system excludes HPWHs in Climate Zones 3, 4, 10, 13, and 14.
- **Section 2.9 Domestic Hot Water (DHW)**
Subsection 2.9.2 Individual Dwelling Units – the Standard Design system

will be dependent on whether the Proposed Design includes a HPWH or not. If a Proposed Design uses a *baseline* level HPWH, the Standard Design in Climate Zones 1 and 16 will additionally include Compact Distribution, and Climate Zone 1 will additionally include drain water heat recovery.

See *Section 7.3 ACM Reference Manual* of this report for the detailed proposed revisions to the text of the ACM Reference Manual.

2.3.4 Summary of Changes to the Residential Compliance Manual

The proposed code change will modify the following section of the Title 24 Compliance Manual:

- **Chapter 5 Water Heating Requirements**
  Section 5.4.1 on Prescriptive Requirements for Single Dwelling Units – The proposed change will update the descriptions for the three new prescriptive pathways involving baseline efficiency HPWH and compact distribution system, NEEA Tier-3 or higher HPWH, and electric water heating with solar water heating.

2.3.5 Summary of Changes to Compliance Documents

The proposed code change will modify the following compliance forms:

- CF2R-PLB-02a-NonHERS-SingleDwellingUnitHotWaterSystemDistribution
- CF2R-PLB-22a-HERS-SingleDwellingUnitHotWaterSystemDistribution

2.4 Regulatory Context

2.4.1 Existing Requirements in the California Energy Code

This topic builds on the 2019 Title 24, Part 6 Standards that allow a dual baseline strategy wherein electrically space- and water-heated systems are compared to a code minimum electrically space- and water-heated systems, whereas natural gas-based systems for space heating and water heating are compared to code minimum natural gas-based systems.

2.4.2 Relationship to Requirements in Other Parts of the California Building Code

There are no relevant requirements in other parts of the California Building Code.

2.4.3 Relationship to Local State, or Federal Laws

U.S. D.O.E. has federal minimum efficiency requirements for DHW and HVAC equipment specified in the Code of Federal Regulations at 10 CFR 430.32(d) (Code of Federal Regulations 2020). Efficiency varies with the equipment class and the equipment capacity. Table 5 and Table 6 give a summary of the federal efficiency requirements. The proposed change includes heat pumps that meet federal minimum efficiency requirements.

Table 6: Federal Minimum Efficiency Requirements for Residential Water Heaters (Partial)

Product class	Rated storage volume and input rating (if applicable)	Draw pattern	Uniform energy factor
Electric Storage Water Heaters	≥20 gallons and ≤55 gallons	Very Small	$0.8808 - (0.0008 \times V_r)$
		Low	$0.9254 - (0.0003 \times V_r)$
		Medium	$0.9307 - (0.0002 \times V_r)$
		High	$0.9349 - (0.0001 \times V_r)$
	>55 gallons and ≤120 gallons	Very Small	$1.9236 - (0.0011 \times V_r)$
		Low	$2.0440 - (0.0011 \times V_r)$
		Medium	$2.1171 - (0.0011 \times V_r)$
		High	$2.2418 - (0.0011 \times V_r)$

*Vr is the Rated Storage Volume (in gallons), as determined pursuant to 10 CFR 429.17.

Table 7 summarizes the federal minimum efficiency requirement for HVAC systems. The federal requirements that go into effect January 1, 2023 will apply during the 2022 Title 24, Part 6 code cycle, which will also go into effect January 1, 2023. The proposed measure does not require HVAC systems having efficiency above the federal standards, thus does not trigger preemption.

Table 7: Federal Minimum Efficiency Requirements for HVAC Systems

Product	Sub-category	Heating Type	Ducts	Capacity	Efficiency	Date
Central air conditioner	Split		Ducted	<45,000 Btu/h	14 SEER; 12.2 EER	January 1, 2015 to January 1, 2023
Central heat pump	Split		Ducted	<65,000 Btu/h	14 SEER; 8.2 HSPF	January 1, 2015 to January 1, 2023
Central air conditioner	Split		Ductless	<45,000 Btu/h	14 SEER; 12.2 EER	January 1, 2015 to January 1, 2023
Central heat pump	Split		Ductless	<65,000 Btu/h	14 SEER; 8.2 HSPF	January 1, 2015 to

						January 1, 2023
Central air conditioner	Packaged			<65,000 Btu/h	14 SEER; 11.0 EER	January 1, 2015 to January 1, 2023
Central heat pump	Packaged			<65,000 Btu/h	14 SEER; 8.0 HSPF	January 1, 2015 to January 1, 2023
Central air conditioner	Split		Ducted	>=45,000 Btu/h; <65,000 Btu/h	14 SEER; 11.7 EER	January 1, 2015 to January 1, 2023
Central air conditioner	Split		Ductless	>=45,000 Btu/h; <65,000 Btu/h	14 SEER; 11.7 EER	January 1, 2015 to January 1, 2023
Central air conditioner	Split		Ducted	<45,000 Btu/h	14.3 SEER2; 11.7 EER2 (if SEER2 < 15.2); 9.8 EER2 (if SEER2 >= 15.2)	January 1, 2023 onwards
Central heat pump	Split		Ducted	<65,000 Btu/h	14.3 SEER2; 7.5 HSPF2	January 1, 2023 onwards
Central air conditioner	Split		Ductless	<45,000 Btu/h	14.3 SEER2; 11.7 EER2 (if SEER2 < 15.2); 9.8 EER2 (if SEER2 >= 15.2)	January 1, 2023 onwards
Central heat pump	Split		Ductless	<65,000 Btu/h	14.3 SEER2; 7.5 HSPF2	January 1, 2023 onwards
Central air conditioner	Packaged			<65,000 Btu/h	13.4 SEER2; 10.6 EER2	January 1, 2023 onwards
Central heat pump	Packaged			<65,000 Btu/h	13.4 SEER2; 6.7 HSPF2	January 1, 2023 onwards
Central air conditioner	Split		Ducted	>=45,000 Btu/h; <65,000 Btu/h	13.8 SEER2; 11.2 EER2 (if SEER2 < 15.2); 9.8 EER2 (if SEER2 >= 15.2)	January 1, 2023 onwards

Central air conditioner	Split		Ductless	>=45,000 Btu/h; <65,000 Btu/h	13.8 SEER2; 11.2 EER2 (if SEER2 < 15.2); 9.8 EER2 (if SEER2 >= 15.2)	January 1, 2023 onwards
VRF Multi-Split Air Conditioner (Air-Cooled)		All Heating Types		<65,000 Btu/h	13.0 SEER	June 16, 2008 onwards
VRF Multi-Split Heat Pump (Air-Cooled)		All Heating Types		<65,000 Btu/h	13.0 SEER, 7.7 HSPF	June 16, 2008 onwards
VRF Multi-Split Heat Pump (Air-Cooled)		No Heating or Electric Resistance Heating		>=65,000 Btu/h; <135,000 Btu/h	11.0 EER, 3.3 COP	January 1, 2010 onwards
VRF Multi-Split Heat Pump (Air-Cooled)		All Other Types of Heating		>=65,000 Btu/h; <135,000 Btu/h	10.8 EER, 3.3 COP	January 1, 2010 onwards
VRF Multi-Split Heat Pump (Air-Cooled)		No Heating or Electric Resistance Heating		>=135,000 Btu/h; <240,000 Btu/h	10.6 EER; 3.2 COP	January 1, 2010 onwards
VRF Multi-Split Heat Pump (Air-Cooled)		All Other Types of Heating		>=135,000 Btu/h; <240,000 Btu/h	10.4 EER; 3.2 COP	January 1, 2010 onwards
VRF Multi-Split Air Conditioner (Air-Cooled)		No Heating or Electric Resistance Heating		>=65,000 Btu/h; <135,000 Btu/h	11.2 EER	January 1, 2010 onwards
VRF Multi-Split Air Conditioner (Air-Cooled)		All Other Types of Heating		>=65,000 Btu/h; <135,000 Btu/h	11.0 EER	January 1, 2010 onwards
VRF Multi-Split Air Conditioner (Air-Cooled)		No Heating or Electric Resistance Heating		>=135,000 Btu/h; <240,000 Btu/h	11.0 EER	January 1, 2010 onwards
VRF Multi-Split Air Conditioner (Air-Cooled)		All Other Types of Heating		>=135,000 Btu/h; <240,000 Btu/h	10.8 EER	January 1, 2010 onwards

As of January 2021, approximately 42 local jurisdictions have adopted local ordinances (Building Decarbonization Coalition 2020) that encourage or require the use of electric water heating in residential and/or nonresidential applications. Some of these ordinances, such as Berkeley, Morgan Hill, and Cupertino, have language similar to the following:

"Exception: Natural Gas Infrastructure may be permitted in a Newly Constructed Building if the Applicant establishes that it is not physically feasible to construct the building without Natural Gas Infrastructure. For purposes of this exception, "physically feasible" to construct the building means either an all-electric prescriptive compliance approach is available for the building under the Energy Code, or the building is able to achieve the performance compliance standards under the Energy Code using commercially available technology and an approved calculation method (City of Berkeley 2019).

2.4.4 Relationship to Industry Standards

American Society of Heating and Refrigeration Engineers Standard 90.2 (ASHRAE 90.2) presents efficiency standards for low-rise residential buildings, including single family homes. ASHRAE 90.2 Tables 5-1 and 5-3 provide the Central Air Conditioner and Heat Pump Specifications and Water Heater Minimum Efficiency that establish the HVAC and service hot water (domestic hot water for Title 24 Part 6) system baselines.

International Energy Conservation Code (IECC) sections 403.6 and 403.5 lays out mandatory and prescriptive requirements for mechanical ventilation (HVAC for Title 24 Part 6) and service hot water (domestic hot water for Title 24 Part 6) systems, respectively. IECC otherwise references federal minimum efficiency rating for equipment.

ASHRAE 90.2 and IECC Residential Provisions map differently to Title 24 Part 6 requirements, and they make direct reference federal minimum equipment efficiency ratings requirements. Both requirement levels are generally less stringent than Title 24 Part 6.

2.5 Compliance and Enforcement

Compliance and enforcement would remain the same for HVAC and water heating designs even though the choice of standard design will change to a heat pump system. The 2022 prescriptive standard would require the applicant to use heat pump systems either for space or water heating, however the specifications for these heat pumps are the same as those currently used to comply with the 2019 Title 24, Part 6 Standards. Appendix E presents how the proposed changes could impact various market actors.

3. MARKET ANALYSIS

The authors performed a market analysis with the goals of identifying market structure, technical feasibility, and market availability, and estimating anticipated market and economic impacts. These are described in detail in the subsections below.

3.1 Market Structure

The heat pump space heating and water heating technology market actors include building owners/developers, design consultant team, contractors, equipment manufacturers, energy consultants and HERS Raters. Each type of market actor is described below.

- **Designers:** Designers are part of the project design consultant team that include architects, mechanical, plumbing, structural, and electrical consultants. Designers plan for the spaces where mechanical and plumbing equipment are installed. Decisions made by designers on the size and location of mechanical/plumbing areas, as well as other aspects of building layout, can significantly impact the feasibility of split heat pump system and variable refrigerant flow (VRF) systems.
- **Building owners/developers:** Owners and developers are the decision-makers on the type of systems that go into their buildings.
- **Mechanical/plumbing contractors:** Mechanical and plumbing contractors are responsible for designing and installing HVAC and DHW systems, respectively. They are responsible for determining system types to be used in the building and ensuring the design satisfies all installation requirements such that the HVAC system can function properly. This involves coordination with the designer to ensure space requirement, structural support, etc. The project consultant team, including mechanical and plumbing contractors, can have a strong influence on building owner/developer in decision of the type of HVAC and plumbing system that go into a building. They need to have the ability to communicate value proposition to the building owner and developers. After installation, maintenance, and repairs of heat pump space heaters and HPWHs may require an HVAC contractor or other processional licensed to work with refrigerant-containing components. There are many contractors with extensive experience in installing heat pump systems.
- **Manufacturers:** Equipment manufacturers develop, market, and sell heat pump space heating and heat pump water heating equipment. Manufacturers support design engineers by providing equipment selection software and suggesting equipment layout concept. They also support equipment installation, start-up testing by providing training to

contractors and builders. Manufacturer's reps provide local design, installation, and commissioning assistance for equipment manufactures not located in California. Details on manufacturers and product availability is in Section 3.

- **Energy consultants:** Energy consultants both complete energy code-compliance modeling and advise design teams on improved design approaches.
- **HERS Raters:** HERS Raters are special inspectors that enforce code compliance. For heat pump space heating systems, they verify duct location and leakage, refrigerant charge, system airflow, fan watt draw, equipment efficiency, and capacity. For water heating systems, HERS Raters verify compact distribution and drain water heat recovery installations.

3.2 Technical Feasibility, Market Availability and Current Practices

Heat pump space heating and heat pump water heating are established technologies and readily available in the market. Including prescriptive requirement for either heat pump space heating or heat pump water heating by climate zone, rather than the same requirement across all climate zones, will allow manufacturers to keep pace with increased demand.

3.2.1 Heat Pump HVAC

Technical Feasibility

Heat pump space heating (HPSH) technology is well established and has been adopted in single family new construction. HPSH systems were installed in 9.9 percent of single family new construction under the 2016 Title 24 code. For 2019 code, HPSH systems were installed in 18.3 percent of single family new construction. This amounts to almost a 100 percent increase in adoption of HPSH systems. A breakdown of these systems by type can be seen in Table 8 below (CalCERTS, 2021). A majority of the HPSH installed were central split and ductless split systems at 74.9 percent and 18.9 percent, respectively.

Table 8: Installed 2019 Code Single Family HPSH Systems by Type.

