IEc

Delphi Panel Phase 2 Summary Report
Building Energy Efficiency

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INDUSTRIAL ECONOMICS, INCORPORATED

INTRODUCTION

IEc convened a Delphi Panel to seek expert insight on the potential market share of technologies and systems funded by EPIC's building energy efficiency grants. The panel's work is a key component of IEc's method for forecasting the potential environmental and health benefits of these grants, and one that is best suited to a structured expert consultation. IEc will use technology-specific market share estimates developed through this panel, combined with applicable construction forecast data, to estimate electricity load reduction and fuel switching over time in California associated with this subset of EPIC grants. IEc will subsequently estimate future GHG reductions, air emission reductions, and avoided health impacts from load reduction and fuel switching. IEc is undertaking a parallel effort focused on EPIC's grants designed to advance grid integration of renewables. These resulting benefit estimates will allow CEC to better communicate the value of EPIC's grant investments in these two key research areas.

This document summarizes the input of the 12 experts from the building energy efficiency panel's second phase of interviews.[1] We begin by presenting an overview of each technology, including clarifications on questions that arose during the Phase 1 interviews about the technologies. We then provide a general summary of the panelists' market share predictions for the EPIC-supported technologies. Then, this report presents the percentage of market share predictions from every expert, for each technology, between 2025-2045 (at five-year intervals), and for each of the relevant market sectors. This includes:

1. Tables that consolidate the estimates across experts with the year by year estimates, a small trend line graphic, and a summary of the rationale provided for each expert's estimate. These tables also include the average estimate across experts.
2. In cases where there were multiple, potentially rivalrous technologies in the same market (e.g., within the HVAC category), we present a summary graphic of estimates over time across the category.

In addition to the technology-specific clarifications provided in the next section, we wanted to provide additional information on the process for using estimates provided by the panel. IEc applied market share estimates to the entire California market where applicable, or to applicable climate zones.[2] The Commission published a breakdown of zip codes within each climate zone. Using these designations, we used the American Community Survey 2013-2018 data to ascertain the population, number of single-family homes, and number of multi-family homes within each climate zone. We also used projections by the CEC Demand Analysis Office to determine commercial floor space across the state, and to estimate

[1] To maintain confidentiality, this memo uses letters rather than names to refer to Delphi panelists (e.g., Expert A).

[2] California is divided into 16 building climate zones due to its wide range of climatic variation; this is adopted into the California Energy Code to enable builders and building officials to account for the variation in their projects.[2] IEc collected information on the 16 climate zones and assigned applicable climate zones to each of the technologies using the grant documents and best professional judgment.

the commercial floor space by climate zone (e.g., a climate zone with 10% of the population is estimated to have 10% of the commercial floor space). Using these various metrics, IEc estimated the energy savings resulting from the market share of each technology as predicted by the Delphi panel of experts.

TECHNOLOGY AND PRACTICES OVERVIEW

The technologies and construction practices funded by EPIC and included in this Panel are described below. During Phase 1 interviews, several questions arose on technologies and practices, prompting us to conduct further research and provide clarifications on certain technology descriptions. We included those clarifications in the Phase 1 report to panelists (these are highlighted in *italics* below). We asked that experts consider these clarifications when refining market estimates during the Phase 2 interviews.

1. **Glass Fiber Insultation of Attics Space**: Sealed attics and insulation are emerging as a strategy to bring the system within the thermal and air flow envelope of the building. The attic insulation approach tested in this project is a lower-cost approach using blown insulation that does not use expensive spray-foam.

   Notably, Title 24 currently requires some insulation in attics, between the rafters, when ducts are in the attic. But if ducts are not located in the attic, then Title 24 does not currently require conditioned attics. [3]

2. **Commercial foodservice appliance designs and energy control technologies:** This project assessed the energy reduction potential of electric commercial plug load foodservice equipment at five different commercial kitchens to demonstrate reduced energy consumption through the use of pre-commercial appliance designs and energy control technologies including setbacks and intelligent monitors to conveyor and vertical toasters, induction burners to replace soup warmers and hot plates, dry wells replacing wet wells, optical sensors on heat strips, and time controlled settings on coffee makers.

3. **Integrated daylighting, shading, controls**: This project creates a holistic, low barrier integrated retrofit solution of shade systems, plug load controls, and HVAC controls for significant energy savings. Installation does not require specialized training. The integration of technologies can produce higher savings than individual technologies operated in isolation.

4. **Solar-reflective cool walls**: Cool walls increase the solar reflectance, or albedo, of the building envelope and reduces the solar heating, which saves electricity and reduces power demand during peak hours by decreasing the need for air conditioning in warm weather.

   Although the project assessed both the performance of Lambertian cool wall technologies (technology that can be mixed into paint or stucco) and developed innovative cool wall solutions (retroreflector design), estimates should be focused on the former, Lambertian cool wall technologies. The technical potential discussed in the expert package is focused on the Lambertian cool walls.

[3] California Energy Commission, 2017. The Electric Program Investment Charge: Proposed 2018 – 2020 Triennial Investment Plan. Publication Number: CEC-500-2017-023-CMF.

5. **HVAC**: HVAC energy efficiency has increased over time, but substantial efficiency opportunities remain. For both residential and commercial equipment, efficiency performance of the systems remains below equipment specifications and technical limits. Opportunities also exist to lower HVAC equipment costs by improving manufacturing methods, potentially increasing market share of more efficient systems.

    a. Hydronic radiant cooling and heating system: This project developed new design and operation tools for radiant cooling and heating systems, to provide a standardized guidance for radiant systems in commercial buildings. The project aimed to produce: (1) a simplified tool for calculating the cooling load and cooling capacity of a radiant slab system, including calculation methods with significant direct solar radiation, (2) a simplified online operational tool for radiant slab systems, and (3) updates to the Title 24 Alternative Calculation Method Reference Manual to enable improved modeling capabilities of radiant systems.

    b. **Next generation HVAC systems designed for CA-specific climate:** This project developed a next-generation residential space-conditioning system optimized for California climates. The advanced efficiency solutions integrated into the HVAC system included: variable-capacity compressor and variable-speed fans using state-of-the-art inverter technology; integrated ventilation to harness fresh air for "free cooling;" intelligent dual-fuel technology to decrease energy cost and empower consumers to choose between electricity and natural gas; zonal control to prevent conditioning of unoccupied rooms; demand-response interactivity to grid flexibility and reliability; advanced fault detection and diagnostics to ensure proper installation, operation, and maintenance; and alternative refrigerants that have a far lower global warming potential and have potential for improved operation.

    Experts should provide a market share assuming that the package of seven technologies would stay as is when introduced to the market, as opposed to assuming that a subset of the technologies would ultimately be marketed together.

    c. Low-cost helical coil Ground Heat Exchanger (GHE): This project addressed the high cost of GHEs for water-to-water and water-to-air heat pumps to facilitate increased implementation of efficient, ground-coupled heat pumps in California. The project team developed models, validated them with field data from three existing sites, identified optimal designs, and developed modeling methods that can be adapted for use with Title 24 standards compliance tools. The project also produced typical design specifications that will support future Title 24 eligibility criteria. A design guide was developed for use by the industry as a training aid, and a position paper was prepared for the Department of Water Resources' California Geothermal Heat Exchange Well Standards Stakeholder Advisory Group.

    d. Low-GWP, high-efficiency heat pump and air conditioner: This project is a heat pump heater and air conditioning unit that mounts modularly over a windowsill. The outdoor portion of the unit contains a low-GWP (R-290) refrigerant, and the indoor portion contains a fan heat exchanger technology. Beyond the energy efficiency advantage from the heat exchanger, the unit’s form factor confers additional benefits: it

allows free use of the window in all seasons, it eliminates any need to remove the unit from the window, it makes the unit's operation much quieter than that of a typical window air conditioner, and it balances indoor and outdoor weight and volume making it highly unlikely for the unit to fall out of the window. The ability to have a split architecture without a professional installation greatly lowers the cost and increases the accessibility of high-performance, low-noise heating and cooling systems like mini-splits.