System Type	Count	% of HP type installed	Avg HSPF	Avg SEER/EER	Avg Cap (btuh)
Central Split HP	6,275	74.93%	9.29	16.8/12.3	45,820
Ductless Split HP	1,583	18.90%	9.66	27.8/20.4	22,107
Central Packaged HP	215	2.57%	9.28	17.4/11.5	40,000
Room HP	170	2.03%	9.06	12.5/13	8,653
Ductless Multi Split HP	82	0.98%	11.80	16.4/11.9	26,388
Hydronic HP	23	0.27%	8.20	11.7/ n/a	61,500
Central Large Packaged HP	13	0.16%	8.5	14.6/12.2	126,153
Hydronic HP_Forced Air	7	0.08%	8.20	14/17.5	40,000
Small Duct High Velocity HP	6	0.07%	9.46	15.3/11.9	43,000
Ductless VRF_HP	1	0.01%	no data	no data	no data

Because much of the state does not typically experience temperatures below freezing, there is currently limited application of heat pumps in cold climates. The data presented in this section primarily represent non-cold climate heat pump installations.

However, in colder climates across the state, heat pumps face a challenge where their capacity for providing heat and the efficiency of the equipment reduces as the outdoor temperature drops. This is especially true for minimal efficiency heat pumps that are the basis for the federal appliance standards.

Across the nation, there have been several initiatives to develop cold climate heat pump specifications. The Northwest Energy Efficiency Partnership has developed and continues to update Cold Climate Air Source Heat Pump Specifications. The latest specification (version 3) was released in June 2020 (NEEP 2020). This specification requires that air source heat pumps have variable capacity compressors with at least three of more distinct operating speeds, indoor and outdoor units must be part of an Air-Conditioning, Heating, and Refrigeration Institute (AHRI) matched system and have higher efficiencies than the federal standards (HSPF ≥9 for Ducted systems and COP 5°F >1.75 (at maximum capacity operation) for all ducted systems and SEER ≥15).

Market Availability

The authors reviewed the product availability of split heat pumps relative to federal and state required minimum efficiency levels.

The Modernized Appliance Efficiency Database System (MAEDbS), which shows appliances compliant under Title 20, indicates that split heat pumps are readily available. About 95 percent of split heat pumps were at or above federal minimum efficiency levels indicating considerable market availability of higher efficiency products if desired.

The authors reviewed split heat pumps that were added to the MAEDbS on or after January 1st, 2015 (the last update to the federal minimum efficiency for split heat pump systems). There were 18 manufacturers with a total of 268 models in the California market. The five manufacturers that had the most models listed were: Carrier Corporation, Nortec Global HVAC, Midea Group, Johnson Controls International PLC, and Rheem Manufacturing Company. All split heat pumps had a cooling capacity of less than 65,000 Btu/h, which has a federal minimum efficiency requirement of SEER at 14.0 and HSPF at 8.2. Nineteen percent of the models available were just meeting federal minimum efficiency, and 23 percent of the models have SEER 16.2 and HSPF 8.5 or better.

Detailed product availability analysis is provided in Appendix G.

3.2.2 Heat Pump Water Heating

Technical Feasibility

Unitary HPWHs can be three times more efficient than their electric resistance counterparts. Their performance is sensitive to the ambient air temperature and the supply water temperature as heat pumps work by moving energy from the surrounding air into the water. It is important that HPWH installation location remains in the 40 to 90-degree Fahrenheit range year around to ensure optimal efficiency performance.

HPWHs serving single family homes come in unitary configuration, and they typically come with several pre-set operating modes to maximize efficiency while meeting hot water loads[1]. HPWHs have lower recovery rate – the amount of hot water a water heater can increase by 90°F in one hour – than electric or gas tank water heaters with similar tank sizes. Selecting HPWH models with a larger in tank capacity helps support higher hot water draw without engaging the electric resistance element as much. Another way to compensate for a lower recovery rate is to set a higher hot water delivery temperature. This is a feasible alternative without compromising safety as the Uniform Plumbing Code already requires an anti-scaling mixing value upstream of delivery points.

[1] Typical operating modes, in the order of decreasing efficiency performance, include *Heat Pump only, Hybrid* (heat pump and electric resistance heating element), *High Demand*/*Boost* (similar to Hybrid but electric resistance heating will engage earlier), and *Vacation* modes.

HPWH installation locations dictate several important aspects in terms of feasibility, performance, and user experience. Most HPWHs require a dedicated 30 Amp breaker at the service panel and a 240 Volt electrical supply. These are relatively easy to accommodate in new construction homes. HPWHs require adequate space for ventilation air, on the order of 700 cubic feet, for heat exchange purposes. Beyond ventilation, there needs to be sufficient space for proper placement for access to the user interface to program and control the unit, and to allow for routine air filter replacement. Additionally, HPWHs require condensate drain hose to discharge condensate from the evaporator coil. Need for adequate electrical connections, ample space requirements, a condensate drain, and low but constant noise all point to garages as the ideal install locations.

The authors identified two areas of trade coordination for HPWH. One addresses the need to situate the HPWH to access the condensate drain, and the second involves designing and installing duct to supply ventilation air if the HPWH were installed inside conditioned or semi-conditioned space.

Market Availability

A wide variety of HPWH products are available to builders and consumers. Products used in California primarily consist of storage type HPWH ranging 50-80 gallons in size. According to data from the HERS registry CalCERTS, HPWH systems made up 0.16 percent of installed residential water heaters in single family new construction for the 2016 Title 24 code. For 2019 code, HPWH systems were installed in 2.08 percent of single family new construction (CalCERTS, 2021).

The authors reviewed NEEA's Advanced Water Heater Specification which NEEA developed to address critical HPWH performance and comfort issues . The Specification has applicability beyond equipment performance in colder climates as it addresses additional key topics that impact energy use. These topics include testing at various levels of electric resistance element use, default, enhanced efficiency operational modes, and demand response features. NEEA's version 7 Specification includes four Tiers, intending to differentiate variations in product performance and configurations, and there are over two hundred unique products certified for Tiers 3 and 4 levels in the database (NEEA, 2021).

3.3 Market Impacts and Economic Assessments

The authors used the IMPLAN model software, along with economic information from published sources, and professional judgement to develop estimates of the economic impacts associated with each proposed code change. The IMPLAN model provides a simple representation of the California economy and approximate direction and magnitude of the estimated economic impacts. In all aspect of this economic analysis, the authors rely on conservative assumptions regarding the likely economic benefits associated with the proposed code change. By following this approach, the authors believe the economic impacts presented below represent lower bound estimates of the actual impacts associated with this proposed code change.

Adoption of this code change proposal would result in relatively modest economic impacts through the additional direct spending by those in the residential building and remodeling industry, as well as indirectly as residents spend all or some of the money saved through lower utility bills on other economic activities.

3.3.1 Impact on Builders

Builders of residential buildings are directly impacted by the measures proposed for the 2022 code cycle. It is within the normal practices of these businesses to adjust their building practices to changes in building codes. When necessary, builders engage in continuing education and training to remain compliant with changes to design practices and building codes.

California's construction industry is comprised of about 80,000 business establishments and 860,000 employees (see Table 7). In 2018, total payroll was $80 billion. Nearly 60,000 of these business establishments and 420,000 employees are engaged in the residential building sector.

Table 9: California Construction Industry, Establishments, Employment, and Payroll

Construction Sectors	Establishments	Employment	Annual Payroll (billions $)
Residential	59,287	420,216	$23.3
Residential Building Construction Contractors	22,676	115,777	$7.4
Foundation, Structure, & Building Exterior	6,623	75,220	$3.6
Building Equipment Contractors	14,444	105,441	$6.0
Building Finishing Contractors	15,544	123,778	$6.2

Source: (State of California, Employment Development Department, n.d.)

The effects on the residential building industry would not be felt by all firms and workers, but rather would be concentrated in specific industry subsectors. Table 8 shows the residential building subsectors the authors expect to be impacted by the changes proposed in this report. The authors' estimates of the magnitude of these impacts are shown in Section 3.4 Economic Impacts.

Table 10: Size of the California Residential Building Industry by Subsector

Residential Building Subsector	Establishments	Employment	Annual Payroll (billions $)
New single family general contractors	10,968	55,592	$3.6
Residential Electrical Contractors	6,095	37,933	$2.1
Residential plumbing and HVAC contractors	8,086	66,177	$3.8
Other Residential Equipment Contractors	263	1,331	$0.1

Source: (State of California, Employment Development Department, n.d.)

3.3.2 Impact on Building Designers and Energy Consultants

Adjusting design practices to comply with changing building codes is within the normal course of business for building designers. Building codes (including Title 24, Part 6) are typically updated on a three-year revision cycle and building designers and energy consultants engage in continuing education and training to remain compliant with changes to design practices and building codes.

Businesses that focus on residential building design are contained within the Architectural Services sector (North American Industry Classification System 541310). Table 11: California Building Designer and Energy Consultant Sectors shows the number of establishments, employment, and total annual payroll for Building Architectural Services. The proposed code changes would potentially impact all firms within the Architectural Services sector.

There is not a North American Industry Classification System (NAICS)[2] code specific for energy consultants. Instead, businesses that focus on consulting related to building energy efficiency are contained in the Building Inspection Services sector (NAICS 541350), which is comprised of firms primarily engaged in the physical inspection of residential and nonresidential buildings.[3] It is not possible to determine which business establishments within the Building

2 NAICS is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy. NAICS was development jointly by the U.S. Economic Classification Policy Committee (ECPC), Statistics Canada, and Mexico's Instituto Nacional de Estadistica y Geografia, to allow for a high level of comparability in business statistics among the North American countries. NAICS replaced the Standard Industrial Classification (SIC) system in 1997.

3 Establishments in this sector include businesses primarily engaged in evaluating a building's structure and component systems and includes energy efficiency inspection services and home inspection services. This sector does not include establishments primarily engaged in providing inspections for pests, hazardous wastes or other environmental contaminates, nor does it include state and local government entities that focus on building or energy code compliance/enforcement of building codes and regulations.

Inspection Services sector are focused on residential energy efficiency consulting. The information shown in Table 11 provides an upper bound indication of the size of this sector in California.

Table 11: California Building Designer and Energy Consultant Sectors

Sector	Establishments	Employment	Annual Payroll (billions $)
Architectural Services [a]	3,704	29,611	$2.91
Building Inspection Services [b]	824	3,145	$0.22

Source: (State of California, Employment Development Department, n.d.)

a. Architectural Services (NAICS 541310) comprises private-sector establishments primarily engaged in planning and designing residential, institutional, leisure, commercial, and industrial buildings and structures
b. Building Inspection Services (NAICS 541350) comprises private-sector establishments primarily engaged in providing building (residential and nonresidential) inspection services encompassing all aspects of the building structure and component systems, including energy efficiency inspection services

The authors do not anticipate that this measure will have a significant impact on building designers and energy consultants.

3.3.3 Impact on Occupational Safety and Health

The proposed code changes do not alter any existing federal, state, or local regulations pertaining to safety and health, including rules enforced by the California Division of Occupational Safety and Health. All existing health and safety rules would remain in place. Complying with the proposed code change is not anticipated to have adverse impacts on the safety or health of occupants or those involved with the construction, commissioning, and maintenance of the building.

3.3.4 Impact on Building Owners and Occupants (including homeowners and potential first-time homeowners)

The U.S. Census reported that 59,200 single family homes were constructed in 2019.

According to data from the U.S. Census, American Community Survey, there were nearly 14.3 million housing units in California in 2018 and nearly 13.1 million were occupied (see Table 12). Most housing units (nearly 9.2 million were single family homes (either detached or attached.

Table 12: California Housing Characteristics

Housing Measure	Estimate
Total housing units	14,277,867
Occupied housing units	13,072,122
Vacant housing units	1,205,745
Homeowner vacancy rate	1.2%
Rental vacancy rate	4.0%
Units in Structure	Estimate
1-unit, detached	8,177,141
1-unit, attached	1,014,941
2 units	358,619
3 or 4 units	783,963
5 to 9 units	874,649
10 to 19 units	742,139
20 or more units	1,787,812
Mobile home, RV, etc.	538,603

Source: (2018 American Communities Survey, n.d.)

Table 13 shows the distribution of California homes by vintage. About 15 percent of California homes were built in 2000 or later and another 11 percent built between 1990 and 1999. The majority of California's existing housing stock (8.5 million homes – 59 percent of the total) were built between 1950 and 1989, a period of rapid population and economic growth in California. Finally, about 2.1 million homes in California were built before 1950.

Table 13: Distribution of California Housing by Vintage

Home Vintage	Units	Percent	Cumulative Percent
Built 2014 or later	343,448	2.4%	2.4%
Built 2010 to 2013	248,659	1.7%	4.1%
Built 2000 to 2009	1,553,769	10.9%	15.0%
Built 1990 to 1999	1,561,579	10.9%	26.0%
Built 1980 to 1989	2,118,545	14.8%	40.8%
Built 1970 to 1979	2,512,178	17.6%	58.4%
Built 1960 to 1969	1,925,945	13.5%	71.9%
Built 1950 to 1959	1,896,629	13.3%	85.2%
Built 1940 to 1949	817,270	5.7%	90.9%
Built 1939 or earlier	1,299,845	9.1%	100.0%
Total housing units	14,277,867	100%	

Source: (2018 American Communities Survey, n.d.)

Table 14 shows the distribution of owner- and renter-occupied housing by household income. Overall, about 55 percent of California housing is owner-occupied and the rate of owner-occupancy generally increases with household income. The owner-occupancy rate for households with income below $50,000 is only 37 percent, whereas the owner occupancy rate is 72 percent for households earning $100,000 or more.

Table 14: Owner- and Renter-Occupied Housing Units in California by Income

Household Income	Total	Owner Occupied	Renter Occupied
Less than $5,000	391,235	129,078	262,157
$5,000 to $9,999	279,442	86,334	193,108
$10,000 to $14,999	515,804	143,001	372,803
$15,000 to $19,999	456,076	156,790	299,286
$20,000 to $24,999	520,133	187,578	332,555
$25,000 to $34,999	943,783	370,939	572,844
$35,000 to $49,999	1,362,459	590,325	772,134
$50,000 to $74,999	2,044,663	1,018,107	1,026,556
$75,000 to $99,999	1,601,641	922,609	679,032
$100,000 to $149,999	2,176,125	1,429,227	746,898
$150,000 or more	2,780,761	2,131,676	649,085
Total Housing Units	13,072,122	7,165,664	5,906,458
Median household income	$75,277	$99,245	$52,348

Source: (2018 American Communities Survey, n.d.)

Understanding the distribution of California residents by home type, home vintage, and household income is critical for developing meaningful estimates of the economic impacts associated with proposed code changes affecting residents. Likewise, impacts may differ for owners and renters, by home vintage, and by household income, information provided in Table 13 and Table 14.

3.3.5 Impact on Building Component Retailers (including manufacturers and distributors)

The proposed change would increase demand from manufacturers, distributors, and retailers for HPWH and HPSH equipment. Supply chains for gas space heating and water heating equipment would experience a decrease in demand. Many manufacturers, distributors, and retailers produce and/or sell both heat pump and gas equipment. These businesses would not experience an increase or decrease in overall demand for space heating or water heating equipment.

3.3.6 Impact on Building Inspectors

Table 15 shows employment and payroll information for state and local government agencies in which many building inspectors are employed.

Building inspectors participate in continuing training to stay current on all aspects of building regulations, including energy efficiency. The authors anticipate no impact on employment of building inspectors or the scope of their role conducting energy efficiency inspections.

Table 15: Employment in California State and Government Agencies with Building Inspectors

Sector	Govt.	Establishments	Employment	Annual Payroll (millions $)
Administration of Housing Programs[a]	State	17	283	$29.0
	Local	36	2,882	$205.7
Urban and Rural Development Admin[b]	State	35	552	$48.2
	Local	52	2,446	$186.6

Source: (State of California, Employment Development Department, n.d.)

a. Administration of Housing Programs (NAICS 925110) comprises government establishments primarily engaged in the administration and planning of housing programs, including building codes and standards, housing authorities, and housing programs, planning, and development.

b. Urban and Rural Development Administration (NAICS 925120) comprises government establishments primarily engaged in the administration and planning of the development of urban and rural areas. Included in this industry are government zoning boards and commissions.

3.3.7 Impact on Statewide Employment

The authors do not anticipate significant employment or financial impacts to any particular sector of the California economy. This is not to say that the proposed change would not have modest impacts on employment in California. In Section 3.3, the authors estimated the proposed change in electric HVAC systems would affect statewide employment and economic output directly and indirectly through its impact on builders, designers, and energy consultants, and building inspectors. In addition, the authors estimated how energy savings associated with the proposed change in electric HVAC and DHW systems would lead to modest ongoing financial savings for California residents, which would then be available for other economic activities.

3.4 Economic Impacts

The estimated impacts that the proposed code change will have on California's economy are discussed below. The statewide life cycle net present value over one three-year code cycle is: $20 million.

3.4.1 Creation or Elimination of Jobs

The authors do not anticipate that the measures proposed for the 2022 code cycle regulation would lead to the creation of new types of jobs or the elimination of existing types of jobs. In other words, the author's proposed change would not result in economic disruption to any sector of the California economy. Rather, the estimates of economic impacts discussed in Section 3.3 would lead to modest changes in employment of existing jobs.

The proposed measures would create additional economic impacts for residential new construction costs due to the increased cost of heat pump HVAC and space heating equipment. Table 16 and Table 17 below summarize these impacts.

Table 16: Heat Pump HVAC Residential Construction & Remodel Economic Impacts

Impact Type	Employment	Labor Income	Value Added	Output
Direct Effect	6.3	$403,987	$680,865	$1,105,614
Indirect Effect	2.4	$155,918	$243,029	$431,580
Induced Effect	3.0	$166,439	$297,840	$486,195
Total Effect	**11.7**	**$726,344**	**$1,221,734**	**$2,023,389**

Source: Analysis by Evergreen Economics of data from the IMPLAN V3.1 modeling software.

a. Employment is in units of "annual average of monthly jobs for the respective industry" per IMPLAN V3.1's definition from the Bureau of Labor Statistics. This is *not* equivalent to a full time equivalent (FTE) but rather represents the industry average mix of full-time and part-time jobs.

b. Output is in terms of the economic value of production.

Table 17: Heat Pump Water Heating Residential Construction & Remodel Economic Impacts

Impact Type	Employment	Labor Income	Value Added	Output
Direct Effect	55.5	$3,559,030	$5,998,259	$9,740,200
Indirect Effect	21.4	$1,373,602	$2,141,032	$3,802,116
Induced Effect	26.3	$1,466,290	$2,623,903	$4,283,263
Total Effect	**103.2**	**$6,398,922**	**$10,763,194**	**$17,825,579**

Source: Analysis by Evergreen Economics of data from the IMPLAN V3.1 modeling software.

a. Employment is in units of "annual average of monthly jobs for the respective industry" per IMPLAN V3.1's definition from the Bureau of Labor Statistics. This is not equivalent to a full time equivalent (FTE) but rather represents the industry average mix of full-time and part-time jobs.
b. Output is in terms of the economic value of production.

3.4.2 Creation or Elimination of Businesses in California

As stated in Section 3.3, the authors' proposed change would not result in economic disruption to any sector of the California economy. The proposed change represents a modest change to HVAC and DHW systems, which would not excessively burden or competitively disadvantage California businesses – nor would it necessarily lead to a competitive advantage for California businesses. Therefore, the authors do not foresee any new businesses being created, nor do the authors think any existing businesses would be eliminated due to the proposed code changes.

3.4.3 Competitive Advantages or Disadvantages for Businesses within California

The proposed code changes would apply to all businesses incorporated in California, regardless of whether the business is located inside or outside of the state.[4] Therefore, the authors do not anticipate that these measures proposed for the 2022 code cycle regulation would have an adverse effect on the competitiveness of California businesses. Likewise, the authors do not anticipate businesses located outside of California would be advantaged or disadvantaged.

3.4.4 Increase or Decrease of Investments in the State of California

The authors analyzed national data on corporate profits and capital investment by businesses that expand a firm's capital stock (referred to as net private domestic investment, or NPDI).[5] As Table 18 shows, between 2015 and 2019, NPDI as a percentage of corporate profits ranged from 26 to 35 percent, with an average of 31 percent. While only an approximation of the proportion of business income used for net capital investment, the authors believe it provides a reasonable estimate of the proportion of proprietor income that would be reinvested by business owners into expanding their capital stock.

[4] Gov. Code, §§ 11346.3(c)(1)(C), 11346.3(a)(2); 1 CCR § 2003(a)(3) Competitive advantages or disadvantages for California businesses currently doing business in the state.

[5] Net private domestic investment is the total amount of investment in capital by the business sector that is used to expand the capital stock, rather than maintain or replace due to depreciation. Corporate profit is the money left after a corporation pays its expenses.

Table 18: Net Domestic Private Investment and Corporate Profits, U.S.

Year	Net Domestic Private Investment by Businesses, Billions of Dollars	Corporate Profits After Taxes, Billions of Dollars	Ratio of Net Private Investment to Corporate Profits
2015	609.3	1,740.4	35%
2016	456.0	1,739.8	26%
2017	509.3	1,813.6	28%
2018	618.3	1,843.7	34%
2019	580.9	1,827.0	32%
		5-Year Average	31%

Source: **Invalid source specified.**

The authors do not anticipate that the economic impacts associated with the proposed measure would lead to significant change (increase or decrease) in investment in any directly or indirectly affected sectors of California's economy.

3.4.5 Effects on the State General Fund, State Special Funds and Local Governments

The authors do not expect the proposed code changes would have a measurable impact on the California's general fund, any state special funds, or local government funds.

4. Energy Savings

4.1 Key Assumptions for Energy Savings Analysis

The authors conducted energy savings and cost-effectiveness analysis separately for HVAC and DHW systems. The authors assumed all HVAC and DHW equipment covered by federal regulations would meet appropriate minimum efficiency requirements.

The authors conducted energy savings analysis using energy models for the two Energy Commission single family prototype buildings modeled in research versions of Title 24 compliance software for both the baseline and proposed cases. The baseline models use HVAC and DHW systems that utilize gas for heating, whereas in the proposed models, the HVAC and DHW systems utilize electric heat pumps for heating. The function that the systems provide is the same between the baseline and the proposed cases (i.e., the HVAC systems provide the same amount of ventilation and maintain space temperatures at the same setpoints in the baseline and the proposed). All other inputs between the baseline and the proposed energy models are the same.

4.2 Energy Savings Methodology

To assess the energy, demand, and energy cost impacts, the authors compared current design practices to design practices that would comply with the proposed requirements. The current design practices are minimally compliant 2019 Title 24 Standards requirements.

For HVAC, the baseline condition includes a forced air furnace for space heating and split air conditioner for space cooling. Both systems were modeled to meet but not exceed federal appliance requirements. The proposed condition included a minimally compliant heat pump for space heating and cooling.

For water heating, the baseline condition assumed an instantaneous gas water heater. The proposed condition included a 50-gallon storage HPWH. In Climate Zone 1, the proposed condition includes compact distribution credit. In Climate Zone 16, the proposed condition includes compact distribution credit and drain water heat recovery.

Residential energy savings are calculated using two prototypes (2100 ft^2 and a 2700 ft^2) available in CBECC-Res. Residential results are weighted 45 percent for the 2100 ft^2 and 55 percent for the 2700 ft^2.

Table 19 presents the prototype buildings used in the analysis and their statewide weighting factors.

Table 19: Prototype Buildings used for Energy, Demand, Cost, and Environmental Impacts Analysis

Building Type ID from Statewide Construction Forecast	Building Prototype for Energy Modeling	Weighting Factors for Statewide Impacts Analysis
Single Family	2,100 ft^2	45%
	2,700 ft^2	55%

Energy savings, energy cost savings and peak demand savings were calculated on an hourly basis using a TDV methodology.

4.3 Per-Unit Energy Impacts and Energy Savings Results

4.3.1 Heat Pump Space Heating

Energy savings, peak demand savings and per-unit energy and demand impacts of the proposed measure are presented in Table 20 and Table 21. Negative savings value indicate increase in energy usage for the fuel in question whereas positive values indicate decrease in energy usage. For the

2100 ft^2 prototype, per-unit electricity usage is expected to increase between 190 to 3,826 Kilowatt-hour (kWh), except for Climate Zone 15 where there are electricity savings. Per-unit natural gas savings is expected to range from 6 to 361 therms. There are no changes in peak demand except for Climate Zone 15 with a savings of 0.15 kilowatts (kW) and Climate Zone 16 with an increase of 0.01 kW. For the 2700 ft^2 prototype, per-unit electricity usage is expected to increase between 234 to 3,646 kWh, except for Climate Zone 15 where there are electricity savings. Per-unit natural gas savings is expected to range from 16 to 387 therms. There are no changes in peak demand except for Climate Zone 15 with a savings of 0.2 kW and Climate Zone 16 with an increase of 0.03 kW.

Table 20: First-Year Energy Impacts per 2,100 ft^2 Prototype – Heat Pump Space Heating

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Savings (kW)	Natural Gas Savings (Therms/yr)	Source Energy Savings (kBtu/ft^2)	TDV Energy Savings (TDVkBTU/yr)
1	(3,826)	0.00	361	8.8	11,004
2	(2,067)	0.00	193	4.3	12,663
3	(1,126)	0.00	114	2.5	8,652
4	(960)	0.00	96	2.1	7,140
5	(1,154)	0.00	97	1.7	693
6	(340)	0.00	33	0.7	2,184
7	(203)	0.00	20	0.4	1,680
8	(190)	0.00	17	0.3	651
9	(356)	0.00	33	0.6	1,554
10	(599)	0.00	53	0.9	2,268
11	(1,657)	0.00	162	3.6	12,327
12	(1,519)	0.00	153	3.4	11,907
13	(1,100)	0.00	107	2.2	6,972
14	(1,736)	0.00	144	2.4	3,066
15	201	0.15	6	0.3	11,319
16	(3,374)	(0.01)	346	8.6	5,880

Table 21: First-Year Energy Impacts per 2,700 ft² Prototype – Heat Pump Space Heating

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Savings (kW)	Natural Gas Savings (Therms/yr)	Source Energy Savings (kBtu/ft²)	TDV Energy Savings (TDVkBTU/yr)
1	(3,547)	0.00	336	6.3	10,719
2	(2,099)	0.00	202	3.5	14,634
3	(1,062)	0.00	109	1.9	8,640
4	(1,043)	0.00	107	1.9	8,802
5	(1,042)	0.00	92	1.3	2,079
6	(405)	0.00	41	0.7	3,186
7	(234)	0.00	25	0.4	2,376
8	(252)	0.00	24	0.4	1,539
9	(451)	0.00	43	0.7	2,808
10	(729)	0.00	67	1.0	3,375
11	(1,967)	0.00	194	3.3	14,931
12	(1,741)	0.00	176	3.1	13,932
13	(1,360)	0.00	134	2.2	9,423
14	(1,973)	0.00	170	2.3	5,697
15	221	0.20	16	0.5	16,362
16	(3,646)	(0.03)	387	7.6	9,315

4.3.2 Heat Pump Water Heating

Energy savings, peak demand savings and per-unit energy and demand impacts of the proposed measure are presented in Table 22 and Table 23. In Climate Zones 1 and 16, heat pump water heating does not achieve TDV equivalence to a natural gas water heater. Compact distribution in each of these climate zones and drain water heat recovery in Climate Zone 16 are included in the energy savings. The measure results in a per-unit increase savings for the first year between 601 and 1,726 kilowatt-hours per year (kWh/yr), savings between 84 and 145 therms/year. Demand is expected to increase between 0.01 and 0.14 kilowatts (kW).