6. **Radiative sky cooling-enabled efficiency improvements on commercial cooling systems.** The project demonstrated SkyCool Panels as a platform technology to reduce electricity usage, GHG emission and water consumption from commercial air conditioning and refrigeration systems. SkyCool's core product is a rooftop-mounted, radiative sky cooling panel. The panels can be integrated into any new or existing cooling system as an efficiency add-on. SkyCool Systems are enabled by a specialized film on our panels; they cool when outside and exposed to the sky.
7. **Scale-up of magnetocaloric materials for high efficiency magnetic refrigeration.** Magnetic refrigeration is a high efficiency refrigeration technology that uses no hydrofluorocarbons (HFCs) and has the potential to replace traditional vapor compression systems. For this project, GE&R developed the processing systems to manufacture materials in forms needed for magnetic refrigeration systems (spheres and thin plates). Equipment with 1kg or larger batch processing was installed to accommodate 1kg/day LRIP. Production at this scale will allow for end users to develop and test magnetic refrigeration prototypes, and ultimately move these systems into production.
8. **MEMS-based ultrasonic anemometer**: This project developed low-cost, low power, accurate, calibration-free, and compact airflow sensors (anemometers) for measuring: (1) room airflow in occupied commercial buildings; and (2) volumetric air flow in heating, ventilation and air conditioning (HVAC) systems. The technology saves energy by using the collected data to correct wasteful HVAC malfunctions that result in inefficient systems and uncomfortable buildings. The anemometers are wireless, able to be inexpensively installed in existing buildings, operate on a battery for years and communicate wirelessly via the internet to the building's control system. The device also senses temperature, and its orientation and location.

   The technology can substitute for traditional wire-based approaches at the price point described.
9. **HVAC – Controls**: Integrated or "smart" ventilation and temperature controls provide the opportunity to respond to changing environmental conditions while meeting indoor air and temperature specifications in both commercial and residential properties. A challenge to these approaches is increasing architects, engineers, and owners' understanding of the effects of air movement on indoor personal comfort.
   a. **Smart ventilation controls**. This project developed approaches and tools to enable smart ventilation techniques suitable for new and existing advanced and ZNE homes. Smart ventilation systems use information about current thermal, occupancy, system, and air quality conditions to optimize performance of ventilation-related equipment.
   b. **Smart ceiling fans and smart thermostat integration.** Smart ceiling fans integrated with smart thermostats represent the next generation of energy efficiency that provides space conditioning while minimizing the need for compressor-based air conditioning

systems. This project advances the state of knowledge and practical applications of an integrated strategy to retrofit applications with smart ceiling fans, addressing occupant thermal comfort, and HVAC energy use through innovative hardware and software. Installation does not require specialized training—appropriately trained contractors or installers can easily perform the task. Operations are simple and do not need users to understand controls, set points, or programming.

10. **Ultra-thin flexible LED lighting panels**: Lucent Optics has developed a new platform technology (CoreGLO™) for making aesthetically appealing wide-area LED lighting luminaires at a fraction of the cost of traditional fluorescent and LED fixtures. If successfully developed and commercialized, CoreGLO could help overcome the existing barriers to a broader adoption of LED lighting and become the technology of choice for replacing linear fluorescent lights in commercial and residential buildings on a grand scale. The core proposed innovation is an ultra-thin and flexible LED lighting panel that employs inorganic LEDs and a thin plastic sheet that distributes light emitted by the LEDs using light guiding principles with controlled light extraction. The combination of a thin strip of high-power LEDs with the thin plastic sheet for guiding and distributing light creates a glare-free, area-distributed light source that is very efficient in term of lighting performance and raw materials use. This novel light source also overcomes the design limitations of traditional lighting luminaires by providing extremely thin form factors and flexible forms. CoreGLO can be incorporated into various types of traditional lighting systems and will also enable creating new luminaire designs of various innovative forms and shapes.

    The panels can be designed to fit into existing fixtures. However, the panel cannot be subsequently repurposed to use in another fixture.

11. **Flexible, networked lighting control systems**: This project tested new desk lamps with localized sensing and user control of overhead ambient lighting. This technology alters the lighting retrofit landscape by inexpensively enabling highly granular lighting control at the occupant's fingertips (previously only zone-level control existed), to control overhead lighting.

12. **Energy efficient plug load designs**: This project designed a methodology guideline for plug load manufacturers to use in developing energy efficient plug load devices. In developing the guideline, the recipient evaluated mobile design practices, hardware components, and power management software kernels to prove their effectiveness. The results were used to develop the first virtual prototypes and reference designs for energy optimized hardware and software that can guide plug load device manufacturers to reach mobile energy efficiency levels. Manufacturers will use these reference designs to develop and mass deploy energy efficient plug load devices into the marketplace.

    This technology could apply to computer equipment, TVs, gaming consoles, and set-up boxes.

13. **Zero Net Energy plug loads**: This project researched and developed new technologies and strategies to eliminate or significantly reduce energy use in standby mode by redesigning the power supply for plug load devices. Specifically, it examined strategies to remove plug load devices from grid AC power by redesigning these devices to use DC power from photovoltaic power sources.

The technology assumes the availability of DC power (either in a DC-wired building or from a PV system). The researchers envision that the first use case would be medical equipment (they mention ventilation systems and oxygen concentrators), and that other use cases include items that are hardwired into buildings: GFCI plugs, AFCIs, hard-wired smoke alarms, and illuminated street numbers.

14. **High Performance Windows:** Windows are key building features that the market demands because they allow for views, daylight and outdoor connections; but they provide less insulation than walls and therefore are a challenge for energy efficiency. Advanced windows that reduce infiltration, limit water leakage, reduce daylight discomfort and glare, generate energy, and support automated controls offer opportunities to reduce building energy use.

    a. **Triple pane insulating glass with low-conductance aluminum frame:** The research team developed an R-5, 1-inch thick, triple-pane, insulating glass unit with a novel low-conductance aluminum frame. This technology can help significantly reduce residential cooling and heating loads, particularly during the evening.

    Although other technologies were researched as part of this grant, experts should focus their estimates on the triple-pane window.

    b. **Advanced energy efficient and energy generating windows (ClearView):** ClearView Power Windows will offer benefits of maintained transparency, while producing electricity and rejecting heat to save energy. CVP provides insulation that can reduce heating and cooling demands up to 30% by preventing the infrared solar heat to pass through the windows.

DELPHI PANEL SUMMARY

The Delphi panel asked experts to consider the scale and timing of the market share for 19 technologies. Estimated penetration rates for the same technology and market sector in 2045 ranged between 16-100% for the largest variation to 0-5% for the smallest. Overall, market estimates and rationale provided for the estimates were varied across experts, although the range of variability narrowed between Phase 1 and Phase 2. The change in standard deviations between Phase 1 and Phase 2 market share estimates saw a decrease >1% in standard deviation between Phase 1 and 2 for 100 estimates, while 6 estimates saw an increase >1%. Most estimates (189) had a change in standard deviation of 1% or less. Standard deviations across technologies and sectors, generally increased for estimates in later years. The table below presents the change in standard deviation between Phase 1 and Phase 2 market estimates.

Change in standard deviation between Phase 1 and Phase 2 market share estimates, 100 estimates saw a decrease (>1%) in standard deviation between Phase 1 and 2, while 6 estimates saw an increase (>1%). The majority of estimates (189) had a change in standard deviation 1% or less.