Table 22: First-Year Energy Impacts per 2,100 ft^2 Prototype – Heat Pump Water Heating (with Compact Design in CZ1 and 16, and Drain Water Heat Recovery (DWHR) in CZ16)

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Savings (kW)	Natural Gas Savings (Therms/yr)	Source Energy Savings (kBtu/ft^2)	TDV Energy Savings (TDVkBTU/yr)
1	(1,550)	(0.14)	129	3.6	2,415
2	(1,314)	(0.08)	118	3.4	8,253
3	(1,268)	(0.12)	118	3.4	8,673
4	(1,097)	(0.07)	111	3.3	10,626
5	(1,255)	(0.12)	118	3.5	7,833
6	(960)	(0.08)	107	3.3	12,894
7	(943)	(0.08)	106	3.3	13,461
8	(872)	(0.08)	103	3.2	14,931
9	(916)	(0.07)	104	3.2	14,448
10	(921)	(0.08)	104	3.2	14,049
11	(1,106)	(0.04)	106	3.1	9,261
12	(1,169)	(0.06)	111	3.3	8,904
13	(988)	(0.01)	103	3.1	11,697
14	(1,175)	(0.08)	108	3.0	7,791
15	(601)	(0.01)	84	2.7	14,742
16	(1,271)	(0.10)	129	3.7	4,347

Table 23: First-Year Energy Impacts per 2,700 ft² Prototype – Heat Pump Water Heating (with Compact Design in CZ1 and 16, and DWHR in CZ16)

Climate Zone	Electricity Savings (kWh/yr)	Peak Electricity Demand Savings (kW)	Natural Gas Savings (Therms/yr)	Source Energy Savings (kBtu/ft²)	TDV Energy Savings (TDVkBTU/yr)
1	(1,726)	(0.15)	143	3.2	3,267
2	(1,457)	(0.09)	131	3.0	10,422
3	(1,432)	(0.13)	132	3.0	9,612
4	(1,221)	(0.06)	123	3.0	13,068
5	(1,413)	(0.12)	132	3.1	7,911
6	(1,067)	(0.05)	119	2.9	14,688
7	(1,044)	(0.06)	119	2.9	14,310
8	(971)	(0.07)	115	2.8	16,848
9	(1,013)	(0.08)	116	2.9	16,821
10	(1,020)	(0.05)	115	2.8	14,985
11	(1,201)	(0.06)	118	2.7	11,205
12	(1,296)	(0.06)	123	2.8	11,124
13	(1,074)	(0.03)	114	2.7	14,067
14	(1,264)	(0.03)	119	2.6	10,152
15	(640)	(0.01)	92	2.4	16,497
16	(1,384)	(0.04)	145	3.3	7,317

5. Cost and Cost-Effectiveness

5.1 Energy Cost Savings Methodology

Energy cost savings were calculated by applying the TDV energy cost factors to the energy savings estimates using the methodology described in Section 4.2. TDV energy is a normalized metric for comparing electricity and natural gas savings that consider the cost of electricity and natural gas consumed during each hour of the year. The TDV values are based on long term discounted costs over 30 years. The TDV cost impacts are presented in 2023 present valued dollars. The TDV cost impacts are based on present-valued cost savings but are normalized in terms of "TDVkBTUs".

5.2 Energy Cost Savings Results

The authors present per-unit energy cost savings realized over a 30-Year Period of Analysis in 2023 present-value dollars in Table 24 through Table 27.

5.2.1 Heat Pump Space Heating

For the 2,100 ft^2 prototype, per-unit first-year electricity costs range from a decrease of $1,562 to an increase of $20,813 in 2023 present-value dollars, while per-unit natural gas costs decrease between $396 and $22,717 in 2023 present-value dollars with the total 30-year TDV energy costs ranging between a saving of $120 and $2,133 in 2023 present-value dollars.

For the 2,700 ft^2 prototype, per-unit first-year electricity costs range from a decrease of $1,803 to an increase of $23,061 in 2023 present-value dollars, while per-unit natural gas costs decrease between $1,028 and $24,672 in 2023 present-value dollars with the total 30-year TDV energy costs ranging between a saving of $266 and $2,831 in 2023 present-value dollars.

The TDV methodology values peak electricity savings more than electricity savings during non-peak periods.

Table 24: TDV Energy Cost Savings Over 30 Year Period of Analysis - Per 2,100 ft² Prototype – Heat Pump Space Heating

Climate Zone	30 Year TDV Electricity Cost Savings (2023 PV $)	30 Year TDV Natural Gas Cost Savings (2023 PV $)	Total 30 Year TDV Energy Cost Savings (2023 PV $)
1	($20,813)	$22,717	$1,904
2	($10,300)	$12,490	$2,191
3	($5,875)	$7,371	$1,497
4	($4,977)	$6,212	$1,235
5	($6,143)	$6,263	$120
6	($1,802)	$2,180	$378
7	($1,050)	$1,341	$291
8	($995)	$1,108	$113
9	($1,849)	$2,118	$269
10	($3,092)	$3,484	$392
11	($8,399)	$10,532	$2,133
12	($7,858)	$9,918	$2,060
13	($5,751)	$6,957	$1,206
14	($8,865)	$9,395	$530
15	$1,562	$396	$1,958
16	($21,039)	$22,056	$1,017

Table 25: TDV Energy Cost Savings Over 30 Year Period of Analysis - Per 2,700 ft^2 Prototype – Heat Pump Space Heating

Climate Zone	30 Year TDV Electricity Cost Savings (2023 PV $)	30 Year TDV Natural Gas Cost Savings (2023 PV $)	Total 30 Year TDV Energy Cost Savings (2023 PV $)
1	($19,450)	$21,304	$1,854
2	($10,556)	$13,088	$2,532
3	($5,605)	$7,100	$1,495
4	($5,432)	$6,955	$1,523
5	($5,577)	$5,937	$360
6	($2,149)	$2,700	$551
7	($1,205)	$1,616	$411
8	($1,317)	$1,583	$266
9	($2,336)	$2,821	$486
10	($3,765)	$4,349	$584
11	($10,015)	$12,598	$2,583
12	($9,052)	$11,463	$2,410
13	($7,114)	$8,744	$1,630
14	($10,113)	$11,098	$986
15	$1,803	$1,028	$2,831
16	($23,061)	$24,672	$1,611

5.2.2 Heat Pump Water Heating

For the 2100 ft^2 prototype, per-unit first-year electricity costs increase between $2,608 and $7,455 in 2023 present-value dollars, while per-unit natural gas costs decrease between $5,159 and $7,934 in 2023 present-value dollars with the total 30-year TDV energy costs ranging between a saving of $418 and $2,583 in 2023 present-value dollars.

For the 2700 ft^2 prototype, per-unit first-year electricity costs increase between $2,826 and $8,160 in 2023 present-value dollars, while per-unit natural gas costs decrease between $5,680 and $8,852 in 2023 present-value dollars with the total 30-year TDV energy costs ranging between a saving of $565 and $2,915 in 2023 present-value dollars.

The TDV methodology values peak electricity savings more than electricity savings during non-peak periods.

Table 26: TDV Energy Cost Savings Over 30 Year Period of Analysis - Per 2,100 ft² Prototype – Heat Pump Water Heating (with Compact Design in CZ1 and 16, and DWHR in CZ16)

Climate Zone	30 Year TDV Electricity Cost Savings (2023 PV $)	30 Year TDV Natural Gas Cost Savings (2023 PV $)	Total 30 Year TDV Energy Cost Savings (2023 PV $)
1	($7,455)	$7,873	$418
2	($5,784)	$7,212	$1,428
3	($5,700)	$7,201	$1,500
4	($4,937)	$6,776	$1,838
5	($5,849)	$7,204	$1,355
6	($4,291)	$6,521	$2,231
7	($4,192)	$6,521	$2,329
8	($3,731)	$6,314	$2,583
9	($3,880)	$6,380	$2,500
10	($3,935)	$6,365	$2,430
11	($4,923)	$6,525	$1,602
12	($5,268)	$6,808	$1,540
13	($4,305)	$6,329	$2,024
14	($5,268)	$6,616	$1,348
15	($2,608)	$5,159	$2,550
16	($7,182)	$7,934	$752

Table 27: TDV Energy Cost Savings Over 30 Year Period of Analysis - Per 2,700 ft² Prototype – Heat Pump Water Heating (with Compact Design in CZ1 and 16, and DWHR in CZ16)

Climate Zone	30 Year TDV Electricity Cost Savings (2023 PV $)	30 Year TDV Natural Gas Cost Savings (2023 PV $)	Total 30 Year TDV Energy Cost Savings (2023 PV $)
1	($8,160)	$8,725	$565
2	($6,170)	$7,973	$1,803
3	($6,348)	$8,011	$1,663
4	($5,250)	$7,511	$2,261
5	($6,652)	$8,020	$1,369
6	($4,708)	$7,249	$2,541
7	($4,783)	$7,259	$2,476
8	($4,106)	$7,021	$2,915
9	($4,176)	$7,086	$2,910
10	($4,456)	$7,049	$2,592
11	($5,255)	$7,193	$1,938
12	($5,601)	$7,525	$1,924
13	($4,545)	$6,978	$2,434
14	($5,544)	$7,301	$1,756
15	($2,826)	$5,680	$2,854
16	($7,586)	$8,852	$1,266

5.3 Incremental First Cost

The authors estimated the current incremental construction costs and post-adoption incremental construction costs. The current incremental construction cost represents the incremental cost of the measure if a building meeting the proposed standard were built today. The post-adoption incremental construction cost represents the anticipated cost assuming full market penetration of the measure as a result of the new standards, resulting in possible reduction in unit costs as manufacturing practices improve over time and with increased production volume of qualifying products the year the Standard becomes effective.

For both the baseline and proposed systems, the authors gathered costs for the new HVAC and DHW systems. The difference between the baseline and proposed systems costs is the incremental costs. Note that the has authors have not included any cost savings from eliminating natural gas infrastructure to the home in the analysis presented in this report. Any natural gas infrastructure savings shown in this report are for gas pipelines from the meter to appliances within the home.

5.3.1 Heat Pump Space Heating

The authors considered equipment cost information submitted through a docketed comment by NRDC in November 2020 (National Resource Defence Council, 2020). These costs included distributor data for four brands of equipment. The authors used cost data for the three brands for which there was cost information for the14 SEER air conditioner with 0.80 AFUE furnace baseline system, excluding cost data for higher efficiency furnaces. The authors used the cost average of the three brands for the baseline system and proposed 14 SEER, 8.2 HSPF heat pump in the analysis. Across the three brands, the incremental equipment cost savings from SZHP ranged from $125 to $441.

Gas furnace costs not applicable to heat pump systems include gas piping to the appliance and an exhaust flue from the appliance. The cost of gas piping is assumed at $200 per gas appliance and flue costs are $350 per home, based on conservative estimates collected through interviews with mechanical contractors and designers. Heat pumps require an additional 240V 20A circuit for electric resistance back-up at an estimates $150 cost (TRC, 2018).

The incremental costs below do not include costs that are constant across base case and proposed scenarios, such as refrigerant piping and ducting. The costs also do not include labor for system installation. The authors assume the labor costs for installing two systems in the case of air conditioning and gas-fired furnace would be greater than installation of a single heat pump system.

Estimated useful life of the heat pump is 15 years and 20 years for the furnace and air conditioner baseline. Consequently, replacement costs are higher for the SZHP system.

Table 28 summarizes incremental costs per home, including equipment and replacement costs during the 30-year period of analysis. Overall cost savings of the SZHP over the gas fired furnace plus air conditioner is $482.

Table 28: Average Per Home Costs for HVAC Systems: SZHP Compared to Gas-Fired Furnace + Split DX

Items	Gas-fired furnace + Split SZAC	SZHP	Incremental Cost of SZHP
HVAC Equipment	$2,582	$2,275	$(307)
Gas piping	$200	$-	$(200)
Flue and pad	$350	$-	$(350)
Electrical circuits	$-	$150	$150
Replacement	$2,050	$2,275	$225
Total	**$5,182**	**$4,700**	**$(482)**

5.3.2 Heat Pump Water Heating

The authors used costs from the City of Palo Alto 2019 Title 24 Energy Reach Code Cost Effectiveness Analysis for cost comparison of an instantaneous gas water heater and HPWH (TRC, 2018). The authors updated equipment costs per Home Depot and supplyhouse.com (SupplyHouse.com, 2021). All costs assume minimum federal efficiency. The instantaneous water heater supplies up to 9.5 gpm. The HPWH is a 50-gal storage water heater. Though water heater equipment and replacement costs for the HPWH are greater, savings for installation, exhaust flue, and maintenance result in a total cost savings of $186 for the HPWH over the 30-year period of analysis. Instantaneous water heaters require regular chemical flushing every two years to remove mineral build-up and cleaning of inducer fan motors at an estimated cost of $205 per occurrence (California Utilities Codes and Standards Team, 2014). HPWH do not require maintenance from a professional service provider. The authors assumed a 20-year lifespan for an instantaneous water heater and a 15-year lifespan for a HPWH.

Table 29 summarizes the costs for the base case gas instantaneous water and HPWH.

Table 29: Average Per Home Costs for DHW Systems: HPWH Compared to Instantaneous Gas Water Heater

Items	Instantaneous Gas Water Heater	HPWH	Incremental Cost of HPWH
Water Heater	$1,306	$1,370	$64
Installation	$1,017	$945	$(72)
Gas Piping	$200	$-	$(200)
Flue	$313	$-	$(313)
Electrical	$331	$500	$169
Replacement	$1,162	$2,315	$1,218
Maintenance	$1,979	$-	$(1,979)
Total	**$5,831**	**$5,138**	**$(1,113)**

In Climate Zones 1 and 16 additional measures are required to meet TDV equivalence. The authors assumed that compact distribution has no incremental cost. The incremental cost for drain water heat recovery, per the 2019 CASE Report, is $771 (California Statewide Utility Codes and Standards Team, 2017).

5.4 Cost-Effectiveness

This measure proposes prescriptive requirements. As such, cost analysis is required to demonstrate that the measure is cost-effective over the 30-year period of analysis.

Design costs were not included nor was the incremental cost of code compliance verification.

A measure is cost-effective if the B/C ratio is greater than 1.0. The B/C ratio is calculated by dividing the total present lifecycle cost benefits by the present value of the total incremental costs.

5.4.1 Heat Pump Space Heating

Results of the per-unit cost-effectiveness analyses are presented in Table 30 and Table 31.

Replacing the mixed-fuel baseline system with a heat pump results in a decrease in TDV energy costs for all climate zones, as well as a decrease in installed costs. The benefit-to-cost ratios are greater than 1 for all prototypes and climate zones.

Table 30: Lifecycle Cost-effectiveness 2,100 ft^2 Prototype – Heat Pump Space Heating

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[1] (2023 PV $)	Costs Total Incremental Present Valued (PV) Costs[2] (2023 PV $)	Benefit-to-Cost Ratio
1	$1,904	($482)	>1
2	$2,191	($482)	>1
3	$1,497	($482)	>1
4	$1,235	($482)	>1
5	$120	($482)	>1
6	$378	($482)	>1
7	$291	($482)	>1
8	$113	($482)	>1
9	$269	($482)	>1
10	$392	($482)	>1
11	$2,133	($482)	>1
12	$2,060	($482)	>1
13	$1,206	($482)	>1
14	$530	($482)	>1
15	$1,958	($482)	>1
16	$1,017	($482)	>1

1. **TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (see http://docketpublic.energy.ca.gov/PublicDocuments/16-BSTD-06/TN212524_20160801T120224_2019_TDV_Methodology_Report_7222016.pdf, Chapter 5 pages 51-53). Other savings are discounted at a real 3 percent rate. Includes incremental first cost savings if proposed first cost is less than current first cost. Includes present value maintenance cost savings if PV of proposed maintenance costs is less than the PV of current maintenance costs.
2. **Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Present value cost = Current cost x (1/(1.03)^n. Costs are discounted by 3 percent real rate. Includes incremental first cost if proposed first cost is greater than current first cost. Includes present value of maintenance incremental cost if PV of proposed maintenance costs is greater than the PV of current maintenance costs. If incremental maintenance cost is negative it is treated as a positive benefit. If there are no Total Incremental Present Valued Costs, the Benefit/Cost Ratio is Infinite.

Table 31: Lifecycle Cost-effectiveness 2,700 ft² Prototype – Heat Pump Space Heating

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[1] (2023 PV $)	Costs Total Incremental Present Valued (PV) Costs[2] (2023 PV $)	Benefit-to-Cost Ratio
1	$1,854	($482)	>1
2	$2,532	($482)	>1
3	$1,495	($482)	>1
4	$1,523	($482)	>1
5	$360	($482)	>1
6	$551	($482)	>1
7	$411	($482)	>1
8	$266	($482)	>1
9	$486	($482)	>1
10	$584	($482)	>1
11	$2,583	($482)	>1
12	$2,410	($482)	>1
13	$1,630	($482)	>1
14	$986	($482)	>1
15	$2,831	($482)	>1
16	$1,611	($482)	>1

1. **TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (see http://docketpublic.energy.ca.gov/PublicDocuments/16-BSTD-06/TN212524_20160801T120224_2019_TDV_Methodology_Report_7222016.pdf, Chapter 5 pages 51-53). Other savings are discounted at a real 3 percent rate. Includes incremental first-cost savings if proposed first cost is less than current first cost. Includes present value maintenance cost savings if PV of proposed maintenance costs is less than the PV of current maintenance costs.
2. **Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Present value cost = Current cost x (1/(1.03)^n. Costs are discounted by 3 percent real rate. Includes incremental first cost if proposed first cost is greater than current first cost. Includes present value of maintenance incremental cost if PV of proposed maintenance costs is greater than the PV of current maintenance costs. If incremental maintenance cost is negative it is treated as a positive benefit. If there are no Total Incremental Present Valued Costs, the Benefit/Cost Ratio is Infinite.

5.4.2 Heat Pump Water Heating

Results of the per-unit cost-effectiveness analyses are presented in Table 32 and Table 33.

Replacing the mixed-fuel baseline system with a HPWH results in a decrease in TDV energy costs for all climate zones. There is an incremental cost decrease.

The benefit-to-cost ratios are greater than 1 for all prototypes and climate zones.

Table 32: Lifecycle Cost-effectiveness 2,100 ft2 Prototype – Heat Pump Water Heating

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[1] (2023 PV $)	Costs Total Incremental Present Valued (PV) Costs[2] (2023 PV $)	Benefit-to-Cost Ratio
1	$418	$(1,113)	>1
2	$1,428	$(1,113)	>1
3	$1,500	$(1,113)	>1
4	$1,838	$(1,113)	>1
5	$1,355	$(1,113)	>1
6	$2,231	$(1,113)	>1
7	$2,329	$(1,113)	>1
8	$2,583	$(1,113)	>1
9	$2,500	$(1,113)	>1
10	$2,430	$(1,113)	>1
11	$1,602	$(1,113)	>1
12	$1,540	$(1,113)	>1
13	$2,024	$(1,113)	>1
14	$1,348	$(1,113)	>1
15	$2,550	$(1,113)	>1
16	$752	$(342)	>1

1. **TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (see http://docketpublic.energy.ca.gov/PublicDocuments/16-BSTD-06/TN212524_20160801T120224_2019_TDV_Methodology_Report_7222016.pdf, Chapter 5 pages 51-53). Other savings are discounted at a real 3 percent rate. Includes incremental first-cost savings if proposed first cost is less than current first cost. Includes present value maintenance cost savings if PV of proposed maintenance costs is less than the PV of current maintenance costs.
2. **Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Present value cost = Current cost x (1/(1.03)^n. Costs are discounted by 3 percent real rate. Includes incremental first cost if proposed first cost is greater than current first cost. Includes present value of maintenance incremental cost if PV of proposed maintenance costs is greater than the PV of current maintenance costs. If incremental maintenance cost is negative it is treated as a positive benefit. If there are no Total Incremental Present Valued Costs, the Benefit/Cost Ratio is Infinite.

Table 33: Lifecycle Cost-effectiveness 2,700 ft² Prototype – Heat Pump Water Heating

Climate Zone	Benefits TDV Energy Cost Savings + Other PV Savings[1] (2023 PV $)	Costs Total Incremental Present Valued (PV) Costs[2] (2023 PV $)	Benefit-to-Cost Ratio
1	$565	$(1,113)	>1
2	$1,803	$(1,113)	>1
3	$1,663	$(1,113)	>1
4	$2,261	$(1,113)	>1
5	$1,369	$(1,113)	>1
6	$2,541	$(1,113)	>1
7	$2,476	$(1,113)	>1
8	$2,915	$(1,113)	>1
9	$2,910	$(1,113)	>1
10	$2,592	$(1,113)	>1
11	$1,938	$(1,113)	>1
12	$1,924	$(1,113)	>1
13	$2,434	$(1,113)	>1
14	$1,756	$(1,113)	>1
15	$2,854	$(1,113)	>1
16	$1,266	$(342)	>1

1. **TDV Energy Cost Savings + Other PV Savings:** Benefits include TDV energy cost savings over the period of analysis (see http://docketpublic.energy.ca.gov/PublicDocuments/16-BSTD-06/TN212524_20160801T120224_2019_TDV_Methodology_Report_7222016.pdf, Chapter 5 pages 51-53). Other savings are discounted at a real 3 percent rate. Includes incremental first-cost savings if proposed first cost is less than current first cost. Includes present value maintenance cost savings if PV of proposed maintenance costs is less than the PV of current maintenance costs.
2. **Total Incremental Present Valued Costs:** Costs include incremental equipment, replacement, and maintenance costs over the period of analysis. Present value cost = Current cost x (1/(1.03)^n. Costs are discounted by 3 percent real rate. Includes incremental first cost if proposed first cost is greater than current first cost. Includes present value of maintenance incremental cost if PV of proposed maintenance costs is greater than the PV of current maintenance costs. If incremental maintenance cost is negative it is treated as a positive benefit. If there are no Total Incremental Present Valued Costs, the Benefit/Cost Ratio is Infinite.

6. First-Year Statewide Impacts

6.1 Statewide Energy and Energy Cost Savings

The authors calculated the first-year statewide savings by multiplying the per-unit savings, which are presented in Section 4.3 Per-Unit Energy Impacts and Energy Savings Results, by the portion of the statewide new construction forecast for 2023 not expected to install HPSH or HPWH in absence of the proposed change. This is presented in more detail in Appendix A: Statewide Savings Methodology. The first-year energy impacts represent the first-year annual savings from all buildings that were completed in 2023.

Given data regarding the new construction forecast for 2023, the authors estimate that the proposed code change will increase annual statewide electricity use by 125 GWh with an associated demand reduction of 4.62 MW. Natural gas use is expected to be reduced by 12.72 million therms. The energy savings for buildings constructed in 2023 are associated with a present valued energy cost savings of approximately PV$206.66 million in (discounted) energy costs over the 30-year period of analysis.

Table 34: Statewide Energy and Energy Cost Impacts

Climate Zone	Statewide Construction in 2023 (res: units)	First-Year[1] Electricity Savings (GWh)	First-Year[1] Peak Electrical Demand Reduction (MW)	First-Year[1] Natural Gas Savings (million therms)	First-Year[1] Source Energy Savings (kBtu/ft²)	Lifecycle[2] Present Valued Energy Cost Savings (PV$ million)
1	534	(0.88)	(0.08)	0.07	6.66	0.26
2	3,170	(4.42)	(0.28)	0.39	6.22	5.18
3	10,172	(11.09)	-	1.14	3.58	15.21
4	5,120	(5.15)	-	0.52	3.27	7.13
5	1,232	(1.65)	(0.15)	0.16	6.38	1.67
6	6,478	(6.60)	(0.40)	0.73	6.02	15.56
7	5,188	(5.18)	(0.34)	0.59	6.09	12.50
8	9,663	(8.95)	(0.71)	1.06	5.93	26.73
9	13,336	(12.92)	(0.99)	1.48	5.95	36.34
10	14,536	(9.75)	-	0.88	1.54	7.23
11	5,037	(5.83)	(0.26)	0.57	5.69	9.00
12	19,509	(24.17)	(1.17)	2.30	5.95	34.17
13	7,181	(8.93)	-	0.87	3.65	10.34
14	2,779	(5.19)	-	0.44	3.84	2.17
15	3,318	(2.07)	(0.03)	0.29	4.99	9.02
16	1,404	(1.87)	(0.09)	0.20	6.87	1.45
TOTAL	108,655	(114.65)	(4.51)	11.69	82.64	193.96

1. First-year savings from all buildings completed statewide in 2023.
2. Energy cost savings from all buildings completed statewide in 2023 accrued during 30-year period of analysis.

6.2 Statewide Greenhouse Gas Emissions Reductions

The authors calculated avoided GHG emissions based on long range emissions forecast included in the 2022 Title 24 proposed TDV methodology. (Energy+Environmental Economics (E3), 2020). The 2022 TDV code cycle includes, for the first time, a second hourly metric – long run marginal source energy. Long run marginal source energy, in this application, is defined as the source energy of fossil fuels following the long-term effects of any associated changes in resource procurement. While TDV is a financial metric, and represents the time-value on money, source energy is strictly defined by lifetime fossil fuel consumption. Unlike TDV, source energy does not discount future years. To calculate source energy for a given hour, the value in that hour for each forecasted year is averaged to get a lifetime average source energy. To get lifetime source energy consumption, one would multiply each hour's value by the lifetime of the building (30 years for residential buildings).