	2025	2030	2035	2040	2045
Glass fiber insulation of attic space					
Residential SF - Existing	**-3.0%**	**-4.4%**	**-6.9%**	**-9.4%**	**-11.7%**
Residential SF - New	**-2.0%**	**-3.4%**	**-5.8%**	**-7.8%**	**-9.9%**
Commercial foodservice appliance designs and energy control technologies					
Commercial - Existing	-0.2%	**-24.7%**	**-22.7%**	**-21.1%**	**-3.5%**
Commercial - New	-0.4%	-0.4%	-0.9%	**-2.5%**	**-6.8%**
Integrated daylighting, shading, controls					
Commercial - Existing	-0.3%	-0.7%	**-1.2%**	**-1.7%**	**-3.5%**
Solar-reflective cool walls					
Commercial - Existing	0.1%	0.0%	-0.4%	-0.4%	**-1.1%**
Residential MF - Existing	0.6%	0.2%	**2.1%**	**2.5%**	0.7%
Residential SF - Existing	0.6%	0.3%	**1.3%**	0.5%	0.1%
Hydronic radiant cooling and heating system					
Commercial - Existing	0.0%	-0.1%	-0.2%	-0.3%	-0.4%
Commercial - New	0.0%	-0.1%	-0.1%	-0.2%	-0.3%
Residential MF - Existing	0.0%	0.1%	0.3%	0.4%	0.4%
Residential MF - New	0.0%	-0.1%	-0.2%	-0.3%	-0.4%
Residential SF - Existing	0.0%	-0.1%	-0.2%	-0.3%	-0.5%
Residential SF - New	-0.2%	-0.3%	-0.2%	-0.2%	-0.1%

	2025	2030	2035	2040	2045
Next generation HVAC systems designed for CA-specific climates					
Residential MF - Existing	**-6.7%**	**-7.6%**	**-8.1%**	**-7.8%**	**-7.9%**
Residential MF - New	**-4.8%**	**-4.2%**	**-3.8%**	**-3.9%**	**-3.9%**
Residential SF - Existing	**-5.0%**	**-5.9%**	**-6.2%**	**-5.2%**	**-5.2%**
Residential SF - New	-0.5%	-0.9%	-0.8%	-0.6%	-0.6%
Low-cost helical coil Ground Heat Exchanger					
Residential MF - Existing	-0.5%	-0.9%	-0.7%	**-1.3%**	**-1.1%**
Residential MF - New	-1.0%	**-1.2%**	**-1.4%**	**-1.2%**	**-1.1%**
Residential SF - Existing	0.0%	0.0%	0.0%	0.0%	0.0%
Residential SF - New	0.0%	0.0%	0.0%	0.0%	0.0%
Low-GWP, high-efficiency heat pump and air conditioner					
Residential MF - Existing	-0.3%	-0.5%	-0.5%	-0.8%	**-1.1%**
Residential MF - New	-0.1%	-0.3%	-0.6%	**-1.1%**	**-1.5%**
Residential SF - Existing	-0.1%	-0.2%	-0.4%	-0.1%	0.6%
Residential SF - New	0.0%	-0.1%	-0.2%	-0.2%	-0.2%
Radiative sky cooling-enabled efficiency improvements on commercial cooling systems					
Commercial - Existing	0.0%	-0.1%	-0.2%	**-2.3%**	**-7.1%**
Scale-up of magnetocaloric materials for high efficiency magnetic refrigeration					
Commercial - Existing	0.0%	0.0%	0.0%	-0.1%	-0.5%
Commercial - New	0.0%	0.0%	0.0%	0.0%	0.0%
Smart ventilation controls					
Residential MF - Existing	0.3%	-0.1%	-0.4%	-0.6%	-0.8%
Residential MF - New	0.0%	0.1%	0.1%	-0.1%	0.3%
Residential SF - Existing	0.6%	0.5%	0.0%	-0.3%	-0.1%
Residential SF - New	0.9%	-0.5%	**-1.1%**	**-1.5%**	**-1.1%**
Smart ceiling fans and smart thermostat integration					
Commercial - Existing	0.0%	0.0%	0.1%	-0.3%	**-2.6%**
Residential MF - Existing	0.0%	0.0%	-0.1%	-0.3%	-0.6%
Residential SF - Existing	0.1%	0.3%	0.3%	0.0%	-0.2%
Ultra-thin flexible LED lighting panels					
Commercial - Existing	0.0%	0.0%	-0.4%	**-3.2%**	**-6.0%**
Commercial - New	0.0%	0.0%	0.0%	**-2.7%**	**-5.5%**
Flexible, networked lighting control systems					
Commercial - Existing	0.1%	0.4%	-0.3%	**-1.1%**	**-9.5%**
Commercial - New	0.0%	-0.4%	**-1.1%**	**-3.4%**	**-12.7%**
Energy efficient plug load designs					
Commercial - Existing	0.0%	0.0%	0.0%	0.0%	0.0%
Commercial - New	0.0%	0.1%	-0.6%	-1.0%	**-1.7%**
Residential MF - Existing	0.0%	0.0%	0.0%	-0.1%	-0.1%
Residential MF - New	0.0%	0.0%	0.0%	0.0%	0.0%
Residential SF - Existing	0.0%	0.0%	0.0%	0.0%	0.0%
Residential SF - New	0.0%	0.0%	0.0%	0.0%	0.0%

	2025	2030	2035	2040	2045
Zero Net Energy plug loads					
Commercial - Existing	**-4.7%**	**-6.7%**	**-8.4%**	**-10.2%**	**-11.8%**
Commercial - New	**-4.8%**	**-6.6%**	**-7.2%**	**-5.2%**	**3.0%**
Residential MF - Existing	**-5.7%**	**-8.9%**	**-11.1%**	**-13.8%**	**-16.0%**
Residential MF - New	**-8.9%**	**-11.0%**	**-4.9%**	**-3.7%**	**1.3%**
Residential SF - Existing	**-7.0%**	**-10.2%**	**-12.0%**	**-15.0%**	**-17.4%**
Residential SF - New	**-6.1%**	**-5.7%**	**-6.4%**	**-4.4%**	**2.8%**
Triple pane insulating glass with low-conductance aluminum frame					
Commercial - Existing	-0.1%	**-3.2%**	**-5.4%**	**-6.8%**	**-7.0%**
Commercial - New	-0.8%	**-3.3%**	**-4.2%**	**-5.7%**	**-7.1%**
Advanced energy efficient and energy generating windows (ClearView)					
Commercial - Existing	0.0%	0.1%	0.1%	**-2.0%**	**-6.2%**
Commercial - New	0.0%	0.0%	-0.1%	**-1.9%**	**-5.8%**
MEMS-based ultrasonic anemometer					
Commercial - Existing	0.3%	0.0%	-0.1%	-0.5%	**-1.5%**

For most technologies, at least one expert declined to offer estimates; most often attributed to the expert indicating that the technology category or market was not their area of expertise. This result is to be expected. On average, there were several technologies that experts estimated would reach 25% or more market share by 2045. These include:

- **Commercial Foodservice Appliance Designs and Energy Control Technologies.** Most experts did not describe this as a clear "winner" in their comments, but market share estimates for this technology were generally high. The average estimate for the new commercial sector was 51% by 2045; estimates for the existing commercial sector were generally lower, but across experts the average market share was 40% by 2045. Many experts anticipated that market share increases would be driven by forthcoming code changes.
- **Ultra-thin Flexible LED Lighting Panels.** Experts found this technology promising due to the opportunity it provides to improve lighting aesthetics and design options, while being cost-effective. Notably the experts that commented on this technology were supportive, although it should be noted that four experts indicated this was not their area of expertise and declined to provide estimates. Estimates for existing commercial reached 35% by 2045, and for new commercial reached 39% by 2045 on average.
- **MEMS-based Ultrasonic Anemometer.** Experts generally estimated this would have relatively high market share by 2045 (30%) but indicated that it still needs to be field tested. Experts also identified this as an area with a market need, as current measurement technologies are often flawed.
- **Triple Pane Insulating Glass with Low-conductance Aluminum Frame**. Experts acknowledged that although the technology still needs to be proven at the larger scale, the benefit of a 1-inch wide triple-pane window makes this product very appealing. Experts also predicted that costs would continue to decrease over time. The average estimate for new commercial buildings is higher (average 28% by 2045) than estimates for existing (average 22% by 2045).

- **Energy Efficient Plug Load Designs**. Experts providing high estimates indicate the low cost and ease of integrating this technology into existing platforms are favorable aspects. There was little variation in estimates across sectors, the lowest average was 20% for Residential MF existing, and highest was for the commercial new sector at 27%.

- Experts generally described the Low-GWP, High-efficiency Heat Pump and Air Conditioner as a potential market "winner" for existing residential, but the average estimate reached only 23% by 2045 for existing MF, and only 16% for existing SF. Rationale for estimates suggested the technology was promising and an improvement to conventional window AC, although there were some concerns about the project's ability to meet their cost estimates.

Experts largely agreed on several technologies that were unlikely to obtain substantial portions of the market (less than 7% by 2045). These technologies include two of the HVAC technologies – the Hydronic Radiant Cooling and Heating System and Low-cost Helical Coil Ground Heat Exchanger – and Scale-up of Magnetocaloric Materials for High Efficiency Magnetic Refrigeration.

- **Hydronic Radiant Cooling and Heating System.** Estimates for this technology were highest for the new commercial sector (7% by 2045) but were lower for all existing market sectors. Experts cited high cost, physical limits where radiant systems could be installed, lack of ventilation during a time of increasing mandates for ventilation, and the complexity of technology.
- **Low-cost Helical Coil Ground Heat Exchanger.** Experts cited high cost, unreliability, large amount of space needed to install the system, and climate-specific limitations (e.g., soil conditions), and increased efficiency and cost-effectiveness of air-to-air heat pumps as reasons why this technology would not obtain substantial market share.
- **Scale-up of Magnetocaloric Materials for High Efficiency Magnetic Refrigeration.** Overall, experts identified this technology as potentially promising but too far from commercialization to forecast market applications. Experts identified the need for rare materials to utilize this technology as another barrier. Five experts opted to not provide market estimates for this technology, explaining that it was not their area of expertise or there was not enough information on the technology to provide an assessment.

Results changed as experts considered the market share assessments of their peers in Phase 2; this often served to narrow the range, but typically did not substantially affect the average estimate. The largest change was an increase in market share estimates for zero net energy plug loads, particularly for existing residential SF; these estimates increased by 3.5% in 2025, 5.1% in 2030, 5.8% in 2035, 7.2% in 2040, and 8.6% in 2045.

TECHNOLOGY AND MARKET-SPECIFIC SUMMARY TABLES

This section contains the tables that consolidate the estimates across experts with the year by year values, a small trend line graphic, and a summary of the rationale provided for each expert's estimate. These tables also include the average estimate (bolded) across experts at the top of the table. Data are highlighted if they are the lowest (yellow), or highest (green) estimate for each year; values are rounded to the nearest percent.

GLASS FIBER INSULATION OF ATTIC SPACE

Climate applicability: Applicable to all CA climate zones.

Residential SF - New

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**8%**	**11%**	**15%**	**19%**	**24%**		
Expert A	10%	20%	30%	40%	50%		· Phase 2: decreased estimates and updated rationale. · Research indicated glass fiber will not seal as well as spray foam; will not be airtight. · Market adoption is likely to vary by climate zone.
Expert B	30%	40%	50%	60%	70%		· It seems to me that this is already being adopted; there is some new code language in Title 24 that gives you extra credit for this approach. There are competing paths to meet the code though.
Expert C	0%	0%	1%	3%	10%		· Phase 2: considered increasing estimates if code were invoked but arguments were not compelling. · Faces both technology-specific and non-technology barriers that slow market uptake, these include: moisture issues; lack of building science savvy with contractors; need for technology to be incorporated into code; risk aversion to innovative techniques; potential for installation failure due to lack of education among workforce. · Retrofit projects tend to lag in market uptake compared to new construction since these are separate sub-industries within residential construction and renovation contractors are even more risk averse.
Expert D	3%	6%	9%	9%	9%		· Phase 2: increased estimates and updated rationale. · Applicability is climate specific: zones 11-15 hot and dry zones would be 10%, 30%, 30% in 25-35-45; would be 0% for all other climate zones. estimates are normalized across all climate zones.
Expert E	0%	0%	3%	5%	10%		· Phase 2: increased estimates and updated rationale. · Increased a bit, but not that much given competing approaches and moisture challenges.
Expert F	5%	10%	15%	25%	30%		· If it's cheaper and faster, some segment of builders will do it. If it provides premium performance , some builders will be interested. Assumes that it will not be mandated by code. "I put 30% because in absence of the code change there is only 30% that would ever learn something new."
Expert G	5%	10%	15%	20%	25%		· Phase 2: decreased estimates and updated rationale. · This is going to be a big change for builders, and is not going to happen quickly. · Fiber glass insulation poses potential health issues and vapor method addresses moisture but may be a contributor to GHG. · Installation of this technique is complicated and will likely result in poor installation quality.
Expert H	2%	5%	7%	10%	10%		· Phase 2: increased estimates and updated rationale. · Previous estimates were at low end and other experts' rationale were compelling. · Proper installation is necessary for avoiding problems so this will generate market resistance even if it is a cheaper option.
Expert I	5%	10%	10%	5%	5%		· Phase 2: updated rationale. · California code should not allow this due to risks. Vented attics can suck in embers from wildfires which is a resiliency issue and moisture problems can lead to poor IAQ.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

GLASS FIBER INSULATION OF ATTIC SPACE

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Expert J	15%	15%	15%	15%	15%		· Could be reasonable market uptake but installers and homeowners tend not to like working with fiberglass given the fine particles. Also potential for moisture issues.
Expert K	10%	10%	10%	10%	10%		· Approach (incorporating attic into conditioned space) has been around a while, primary barrier has been moisture/mold issues and the liability for this still outweighs the energy saving potential. Additionally fiber glass is an airborne hazard and toxic. · estimates assume that there would be no increase in market share of these types of products based on this research and that current trends would continue.
Expert L	5%	10%	20%	30%	40%		· Estimates assume Title 24 will require conditioned attics and this is one approach to get there. It's inexpensive, but builders will not want the mold liability. Also there are alternatives available for meeting this code requirement.

Residential SF - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**6%**	**9%**	**12%**	**14%**	**16%**		
Expert A	10%	20%	30%	40%	50%		· Phase 2: decreased estimates and updated rationale. · Research indicated glass fiber will not seal as well as spray foam; will not be airtight. · Since defined as relevant to "applicable renovations," the market share estimates would be the same as for new single-family homes. · Market adoption is likely to vary by climate zone.
Expert B	20%	28%	35%	43%	50%		· Existing buildings are harder for this practice from both a technical and cost perspective.
Expert C	0%	0%	0%	1%	3%		· Phase 2: considered increasing estimates if code were invoked but arguments were not compelling. · Faces both technology-specific and non-technology barriers that slow market uptake, these include: moisture issues; lack of building science savvy with contractors; need for technology to be incorporated into code; risk aversion to innovative techniques; potential for installation failure due to lack of education among workforce. · Retrofit projects tend to lag in market uptake compared to new construction since these are separate sub-industries within residential construction and renovation contractors are even more risk averse.
Expert D	3%	6%	9%	9%	9%		· Phase 2: increased estimates and updated rationale. · Applicability is climate specific: zones 11-15 hot and dry zones would be 10%, 30%, 30% in 25-35-45; would be 0% for all other climate zones. estimates are normalized across all climate zones.
Expert E	0%	0%	1%	1%	5%		· Phase 2: decreased estimates and updated rationale. · The challenge here is retrofitting existing structures. · Used market adoption of 2035 as provided. Improved knowledge of moisture management practices will take time. Assumes worst of challenges are addressed by 2035. Once that is addressed, this should be a strong option for more innovative builders.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

GLASS FIBER INSULATION OF ATTIC SPACE

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Expert F	4%	8%	12%	16%	20%		· There is more complexity in applying this to existing homes, leading to more time required for the job.
Expert G	5%	5%	10%	10%	10%		· Phase 2: decreased estimates and updated rationale. · This won't be as big in the existing market because of lack of experience among renovation contractors. · Fiber glass insulation poses potential health issues and vapor method addresses moisture but may be a contributor to GHG. · Installation of this technique is complicated and will likely result in poor installation quality.
Expert H	5%	15%	15%	15%	15%		· Proper installation is necessary for avoiding problems so this will generate market resistance even if it is a cheaper option. · Higher uptake in existing since renovation contractors are less resistant to adopt new technologies that are cheaper options (whole house builders tend to be more reluctant due to concerns regarding long-term liability).
Expert I	1%	5%	10%	5%	0%		· Phase 2: updated rationale. · California code should not allow this due to risks. Vented attics can suck in embers from wildfires which is a resiliency issue and moisture problems can lead to poor IAQ. · This should not happen in existing; should be a non-vented attic with spray foam on top.
Expert J	15%	15%	15%	15%	15%		· Could be reasonable market uptake but installers and homeowners tend not to like working with fiberglass given the fine particles. Also potential for moisture issues.
Expert K	3%	3%	3%	3%	3%		· Approach (incorporating attic into conditioned space) has been around a while, primary barrier has been moisture/mold issues and the liability for this still outweighs the energy saving potential. Additionally fiber glass is an airborne hazard and toxic. · Added cost in retrofitting suggests lower market share.
Expert L	1%	3%	6%	10%	15%		· Phase 2: increased estimates due to rationale provided by other experts. · This appears to be required in some homes already.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

COMMERCIAL FOODSERVICE APPLIANCE DESIGNS AND ENERGY CONTROL TECHNOLOGIES

Climate applicability: Applicable to all CA climate zones.