For electricity, long run marginal source energy has a similar hourly shape to wholesale energy prices, as seen in Figure 1, with low or zero source energy during periods of heavy solar generation, along with higher source energy in periods where natural gas power plants are the marginal grid resource

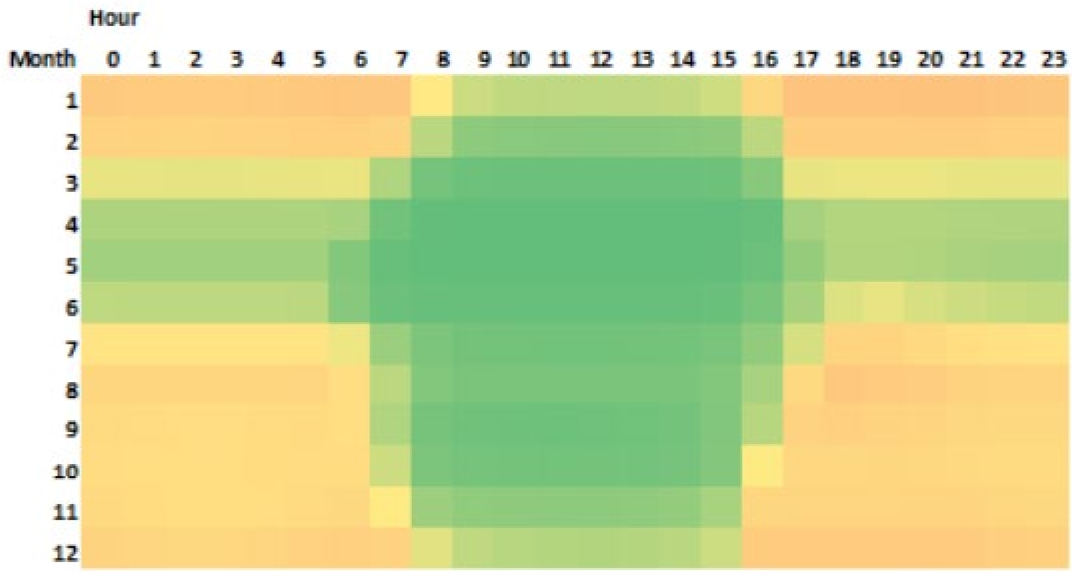

Figure 1: Month hour averages of electricity long run marginal source energy for 2022 TDV.

Table 12 presents the estimated first year avoided GHG emissions of the proposed code change. During the first-year greenhouse gas emissions of 50,133 million metric tons of carbon dioxide equivalents ($MMTCO_2e$).

Table 35: Statewide Greenhouse Gas Emissions Impacts

	Electricity Savings (GWH/yr)	Reduced GHG Emissions from Electricity Savings (MT CO_2e)	Natural Gas Savings (Million Therm/yr)	Reduced GHG Emissions from Natural Gas Savings (MT CO_2e)	Total Reduced CO2e Emissions[2] (MMT CO_2e)
Heat pump HVAC	(49.09)	(12,987)	4.72	27,733	14,746
HPWH	(76.14)	(11,290)	8.00	46,677	35,387

6.3 Statewide Water Use Impacts

The proposed code change will not result in water savings.

6.4 Statewide Material Impacts

6.4.1 Heat Pump HVAC Material Impacts

To estimate the statewide material impacts for a SZHP system, the authors looked at the difference in materials used in the indoor units, as well as the additional furnace, gas piping and flue used in the baseline system. There is negligible difference in outdoor units between the proposed and baseline and were excluded from the analysis. The authors reviewed manufacturer websites for estimates of materials used in their products. Relative to weight,

Furnaces (40 kBtu/h) were estimated to be 95 percent steel

Indoor units (3 ton) were estimated to be 95 percent steel excluding weight from the aluminum coils. The proposed case included a blower in the indoor unit.

Weight of aluminum coils and refrigerant were the same for both baseline and proposed cases.

The authors also calculated the length of gas piping required for the baseline system and estimated using 10 feet of piping for each single family unit for the flue. Gas piping was assumed to be all steel and piping for the flue was all polyvinyl chloride. The final statewide material impacts are shown in Table 36.

Table 36: First-Year Statewide Impacts on Material Use - SZHP

Material	Impact (I, D, or NC)[a]	Impact on Material Use (pounds/year)	
		Per-Unit Impacts	First-Year[b] Statewide Impacts
Steel	D	60	3,235,562
PVC	D	3	331,167
Aluminum	NC	N/A	N/A
Refrigerant (R410a)	NC	N/A	N/A

a. Material Increase (I), Decrease (D), or No Change (NC) compared to base case (lbs/yr).

b. First-year savings from all buildings completed statewide in 2023.

6.4.2 HPWH Material Impacts

To estimate the statewide material impacts for the HPWH measure, the authors reviewed materials used in products in the base and proposed cases. The authors reviewed manufacturer websites and asked manufacturers for estimates of materials used in their products. Relative to their weight,

- Gas water heaters are estimated to be 70 percent steel, 25 percent iron, and 5 percent insulation
- Heat pumps are estimated to be 70 percent steel, 5 percent insulation, 10 percent copper and 15 percent aluminum

Table 37 below shows the statewide impacts for the HPWH measure. Results show an increase in copper, aluminum, and refrigerant and a decrease in steel, iron, and insulation.

Table 37: Impacts of Material Use

Material	Impact (I, D, or NC)[a]	Impact on Material Use (pounds/year)	
		Per-Unit Impacts	First-Year[b] Statewide Impacts
Steel	D	1.4	68,181
Iron	D	49.5	2,410,700
Copper	I	19.6	954,540
Insulation	D	0.1	4,870
Aluminum	I	29.4	1,431,809
Refrigerant (R134a)	I	1.8	87,662

a. Material Increase (I), Decrease (D), or No Change (NC) compared to base case (lbs/yr).

b. First-year savings from all buildings completed statewide in 2023.

6.5 Other Non-Energy Impacts

Electric heat pump water and space heating systems save on-site and system-wide emissions as captured in Section 6.4.2. Additionally, use of the heat pump technologies provides improved indoor air quality due to the lack of any combustion devices in these systems and they replace natural gas or propane systems that produce harmful pollutants in the space. These air quality improvements in turn provide health benefits to occupants, especially those with respiratory illnesses such as asthma.

6.5.1 Improved Safety

Buildings with heat pump space heating and DHW systems have less combustion equipment and less gas piping. All-electric designs eliminate gas piping and combustion from the property, and with them the associated risk of fire and explosion (particularly during/after an earthquake). Eliminating combustion from a building via all-electric design also significantly reduces sources of carbon monoxide poisoning for occupants.

Since there is no combustion in electric heat pump water heating systems, projects would have no combustion safety testing requirements for water heating equipment. Depending on local fire inspector requirements, eliminating combustion equipment from a building may also eliminate some other requirements under California Fire Code.

6.5.2 Improved Air Quality and Resiliency

Heat pump HVAC and DHW systems improve air quality at the building, as well as locally and regionally by eliminating a source NOx emission. While recent years have seen California residents subject to more frequent, and longer-duration electricity outages than in previous years, electric HPWH systems are likely to be more resilient than gas water heating systems for a number of reasons.

All modern gas equipment requires electricity to operate. Since modern gas equipment has done away with standing pilot lights in favor of electronic ignition, power outages would take both gas and electric equipment offline.

Studies show that after a natural disaster, such as an earthquake, electricity is restored more quickly than gas service.

6.5.3 Increase in Refrigerant Amount

Increase adoption of heat pump space heating and water heating would increase the amount of refrigerant usage. Refrigerants are very potent greenhouse gas emitters when released into the environment and regulatory bodies are working to encourage use of less potent refrigerants to curb this environmental issue. Due to their destructive properties, refrigerants with very high GWP are getting phased out and will not be allowed to be used in new products including a halt of production and import. Section 6.4 estimates the refrigerant increase of the proposed measures on. However, the estimation was based on existing product information. Most manufacturers are actively developing products with low GWP refrigerants, and the impact is likely less significant as lower GWP products become available.

7. Proposed Revisions to Code Language

The proposed changes to the Standards, Reference Appendices, and the ACM Reference Manuals are provided below. Changes to the 2019 documents are marked with underlining (new language) and ~~strikethroughs~~ (deletions).

7.1 Standards

Section 150.1(c)

7. Space Heating and Space Cooling. All space heating and space cooling equipment shall comply with minimum Appliance Efficiency Regulations as specified in Sections 110.0 through 110.2 and meet all applicable requirements of Sections 150.0 and 150.1(c)7A. For Climate Zones 3, 4, 10, 13 and 14, the space conditioning system shall be a heat pump, or shall meet the performance compliance requirements of Section 150.1(b)1.

Section 150.1(c)

8. **Domestic Water-Heating Systems.** Water-heating systems shall meet the requirements of A, B, C, or shall meet the performance compliance requirements of Section 150.1(b)1~~C~~. For recirculation distribution systems ~~serving individual dwelling unit~~, only Demand Recirculation Systems with manual on/off control as specified in the Reference Appendix RA4.4.9 shall be used:

   A. ~~A. For systems serving individual dwelling units, the water heating system shall meet the requirement of i, ii, iii, iv, or v:~~

   ~~A. i. One or more gas or propane instantaneous water heater with an input of 200,000 Btu per hour or less and no storage tank.~~

   ~~B. ii. A single gas or propane storage type water heater with an input of 75,000 Btu per hour or less, rated volume less than or equal to 55 gallons and that meets the requirements of Sections 110.1 and 110.3. The dwelling unit shall have installed fenestration products with a weighted average U-factor no greater than 0.24, and in addition one of the following shall be installed:~~

   ~~C. a. A compact hot water distribution system that is field verified as specified in the Reference Appendix RA4.4.16; or~~

   ~~D. b. A drain water heat recovery system that is field verified as specified in the Reference Appendix RA3.6.9.~~

   ~~i. A single gas or propane storage type water heater with an input of 75,000 Btu per hour or less, rated volume of more than 55 gallons.~~

   ~~ii.~~ A single 240 volt heat pump water heater. The storage tank shall be located in the garage or conditioned space. In addition, ~~one of~~meet the following:

i~~a~~. A compact hot water distribution system as specified in the Reference Appendix RA4.4.6 ~~and~~ in Climate Zone 1 and 16; and

ii ~~a~~A drain water heat recovery system that is field verified as specified in the Reference Appendix RA3.6.9 in Climate Zone 16~~; or~~

~~b. For Climate Zones 2 through 15, a photovoltaic system capacity of 0.3 kWdc larger than the requirement specified in Section 150.1(c)14; or~~

~~c. For Climate Zones 1 and 16, a photovoltaic system capacity of 1.1 kWdc larger than the requirement specified in Section 150.1(c)14.~~

B. ~~v.~~ A single 240 volt heat pump water heater that meets the requirements of NEEA Advanced Water Heater Specification Tier 3 or higher. The storage tank shall be located in the garage or conditioned space. In addition, for Climate Zones ~~1 and~~ 16, ~~a photovoltaic system capacity of 0.3 kWdc larger than the requirement specified in Section 150.1(c)14 or a compact hot water distribution system as specified in the Reference Appendix RA4.4.6.~~ a drain water heat recovery system that is field verified as specified in the Reference Appendix RA3.6.9.

C. An electric water heating system with a solar water-heating system meeting the installation criteria specified in Reference Residential Appendix RA4 and with a minimum annual solar savings fraction of 0.7.

EXCEPTION 1 to Section 150.1(c)8: For Climate Zones 3, 4, 10, 13 and 14, a gas or propane instantaneous water heater with an input of 200,000 Btu per hour or less and no storage tank may be installed.

NOTE: The space conditioning system shall be a heat pump as specified in Section 150.1(c)7.

EXCEPTION 2 to Section 150.1(c)8: An instantaneous electric water heater with point of use distribution as specified in RA4.4.5 may be installed for new dwelling units with a conditioned floor area of 500 square feet or less.

Section 150.2(b)1

C. **Entirely New or Complete Replacement Space-Conditioning Systems** installed as part of an alteration, shall include all the system heating or cooling equipment, including but not limited to: condensing unit~~ and~~, cooling or heating coil, and air handler for split systems; or complete replacement of a packaged unit; plus entirely new or replacement duct system (Section 150.2(b)1Diia)~~; plus a new or replacement air handler~~. Entirely new or complete replacement space-conditioning systems shall~~:~~

~~i. M~~ meet the requirements of Sections 150.0(h), 150.0(i), 150.0(j)2, 150.0(j)3, 150.0(m)1 through 150.0(m)10; 150.0(m)12; 150.0(m)13, 150.1(c)6, 150.1(c)7, and 150.1(c)10, and TABLE 150.2-A; and

~~ii. Be limited to natural gas, liquefied petroleum gas, or the existing fuel type.~~

EXCEPTION to Section 150.2(b)1C~~ii~~: When the fuel type of the replaced heating system was natural gas or liquefied petroleum gas, the new or complete replacement space-conditioning system ~~may~~ is not required to be a heat pump.

7.2 Reference Appendices

There are no proposed changes to the Reference Appendices.

7.3 ACM Reference Manual

2.4.1 Heating Subsystems

STANDARD DESIGN

When electricity is used for ducted heating, the heating equipment for the standard design is an electric split-system heat pump with default ducts in the attic and a heating seasonal performance factor (HSPF) meeting the current Appliance Efficiency Regulations minimum efficiency for split systems. The standard design heat pump compressor size is determined by the software as the larger of the compressor size calculated for air-conditioning load, or the compressor with a 47°F rating that is 75 percent of the heating load (at the heating design temperature).

For Climate Zones 3, 4, 10, 13, and 14 only, if the proposed design for *water heater* excludes heat pump water heater, then the standard design for a space heating is a ducted heat pump system with the minimum HSPF for regardless of the proposed heat system types. For the other climate zones, the standard design will have the same space heating system type as the proposed system, as described in the following two paragraphs.

When electricity is used for a proposed ductless heating system, the standard design is a ductless system with the minimum HSPF from the Appliance Efficiency Regulations.

When proposed heating equipment is a ducted gas system, the equipment used in the standard design building is a gas furnace (or propane if natural gas is not available) with default ducts in the attic and an annual fuel utilization efficiency (AFUE) meeting the Appliance Efficiency Regulations minimum efficiency for central systems. When a proposed design uses both electric and nonelectric heat, the standard design is a gas furnace.