Commercial - New

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**9%**	**26%**	**34%**	**42%**	**51%**		
Expert A	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert B	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert C	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise; relative service life and replacement costs will influence market share.
Expert D	20%	35%	50%	65%	80%		· Designs were applicable to multiple appliances and some of these designs have more merit than others; however many of them will be standard by 2045.
Expert E	5%	7%	10%	15%	25%		· Phase 2: increased estimates and updated rationale. · Inductive technology is much safer and easier. · Some companies will want to make a wholesale change; so there is early adoption potential.
Expert F	2%	10%	20%	30%	40%		· There are a myriad of other benefits to the induction system other than energy savings- increased safety, reduced heat; will lead to fewer injuries and fewer missed work days due to injuries. Ultimately premium equipment will all be induction and no one in the industry is gong to want to use current technology; changeover is inevitable.
Expert G	5%	19%	33%	46%	60%		· Market uptake will be driven by manufacturers use of the technologies.
Expert H	10%	15%	20%	25%	30%		· Phase 2: increased estimates and updated rationale. · Code change is not unlikely.
Expert I	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert J	20%	100%	100%	100%	100%		· Assumes there will be a code change that will help adoption. Consumer education will be critical though. There will be significant water savings as well from the drywell replacement.
Expert K	1%	5%	11%	19%	26%		· Phase 2: estimates reflect both types of technologies. · Two separate technologies, 1) induction technology and 2) setback features. Induction technology holds a lot of promise; the setback features are basic and depends on food service operation characteristics. Induction is more expensive option so slower uptake and if changing from gas to electric in existing buildings it is cost prohibitive.
Expert L	5%	15%	30%	40%	50%		· Phase 2: decreased estimates due to rationale provided by other experts. · The technology will become more readily available and will eventually be required by code, however, this equipment will only be installed in existing kitchens when current/conventional versions die and need to be replaced.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

COMMERCIAL FOODSERVICE APPLIANCE DESIGNS AND ENERGY CONTROL TECHNOLOGIES

Commercial - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**8%**	**12%**	**17%**	**25%**	**40%**		
Expert A	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert B	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert C	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise;· relative service life and replacement costs will influence market share.
Expert D	5%	13%	20%	30%	40%		· This project presented multiple appliances and some of these designs have more merit than others; regardless, many of them will be standard by 2045. · Large corporate chains that expand into new territories are more likely to adopt than existing small businesses.
Expert E	5%	7%	10%	15%	25%		· Phase 2: increased estimates and updated rationale. · Inductive technology is much safer and easier. · Technology is an easy retrofit; you remove an item (i.e., the water bath). Prior belief was that existing buildings were barrier, but current understanding is that they are not.
Expert F	2%	5%	10%	30%	40%		· Induction is also inevitable in the existing kitchen market, but it will take more time. Eventually natural gas lines are going to get pulled out too.
Expert G	5%	11%	18%	24%	30%		· Market uptake will be driven by manufacturers use of the technologies. · Penetration is lower in existing, but would be implemented as equipment is replaced.
Expert H	10%	15%	20%	25%	30%		· Phase 2: increased estimates and updated rationale. · Code change is not unlikely, but would not affect all existing places in the same way.
Expert I	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert J	30%	30%	35%	40%	100%		· Phase 2: decreased estimates and updated rationale. · Previous estimates were high and acknowledges this is more difficult in existing. · Assumes there will be a code change that will help adoption. Consumer education will be critical though. There will be significant water savings as well from the drywell replacement.
Expert K	1%	4%	8%	13%	16%		· Phase 2: estimates reflect both types of technologies. · Two separate technologies, 1) induction technology and 2) setback features. Induction technology holds a lot of promise; the setback features are basic and depends on food service operation characteristics. Induction is more expensive option so slower uptake and if changing from gas to electric in existing buildings it is cost prohibitive.
Expert L	5%	10%	15%	25%	40%		· The technology will become more readily available and will eventually be required by code, however, this equipment will only be installed in existing kitchens when current/conventional versions die and need to be replaced.

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INTEGRATED DAYLIGHTING, SHADING, CONTROLS

Climate applicability: Applicable to all CA climate zones.

Commercial - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**4%**	**8%**	**13%**	**17%**	**23%**		
Expert A	5%	10%	15%	20%	25%		· Phase 2: included estimates and updated rationale. · Agreed with rationale and estimates provided by Experts B and C.
Expert B	10%	20%	30%	40%	50%		· Should be relatively easy to install, but concerns about maintaining the system (e.g., economizers in HVAC). Since this is heavily controls oriented, it will likely fail at some point. And the trades do not have the technical skills to deal well with controls.
Expert C	0%	1%	5%	10%	20%		· Phase 2: decreased estimates and updated rationale. · Previous estimates were high, especially considering lack of cost-estimates. · This project addresses occupant comfort, which has good potential in the marketplace. · Uncertainties in the project remain: quantifying the reduced labor costs and lack of clarity on control implementation.
Expert D	1%	3%	5%	8%	10%		· Similar components of this technology are already in the market but anything that provides individual controls to a space is better.
Expert E	1%	2%	3%	4%	5%		· Phase 2: increased estimates and updated rationale. · Policy demands increase in EE in California, but these are too complicated for mass adoption. · Building owners concerned about how lessee will react to the shading, which will keep market share low.
Expert F	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert G	1%	11%	21%	30%	40%		· As enthusiasm for ZNE buildings grow, this will gain traction in the market for those wanting to go above code.
Expert H	2%	5%	10%	10%	10%		· This seems difficult to fit into existing buildings; it should also be designed in conjunction with lighting system. · Requires educated users; the estimates assume users accept and understand control options.
Expert I	2%	5%	15%	25%	35%		· Estimates focus on the non-energy benefits associated with integrated daylighting and shading systems relative to increased productivity, worker retention, and comfort. · Given the profile for commercial building owner expenses (e.g., $300/sf payroll/$30/sf rent/$3/sf energy), substantial market penetration because this measure will substantially improve working conditions.
Expert J	15%	15%	15%	15%	15%		· Great glare control and will work for a time. However, anticipate high maintenance costs due to complexity and high likelihood of components failing.
Expert K	1%	3%	5%	10%	15%		· Phase 2: increased estimates and updated rationale. · Solution may have operational issues relating to repairs/maintenance with PV and likely will remain costly but provides a nice plug and play option with desired elements already integrated.
Expert L	5%	10%	15%	20%	25%		· Lack of cost data makes it difficult to estimate; seems promising but only if it us cost-effective. · Grantee's technical potential estimates look to high.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

SOLAR-REFLECTIVE COOL WALLS

Climate applicability: Applicable to hot and dry CA climate zones with a greater need for cooling in the summer than heating in the winter.

Residential SF - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**6%**	**9%**	**15%**	**20%**	**27%**		
Expert A	5%	10%	15%	20%	25%		· Aesthetics are likely to affect market uptake, because of this, uptake by existing single-family homes are likely to be less than multi-family or commercial buildings.
Expert B	15%	20%	35%	40%	50%		· Phase 2: increased estimates and updated rationale. · Has potential but will be limited by climate zone · Aesthetic concerns - assumed that mirror structures would be needed. Older building with poor walls can be improved with traditional means.
Expert C	0%	1%	2%	5%	10%		· Phase 2: updated rationale. · Comfort is best during the day when people are not home, and decreases at night, which does not make sense. · Estimates assume this is applicable only to the solar reflective coatings; corrugated aluminum siding proposal is absolute non-starter. Overall, market uptake will only occur if this is a very cheap option.
Expert D	10%	15%	20%	30%	40%		· This technology is most impactful if applied to Residential SF since owners bear costs of cooling. · Only beneficial in warmer climate zones.
Expert E	1%	1%	5%	10%	15%		· Color choice by SF owners is very specific, they want more choices not less. Cost is expected to be a factor for this, relative to benefit. Codes now have some support for cool wall concepts. When codes change to better support this technology, volume goes up and costs come down.
Expert F	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert G	1%	6%	11%	15%	20%		· This technology is only applicable in very specific situations: direction of walls and trees are considerations. · This would need incentives or other programs to increase market share; Title 24 would not include this.
Expert H	2%	3%	4%	4%	5%		· Phase 2: increased estimates and updated rationale. · Aesthetic issues still cause concern, but rationale provided by other experts makes sense.
Expert I	2%	10%	20%	30%	50%		· Given there are very few cost-effective strategies to add insulation to existing walls and that the California climates are relative mild, this measure appears to be a perfect fit and easy to scale.
Expert J	25%	30%	35%	40%	45%		· Quite a bit of potential. But may have climate zone limitations and consumer education will be needed.
Expert K	0%	3%	5%	10%	15%		· Reflective paints are currently in the marketplace, but mainstreaming them would be useful. · Cool wall systems are only effective in certain climate zones and building orientations; heat gain is desired in cooler climates.
Expert L	1%	5%	10%	15%	20%		· Phase 2: increased estimates due to clarification that technology is simple paint.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

SOLAR-REFLECTIVE COOL WALLS

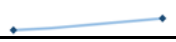
Residential MF - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**6%**	**9%**	**15%**	**20%**	**25%**		
Expert A	10%	20%	30%	40%	50%		· Aesthetics are likely to affect market uptake, multi-family and commercial buildings will likely have less resistance to implementing energy efficiency measures that affect exterior building aesthetics.
Expert B	15%	20%	40%	50%	50%		· Phase 2: increased estimates and updated rationale. · Any work on exterior is easier than SF for building owner to do. · MF buildings are less aesthetically oriented so higher uptake.
Expert C	1%	2%	5%	10%	20%		· Phase 2: updated rationale. · Could have more uptake in senior housing. · Estimates assume this is applicable only to the solar reflective coatings; corrugated aluminum siding proposal is absolute non-starter. Overall market uptake will only occur if this is a very cheap option.
Expert D	5%	8%	10%	15%	20%		· Building envelope loads are less important to owners of MF buildings because tenants pay for cooling. · Only beneficial in warmer climate zones.
Expert E	1%	3%	5%	7%	9%		· Phase 2: increased estimates and updated rationale. · Color choice is not as problematic in MF, and with state moving towards ZNE, this is a cost-effective strategy.
Expert F	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert G	1%	6%	11%	15%	20%		· This technology is only applicable in very specific situations: direction of walls and trees are considerations. · This would need incentives or other programs to increase market share; Title 24 would not include this.
Expert H	2%	3%	4%	4%	5%		· Phase 2: increased estimates and updated rationale. · Aesthetic issues still cause concern, but rationale provided by other experts makes sense.
Expert I	1%	5%	10%	15%	25%		· Given there are very few cost-effective strategies to add insulation to existing walls and that the California climates are relative mild, this measure appears to be a perfect fit and easy to scale. · Split-incentive with MF owners will result in lower market share.
Expert J	25%	30%	35%	40%	45%		· Quite a bit of potential. Companies that own MF developments may see this as a good compliance strategy for a ZNE building code.
Expert K	0%	3%	5%	10%	15%		· Reflective paints are currently in the marketplace, but mainstreaming them would be useful. · Cool wall systems are only effective in certain climate zones and building orientations; heat gain is desired in cooler climates.
Expert L	1%	5%	10%	15%	20%		· Phase 2: increased estimates due to clarification that technology is simple paint. · Split incentive problem will slow growth in this market.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

SOLAR-REFLECTIVE COOL WALLS

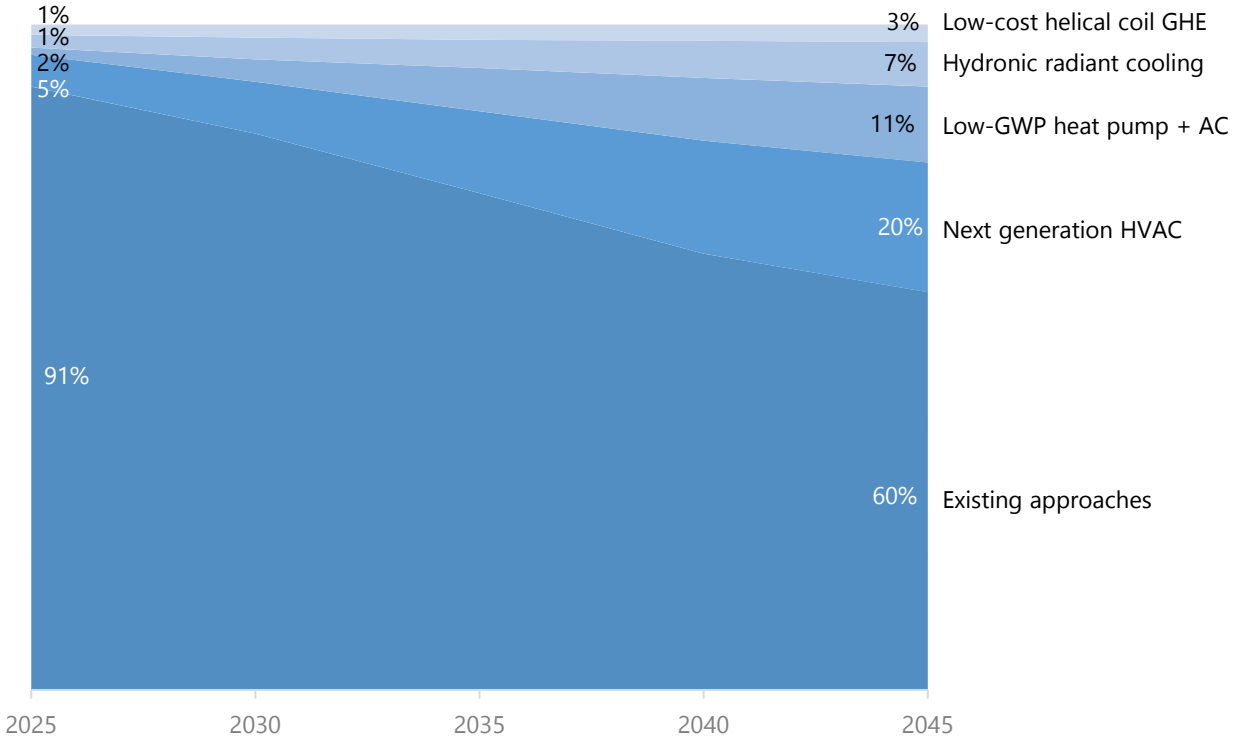
Commercial - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**5%**	**9%**	**14%**	**19%**	**24%**		
Expert A	10%	20%	30%	**40%**	**50%**		· Aesthetics are likely to affect market uptake, multi-family and commercial buildings will likely have less resistance to implementing energy efficiency measures that affect exterior building aesthetics.
Expert B	10%	15%	20%	30%	30%		· Commercial buildings are less aesthetically oriented so higher uptake.
Expert C	**1%**	**2%**	5%	10%	20%		· Estimates assume this is applicable only to the solar reflective coatings; corrugated aluminum siding proposal is absolute non-starter. · Market uptake will only occur if this is a very cheap option. · This is most beneficial to buildings that are daytime occupied.
Expert D	**1%**	**2%**	3%	4%	5%		· Commercial building owners least likely to adopt this technology because they do not pay for cooling costs. · Only beneficial in warmer climate zones.
Expert E	**1%**	3%	5%	7%	9%		· Phase 2: increased estimates and updated rationale. · Color choice is not as problematic in MF, and with state moving towards ZNE, this is a cost-effective strategy. · Retroreflector described as most promising, but aesthetics and redirected light issues were not addressed; this option not likely to be taken up by market.
Expert F	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert G	**1%**	6%	11%	15%	20%		· This technology is only applicable in very specific situations: direction of walls and trees are considerations. · This would need incentives or other programs to increase market share; Title 24 would not include this.
Expert H	2%	**2%**	**2%**	**2%**	**2%**		· Low market share; may not be accepted aesthetically, only applicable under specific conditions, similar treatments (e.g., windows) have not been accepted by market.
Expert I	2%	8%	15%	25%	40%		· Given that cool walls can significantly improve comfort and by extension worker productivity, estimates a higher market penetration for Commercial renovations (e.g., offices, warehouses, retail) .
Expert J	**25%**	**30%**	**35%**	**40%**	45%		· Commercial building owners care more about curbside aesthetics than MF owners. Will take some education to engage this sector with this technology but overall has potential.
Expert K	2%	10%	15%	20%	25%		· Reflective paints are currently in the marketplace, but mainstreaming them would be useful. · Cool wall systems are only effective in certain climate zones and building orientations; heat gain is desired in cooler climates. · LEED or other sustainability efforts may drive higher uptakes in commercial settings.
Expert L	2%	5%	10%	15%	20%		· Phase 2: increased estimates due to clarification that technology is simple paint. · If LEED picks this up and it can be counted as a LEED point, that may influence some green building owners.