2.9.2 Individual Dwelling Units

~~If the proposed water heater is natural gas or propane, the standard design is a single gas or propane consumer instantaneous water heater for each dwelling unit. The single consumer instantaneous water heater is modeled with an input of 200,000 Btu/h, a tank volume of zero gallons, a high draw pattern, and a UEF meeting the minimum federal standards. The current minimum federal standard for a high-draw-pattern instantaneous water heater is 0.81 UEF or the equivalent of 0.82 energy factor for the standard system.~~

~~If the proposed water heater is an electric resistance or a heat pump water heater, the standard design is a single heat pump water heater with a 2.0 UEF. The water heater is installed in an attached garage (if available) or the location specified in Table 24, with compact distribution credit (Table 28), and a drain water heat recovery system in CZ 1 and 16. In Climate Zone 1, the standard design DWHR has an exchanger efficiency of 0.42, serving 100 percent of showers, with an unequal shower configuration. In Climate Zone 16, DWHR has an exchanger efficiency of 0.65, serving 100 percent of showers, with an equal shower configuration.~~

If the proposed design includes Heat Pump Water Heaters (HPWH(s)), then the standard design uses gas space heating and heat pump water heating.

For proposed designs excluding HPWH(s), the standard design in climate zones 3,4,10,13,14 use heat pump space heating and gas water heating, and all other climate zones use gas space heating and heat pump water heating.

In addition, the standard design in Climate Zones 1 & 16 includes Basic Compact Distribution (compactness factor of 0.7) and Climate Zone 16 also includes drain water heat recovery (CSA rated efficiency of 65 percent present on all showers, feeding showers' cold side and water heater, aka "equal flow" configuration).

7.4 Compliance Manuals

Chapter 4 and 5 of the Residential Compliance Manual will need to be revised.

Chapter 4 Heating Equipment
Section 4.2.2 Prescriptive Requirements for Heating Equipment

Prescriptive component compliance requires the installation of a gas heating system or heat pump that meets the required minimum energy efficiency. (See Table 4-1 through Table 4-4) Supplemental heating systems are allowed prescriptively, and the designer may elect to provide supplemental heating to a space such as a bathroom. In this instance, the supplemental heating system must be installed in a space that is served by the primary heating system and must have a thermal capacity of less than 2 kilowatts (kW) or 7,000 Btu/hr while being controlled by a time-limiting device not exceeding 30 minutes. Electric resistance and electric radiant heating installation are allowed as the primary heating system only when using the performance compliance method.

Notably, if a building does not use heat pump water heater for water heating, the prescriptive heating equipment for Climate Zones 3, 4, 10, 13, and 14 becomes a ducted heat pump system. When using the prescriptive compliance approach, no additional credit is given for selecting equipment that is higher efficiency than what is required by the prescriptive component package.

Chapter 5 Water Heating Requirements
Section 5.4.1 on Prescriptive Requirements
Subsection 5.4.1 Single Dwelling Units

There are three ~~five~~ options to comply with the prescriptive water heating requirements for newly constructed single dwelling units. For all three ~~five~~ options, the water heater must comply with the mandatory requirements for water heaters. (See Section 5.3.) If a recirculation distribution system is installed, only demand recirculation systems with manual control pumps are allowed. The ~~five~~ options are described below.

~~Option 1: Install one or more natural gas or propane instantaneous water heater with an input rating of 200,000 BTU per hour or less and no storage tank.~~

~~Option 2: Install a single natural gas or propane storage water heater with a rated storage volume 55 gallons or less and an input rating of 75,000 BTU per hour or less. In addition, the dwelling unit shall have installed fenestration products with a weighted average U- factor no greater than 0.24, as well as one of the following requirements~~

~~1. Use a compact hot water distribution design, which requires a HERS Rater to verify that the system has been designed and installed in accordance with the Energy Standards (See Reference Appendix RA4.4.16.)~~

~~2. Use a drain water heat recovery system, which requires a HERS Rater to verify that the system has been designed and installed in accordance with the Energy Standards (See Reference Appendix RA4.4.21.)~~

~~Option 3: Install a single natural gas or propane storage water heater with a rated storage volume greater than 55 gallons and an input rating of 75,000 BTU per hour or less.~~

Option 1 ~~4~~: Install a single heat pump water heater. The storage tank shall be located in the garage or conditioned space. In addition, the building must comply with both ~~one~~ of the following:

1. In Climate Zones 1 and 16, a compact hot water distribution design earning the Basic Compact Design –credit ~~and a HERS-verified drain water heat recovery system~~.

2. Additionally, ~~F~~for Climate Zone 1, a drain water heat recovery system installed per RA4.4.21 is required. ~~s 2 through 15, a photovoltaic system capacity of 0.3 kW direct current (dc) larger than the requirement specified in Section150.1(c)14.~~

~~3. For Climate Zones 1 and 16, a photovoltaic system capacity of 1.1 kWdc larger than the requirement specified in Section150.1(c)14.~~

~~Option 5: Install a single heat pump water heater that meets the requirements of NEEA Advanced Water Heater Specification Tier 3 or higher. The storage tank shall be located in the garage or conditioned space. In addition, for Climate Zones 1 and 16, a photovoltaic system capacity of 0.3 kWdc larger than the requirement specified in §150.1(c)14 or a compact hot water distribution system earning the Basic Compact Design credit.~~

If Option 2, 4, or 5 is pursued, then one or more additional building features must be installed as shown above. These additional building features require consideration at the start of the design process and must be coordinated with several players including the designer, general contractor, sub-contractor, and HERS Rater.

Option 2: Install a single higher-efficiency level heat pump water heater that meets the NEEA Advanced Water Heater Specification Tier 3 or higher. The storage tank shall be located in the garage or conditions space with additional building features required.

The list of qualified product list of NEEA HPWH can be found here: https://neea.org/img/documents/qualified-products-list.pdf

Option 3: Install an electric resistance water heater with a solar water heating system that meets the criteria established in RA 4 and has a minimum solar savings fraction of 0.7.

For more information on HERS-verified compact hot water distribution design, see Section 5.6.2.4. HERS-verified compact hot water distribution designs are included in Options 2 described above.

For more information on HERS-verified drain water heat recovery system requirements, see Example 5-9 below and Section 5.6.2.5 of this chapter. The Reference Appendix contains the requirements for the proper installation of the system (see RA4.4.21). A HERS-verified drain water heat recovery system is included in Option 1 s 2 and 4 described above.

Any other water heating system that differs from the five options described in this section does not meet the prescriptive requirements. Other systems can be installed if using the performance approach as described in Section 5.5.

For additions, the prescriptive requirements described above apply only if a water heater is being installed as part of the addition. The prescriptive requirements apply only to the space that is added, not the entire building.

For alterations where an existing water heater is being replaced, the water heater must meet the mandatory equipment efficiency requirements. Pipe insulation requirements do not apply to alteration for the portion of the pipes that are inaccessible. See Chapter 9 for a more detailed explanation for the water heating alteration requirements.

7.5 Compliance Forms

The following forms will need to be revised.

- CF1R-NCB-01-E-PrescriptiveNewlyConstructedBuilding – auto prompts or point out in Table M field 5 “Water Heater Type” to be “heat pump” for climate zones
- CF2R-PLB-02a-NonHERS-SingleDwellingUnitHotWaterSystemDistribution – auto prompts Table G for Compact Hot Water Distribution Basic (CHWDS) for only for Climate Zones 1 and 16; add a new Table for drain water heat recovery for Climate Zone 1
- CF2R-PLB-22a-HERS-SingleDwellingUnitHotWaterSystemDistribution – auto prompts Table H for Compact Hot Water Distribution Basic (CHWDS) for only for Climate Zones 1 and 16; auto prompts the drain water heat recovery already presented in Table I

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APPENDICES

Appendix A: Statewide Savings Methodology

The authors estimated statewide impacts for the first year by multiplying per-unit savings estimates by statewide construction forecasts. Table 38 presents the number of homes, both newly constructed and existing, that the authors assumed would be impacted by the proposed code change during the first year the 2022 code is in effect. The percentage of new construction impacted is reduced by the percentage of homes built under 2019 Title 24, Part 6 with HPSH in Climate Zones 3, 4, 10, 13, and 14 and by the percentage of homes built with HPSH in Climate Zones 1, 2, 5, 6, 7, 8, 9, 11, 12, 15, and 16.

Table 38: Estimated New Construction and Existing Building Stock for Single Family Buildings by Climate Zone

Building Climate Zone	New Construction in 2023 (number buildings)			Existing Building Stock in 2023 (number of buildings)		
	Total Buildings Completed in 2023 [A]	Percent of New Buildings Impacted by Proposal [B]	Buildings Impacted by Proposal in 2023 C = A x B	Total Dwelling Units Completed in 2020 [D]	Percent of Existing Buildings Impacted by Proposal [E]	Buildings Impacted by Proposal in 2023 F = D x E
1	545	97.9%	534	43,798	0%	0
2	3,238	97.9%	3,170	260,224	0%	0
3	12,451	81.7%	10,172	963,408	0%	0
4	6,267	81.7%	5,120	489,254	0%	0
5	1,258	97.9%	1,232	95,423	0%	0
6	6,617	97.9%	6,478	589,387	0%	0
7	5,299	97.9%	5,188	488,748	0%	0
8	9,870	97.9%	9,663	913,789	0%	0
9	13,622	97.9%	13,336	1,237,621	0%	0
10	17,792	81.7%	14,536	1,043,549	0%	0
11	5,145	97.9%	5,037	317,948	0%	0
12	19,927	97.9%	19,509	1,275,153	0%	0
13	8,790	81.7%	7,181	612,938	0%	0
14	3,401	81.7%	2,779	236,635	0%	0
15	3,389	97.9%	3,318	168,190	0%	0
16	1,434	97.9%	1,404	92,126	0%	0
TOTAL	119,045		108,655	8,828,191		**0**

Appendix B: Embedded Electricity in Water Methodology

There are no on-site water savings associated with the proposed code change.

Appendix C: Environmental Impacts Methodology

This section is excerpted from the Proposed 2022 Title 24 TDV Methodology Report posted to the 2022 Title 24 Pre-Rulemaking Docket#19-BSTD-03, TN# 233345 docketed on June 6, 2020.

The 2022 TDV code cycle includes, for the first time, a second hourly metric – long run marginal source energy. Long run marginal source energy, in this application, is defined as the source energy of fossil fuels following the long-term effects of any associated changes in resource procurement. While TDV is a financial metric, and represents the time-value on money, source energy is strictly defined by lifetime fossil fuel consumption. Unlike TDV, source energy does not discount future years. To calculate source energy for a given hour, the value in that hour for each forecasted year is averaged to get a lifetime average source energy. To get lifetime source energy consumption, one would simply multiply each hour's value by the lifetime of the building (15 years or 30 years).

For electricity, long run marginal source energy has a similar hourly shape to wholesale energy prices, as seen in Figure 1, with low or zero source energy during periods of heavy solar generation, along with higher source energy in periods where natural gas power plants are the marginal grid resource

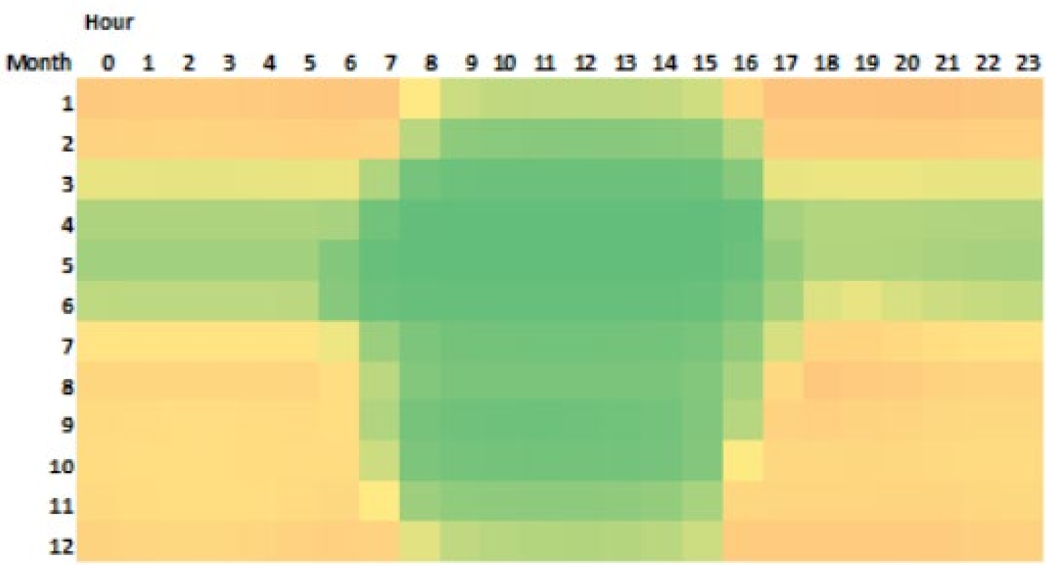


Figure 2: Month hour averages of electricity long run marginal source energy for 2022 TDV.

Greenhouse Gas Emissions Monetization Methodology

The 2022 TDV cost values used in the LCC Methodology includes the monetary value of avoided GHG emissions based on a proxy for permit costs (not social costs) and the Cost-effectiveness Analysis presented in Section 5 of this report does include the cost savings from avoided GHG emissions. To demonstrate the cost savings of avoided GHG emissions, the authors disaggregated value of avoided GHG emissions from the other economic impacts. The authors used the same monetary values that are used in the TDV factors – \$106/$MTCO_2e$.

Water Use and Water Quality Impacts Methodology

There are no impacts to water quality or water use.

Appendix D: CBECC Software Specification

The proposed code change will require adjustments to the Standard Design assumptions. It will not require changes to user inputs.

If the user's proposed design includes Heat Pump Water Heaters (HPWH(s)), then the standard design uses gas space heating and heat pump water heating.

For proposed designs excluding HPWH(s), the standard design in climate zones 3,4,10,13,14 use heat pump space heating and gas water heating, and all other climate zones use gas space heating and heat pump water heating.