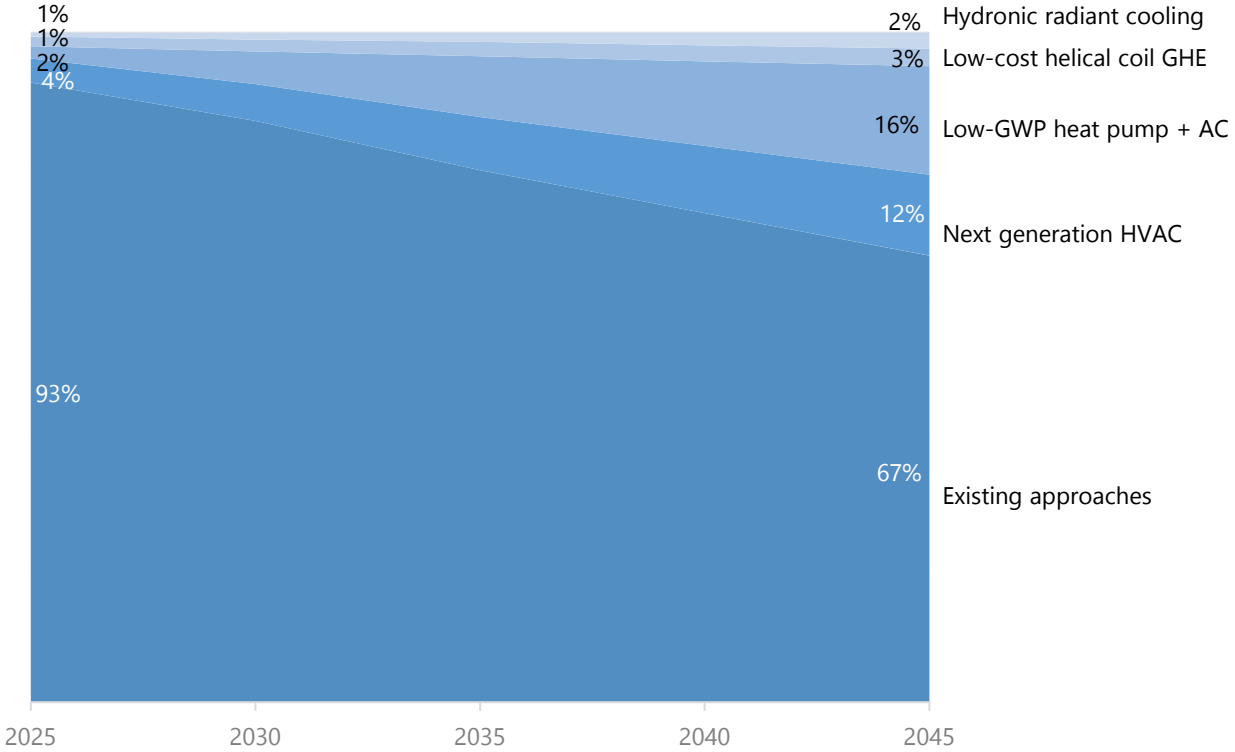
Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