In addition, the standard design in Climate Zones 1 & 16 includes Basic Compact Distribution (compactness factor of 0.7) and Climate Zone 16 also includes drain water heat recovery (CSA rated efficiency of 65 percent present on all showers, feeding showers' cold side and water heater ("equal flow" configuration)).

Appendix E: Impacts of Compliance Process on Market Actors

This appendix discusses how the recommended compliance process, which is described in Section 7, could impact various market actors. Table 39 identifies the market actors who would play a role in complying with the proposed change, the tasks for which they would be responsible, their objectives in completing the tasks, how the proposed code change could impact their existing workflow, and ways negative impacts could be mitigated.

The compliance process for all-electric HVAC and HPWH systems generally fit within the current workflow of market actors involved.

Table 39: Roles of Market Actors in the Proposed Compliance Process

Market Actor	Task(s) In Compliance Process	Objective(s) in Completing Compliance Tasks	How Proposed Code Change Could Impact Workflow	Opportunities to Minimize Negative Impacts of Compliance Requirement
Plumbing Designer	• Performs equipment sizing and system design to confirm compliance • Coordinates design with other team members, including energy consultant • Completes compliance document for permit application	• Ensures equipment and system design meets hot water loads • Streamlined coordination with team members • Demonstrates compliance with system characteristics and calculations • Quickly completes compliance documents	• Would need to document calculations in further detail • Would need elevated coordination with team members • Would need to manage and submit compliance form for prescriptive path	• Revise compliance forms to automate data field QC/check for compliance with standards • Modeling software would queue applicable compliance forms to simplify process for performance path • Software model training may help with team collaboration
Energy Consultant	• Performs compliance modeling and coordinates with	• Streamlined coordination with team members	• Would work with designer to iterate on	• Revise compliance forms to automate

	team members, including designers • Completes compliance document for permit application	• Quickly completes compliance documents	system designs for compliance purposes • Would need to manage and submit compliance forms for performance path	data field QC/check for compliance with standards • Modeling software would queue applicable compliance forms to simplify process for performance path • Software model training helps accurate use of features and accelerate learning curve
Energy Commission	NA	NA	NA	• Incorporate and update HERS verification scope and procedure in compliance forms. • Determine and support HERS or ATT infrastructure needs for compliance data hosting and maintenance
Plans Examiner	• Identifies relevant requirements • Confirms plans/specifications match data on documents • Confirms data on documents are compliant	• Quickly determines requirements based on project scope • Easily locates and checks plans against	• Would need to verify new data fields and calculations are compliant • Would need to verify	• Revise compliance forms to automate data field QC/check for compliance with standards • Modeling software

	• Provides correction comments if necessary	submitted documents • Provides comments that will resolve issues	calculations match plans	would queue applicable compliance forms to simplify process
Contractor / Installer	• Performs installation as design drawings dictate for both HPWH and space heating heat pumps • Populates and signs the Certificate of Installations	• Quickly install the system as designed • Smooth completion and satisfactory submission of compliance forms	• Would need to self-certify system installations meet design plans and code requirement s	• Technology training to increase understandin g and familiarity and enhance compliance performance •
HERS Rater	• Performs field verification • Populates and signs the Certificate of Verification	• Accurately and efficiently perform visual verification • Smooth completion and submission of compliance forms	• NA	• HERS Rater training to increase understandin g and familiarity with verification protocols

Appendix F: Summary of Stakeholder Engagement

This appendix summarizes the stakeholder engagement that the authors conducted when developing and refining the recommendations presented in this report.

The Energy Commission hosted staff workshops titled Proposed 2022 Energy Code Solar Photovoltaic and Electrification (California Energy Commission, 2021) on October 16, 2020 and Proposed 2022 Energy Code Low-rise Residential Heat Pump Baselines (California Energy Commission, 2020) on January 26, 2021. URL locations for related materials are included in the bibliography.

Following the workshops, the authors responded to comments posted to the docket and adjusted the proposed measures, including a docketed comment by NRDC proposing adding flexibility by including either HPSH or HPWH, rather than prescribing HPSH across all climate zones (Nations Resource Defense Council, 2021). The authors adjusted the proposal in response to this suggestion, to include a mix of HPSH and HPWH baselines that will allow the industry to adapt more easily. (National Resource Defence Council, 2020). The authors have included cost information from that comment in this report.

The authors also met with the California Building Industry Association to gather input on the proposed measure feasibility and industry acceptance.

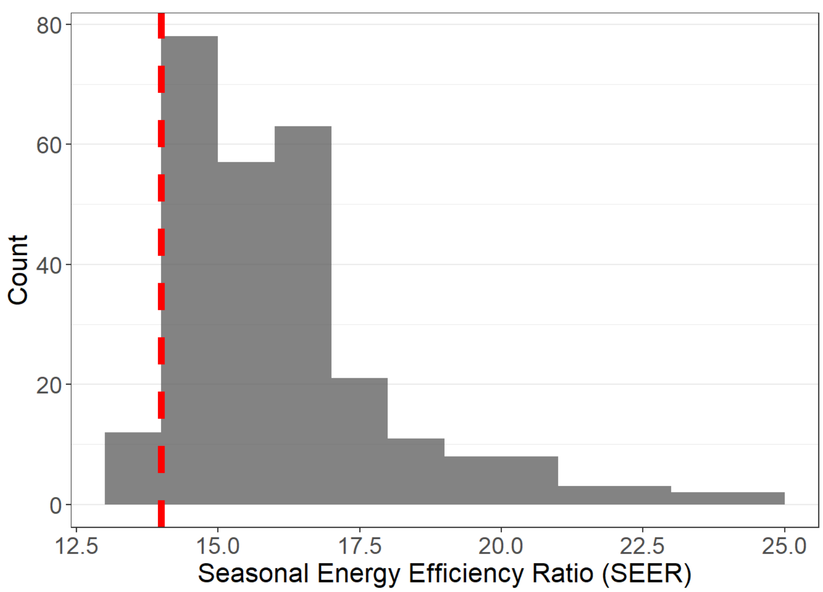
Appendix G: Heat Pump Product Availability Analysis

The authors reviewed the availability of split heat pumps using the Modernized Appliance Efficiency Database System (MAEDbS), which shows appliances compliant under Title 20. Since.

Split Heat Pump

The authors considered split heat pumps that were added to the MAEDbS on or after January 1st, 2015 (the last update to the federal minimum efficiency for split heat pump systems)[6]. In this subset of heat pumps in the MAEDbS, there were 20 manufacturers with a total of 268 models offering in the California market. The five manufacturers that have the most models available are: Carrier Corporation, Nortec Global HVAC, Midea Group, Johnson Controls International plc, and Rheem Manufacturing Company.

To compare split heat pump efficiencies of the market to the federal minimum efficiency, the authors considered split heat pumps that were added to the MAEDbS on or after January 1st, 2015 (the last update to the federal minimum efficiency for split heat pump systems). In Figure 3 and Figure 4, the red dashed line indicates the federal minimum efficiency, in terms of SEER and HSPF. All split heat pumps had a cooling capacity of less than 65,000 Btu/h, which has a federal minimum efficiency requirement of SEER at 14.0 and HSPF at 8.2. Nineteen percent of the models available are just meeting federal minimum efficiency.



[6] The following AHRI heat pump types are included: 1) HRCU-A-C: heat pump with remote outdoor unit, no indoor fan, air source; 2) HRCU-A-CB: split system: heat pump with remote outdoor unit, air source; 3) HRCU-A-CB-O: split system: heat pump with remote outdoor unit, air source, free delivery.

Figure 3: SEER of split heat pumps in MAEDbS.

Source: Statewide CASE Team

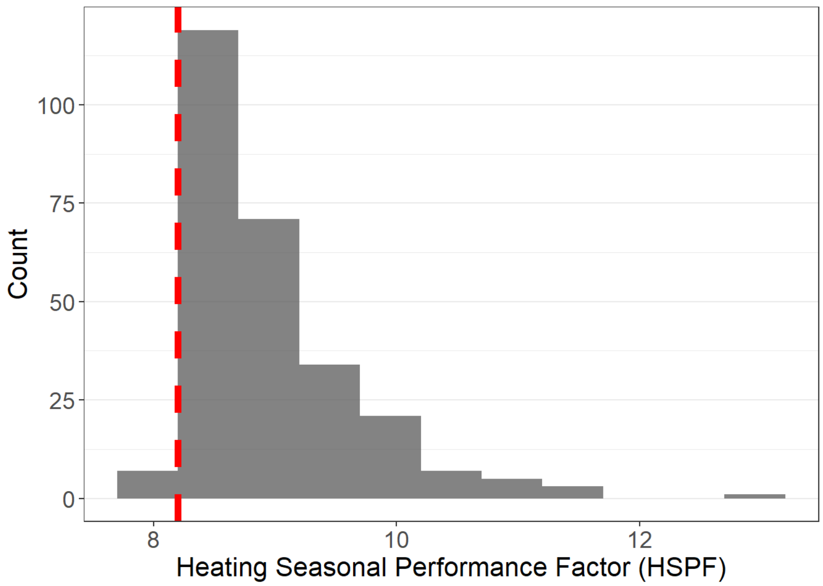


Figure 4: HSPF of split heat pumps in MAEDbS.

Source: Statewide CASE Team

Appendix H: Nominal Savings Tables

In Section 6.1, the energy cost savings of the proposed code changes over the 30-year period of analysis are presented in 2023 present value dollars.

This appendix presents energy cost savings in nominal dollars. Energy costs are escalating as in the TDV analysis, but the time value of money is not included so the results are not discounted.

Table 40: TDV Energy Cost Savings Over 30 Year Period of Analysis - Per 2,100 ft² Prototype – Heat Pump Space Heating

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal $)	30-Year TDV Natural Gas Cost Savings (Nominal $)	Total 30-Year TDV Energy Cost Savings (Nominal $)
1	($42,668)	$46,343	$3,675
2	($21,114)	$25,480	$4,366
3	($12,043)	$15,038	$2,995
4	($10,203)	$12,673	$2,470
5	($12,594)	$12,777	$183
6	($3,694)	$4,447	$753
7	($2,152)	$2,735	$582
8	($2,041)	$2,260	$220
9	($3,791)	$4,321	$530
10	($6,338)	$7,107	$770
11	($17,219)	$21,485	$4,266
12	($16,109)	$20,233	$4,124
13	($11,790)	$14,193	$2,403
14	($18,172)	$19,166	$993
15	$3,202	$808	$4,010
16	($43,129)	$44,994	$1,865

Table 41: TDV Energy Cost Savings Over 30 Year Period of Analysis - Per 2,700 ft² Prototype – Heat Pump Space Heating

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal $)	30-Year TDV Natural Gas Cost Savings (Nominal $)	Total 30-Year TDV Energy Cost Savings (Nominal $)
1	($39,873)	$43,461	$3,588
2	($21,641)	$26,700	$5,059
3	($11,491)	$14,484	$2,993
4	($11,136)	$14,188	$3,052
5	($11,433)	$12,111	$678
6	($4,405)	$5,508	$1,103
7	($2,470)	$3,297	$826
8	($2,700)	$3,230	$530
9	($4,788)	$5,755	$968
10	($7,718)	$8,871	$1,153
11	($20,530)	$25,699	$5,169
12	($18,557)	$23,384	$4,826
13	($14,584)	$17,838	$3,254
14	($20,731)	$22,641	$1,909
15	$3,696	$2,096	$5,793
16	($47,274)	$50,331	$3,057

Table 42: TDV Energy Cost Savings Over 30 Year Period of Analysis - Per 2,100 ft^2 Prototype – Heat Pump Water Heating (with Compact Design in CZ1 and 16, and DWHR in CZ16)

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal $)	30-Year TDV Natural Gas Cost Savings (Nominal $)	Total 30-Year TDV Energy Cost Savings (Nominal $)
1	($15,283)	$16,060	$778
2	($11,857)	$14,711	$2,855
3	($11,685)	$14,689	$3,004
4	($10,121)	$13,822	$3,701
5	($11,991)	$14,697	$2,706
6	($8,796)	$13,303	$4,508
7	($8,595)	$13,303	$4,709
8	($7,649)	$12,881	$5,232
9	($7,954)	$13,014	$5,060
10	($8,066)	$12,985	$4,919
11	($10,092)	$13,311	$3,219
12	($10,799)	$13,889	$3,090
13	($8,825)	$12,911	$4,085
14	($10,799)	$13,496	$2,697
15	($5,347)	$10,524	$5,177
16	($14,724)	$16,186	$1,462

Table 43: TDV Energy Cost Savings Over 30 Year Period of Analysis - Per 2,700 ft^2 Prototype – Heat Pump Water Heating (with Compact Design in CZ1 and 16, and DWHR in CZ16)

Climate Zone	30-Year TDV Electricity Cost Savings (Nominal $)	30-Year TDV Natural Gas Cost Savings (Nominal $)	Total 30-Year TDV Energy Cost Savings (Nominal $)
1	($16,728)	$17,800	$1,071
2	($12,649)	$16,266	$3,616
3	($13,013)	$16,342	$3,329
4	($10,763)	$15,322	$4,559
5	($13,636)	$16,361	$2,725
6	($9,652)	$14,789	$5,137
7	($9,805)	$14,808	$5,002
8	($8,417)	$14,322	$5,905
9	($8,561)	$14,455	$5,895
10	($9,135)	$14,379	$5,244
11	($10,772)	$14,674	$3,902
12	($11,481)	$15,351	$3,870
13	($9,317)	$14,236	$4,919
14	($11,366)	$14,894	$3,527
15	($5,793)	$11,587	$5,794
16	($15,551)	$18,057	$2,506