HVAC - ALL TECHNOLOGIES

Residential SF - New

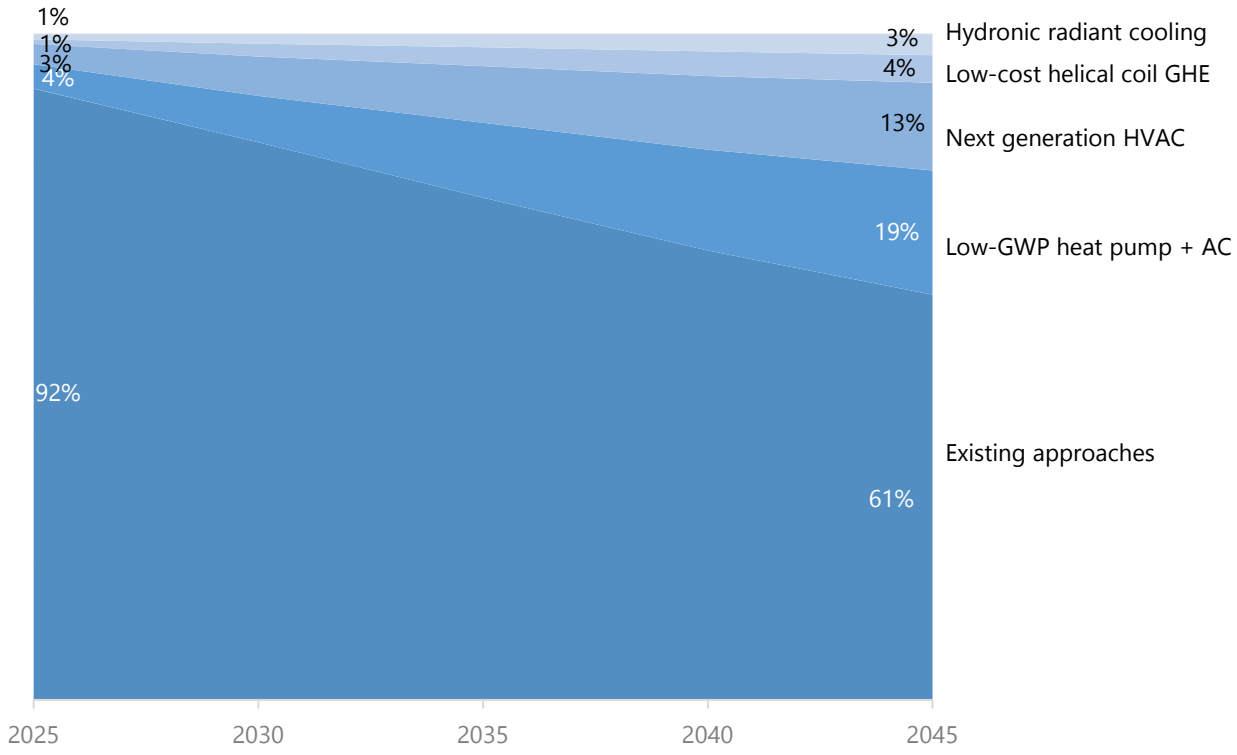


Residential SF - Existing

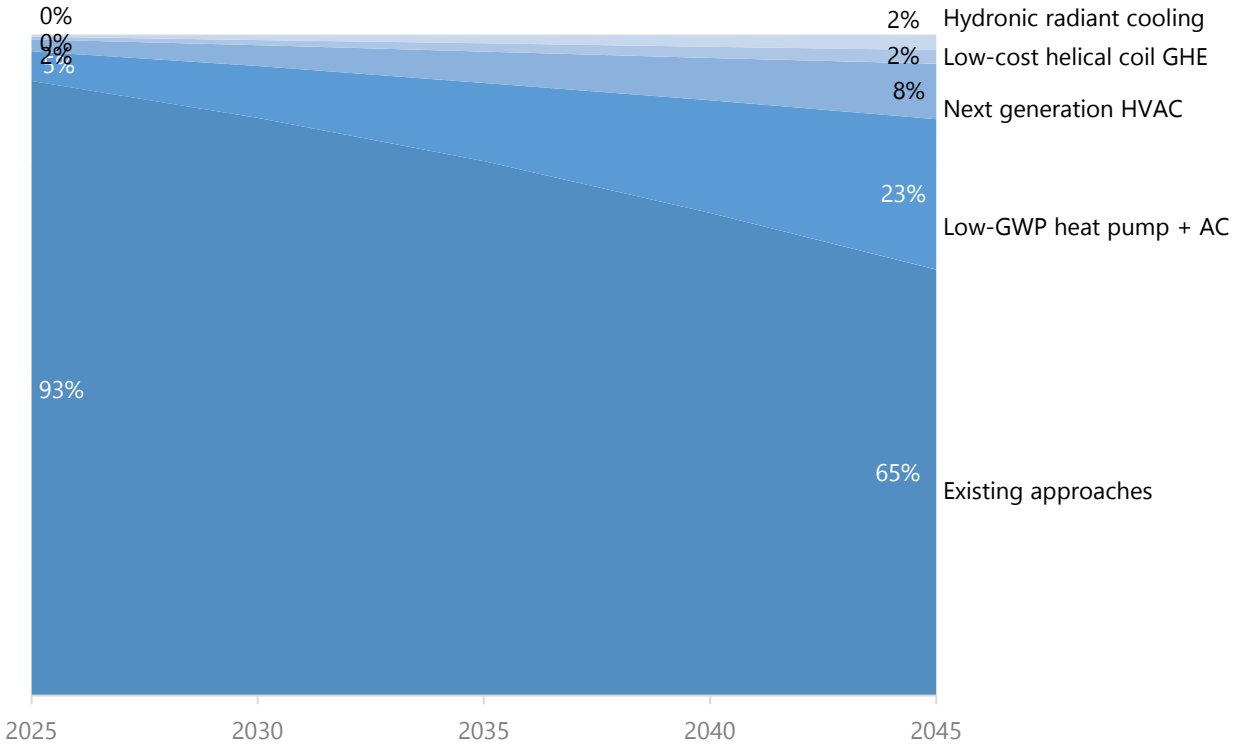


HVAC - ALL TECHNOLOGIES

Residential MF - New



Residential MF - Existing



HYDRONIC RADIANT COOLING AND HEATING SYSTEM

Climate applicability: Applicable to all CA climate zones.

Residential SF - New

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**2%**	**3%**	**4%**	**6%**	**7%**		
Expert A	0%	0%	0%	0%	0%		· Phase 2: updated rationale. · Cooling requires dehumidification which is an obstacle to adoption. · It does not seem likely this technology would be easily applied in residential sector.
Expert B	2%	5%	9%	12%	15%		· Air to air heat pumps are cheap and effective, and these other technologies are complicated and more expensive. · Radiant floors take filtration out of the building which is now mandated for all sectors. · ASHRAE guidance for managing virus air filtration is forthcoming.
Expert C	0%	0%	0%	1%	2%		· Phase 2: decreased estimates and updated rationale. · Radiant is a luxury option and too expensive for most homes. · Technology faces technological and market barriers including obtaining applicability to ASHRAE standards for cooling load which would result in delayed market uptake.
Expert D	0%	1%	2%	4%	5%		· Phase 2: included estimates and updated rationale. · Agree with Expert G, this would have low market share; it is so unique and complicated, builders and buyers will not be accustomed to it.
Expert E	1%	2%	3%	4%	5%		· Phase 2: increased estimates and updated rationale. · Unlikely manufacturers will solve moisture management problem with cooling but heating is ok until the system breaks. However, there will be some who want to try it.
Expert F	1%	3%	5%	7%	7%		· Hydronic has merit, but it will take time for Americans to get used to them, and they will be a higher end application . Much more potential in commercial systems. Bulk of what will be done is ducted systems.
Expert G	0%	1%	2%	4%	5%		· Low market share; it is so unique and complicated builders and buyers will not be accustomed to it.
Expert H	2%	5%	5%	8%	10%		· Only applicable in very niche situations: research finding that climate conditions (e.g., drought) affected performance was important and highlighted limitation of technology.
Expert I	0%	0%	0%	0%	0%		· Hydronic radiant heating/cooling systems do not have market potential. California is moving to ZNE with small with heating and cooling loads and appropriate ventilation; this approach also mitigates the most significant benefit of radiant systems (better surface temperatures).
Expert J	15%	18%	18%	18%	18%		· This approach makes sense for SF residential, new homes.
Expert K	1%	2%	3%	4%	5%		· Project did not address biggest barriers: high costs and physical limitations to where this could be applied. · Little application in residential space and improving controls does not overcome residential barriers.
Expert L	1%	2%	4%	6%	8%		· HVAC market is well established, existing manufacturers have more resources and are better able to meet new codes/standards. Likelihood of success will increase if existing manufacturer purchases technology.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

HYDRONIC RADIANT COOLING AND HEATING SYSTEM

Residential SF - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**1%**	**1%**	**1%**	**2%**	**2%**		
Expert A	0%	0%	0%	0%	0%		· Phase 2: updated rationale. · Cooling requires dehumidification which is an obstacle to adoption. · Retrofitting a this technology into an existing building seems very unlikely.
Expert B	0%	1%	1%	2%	2%		· Air to air heat pumps are cheap and effective, and these other technologies are complicated and more expensive. · Radiant floors take filtration out of the building which is now mandated for all sectors. · ASHRAE guidance for managing virus air filtration is forthcoming.
Expert C	0%	0%	0%	0%	0%		· Technology is prohibitively expensive for retrofit SF.
Expert D	0%	1%	2%	4%	5%		· Phase 2: included estimates and updated rationale. · Agree with Expert G, this would have low market share; it is so unique and complicated, builders and buyers will not be accustomed to it.
Expert E	0%	1%	1%	1%	1%		· Phase 2: decreased estimates and updated rationale. · Longer time for market uptake.
Expert F	0%	0%	0%	0%	0%		· Hydronic has merit, but it will take time for Americans to get used to them, and they will be a higher end application . Much more potential in commercial systems. Bulk of what will be done is ducted systems.
Expert G	0%	1%	2%	4%	5%		· Low market share; it is so unique and complicated builders and buyers will not be accustomed to it.
Expert H	1%	3%	3%	4%	5%		· Only applicable in very niche situations: research finding that climate conditions (e.g., drought) affected performance was important and highlighted limitation of technology.
Expert I	0%	0%	0%	0%	0%		· Hydronic radiant heating/cooling systems have too many challenges for existing home retrofit applications. There is such a greater return investing in an EnergieSprong passive house type of retrofit infrastructure that leads to tiny heating and cooling loads again making radiant heating and cooling not practical.
Expert J	5%	5%	5%	5%	5%		· No one is going to install hydronic systems in existing homes.
Expert K	0%	0%	1%	1%	1%		· Project did not address biggest barriers: high costs and physical limitations to where this could be applied. · Little application in residential space and improving controls does not overcome residential barriers, especially for existing.
Expert L	1%	2%	3%	4%	5%		· Phase 2: decreased estimates and updated rationale. · Barriers in existing buildings are too much to see substantial uptake in existing.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

HYDRONIC RADIANT COOLING AND HEATING SYSTEM

Residential MF - New

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**1%**	**1%**	**2%**	**3%**	**3%**		
Expert A	0%	0%	0%	0%	0%		· Phase 2: updated rationale. · Cooling requires dehumidification which is an obstacle to adoption. · It does not seem likely this technology would be easily applied in residential sector.
Expert B	1%	2%	3%	4%	5%		· Air to air heat pumps are cheap and effective, and these other technologies are complicated and more expensive. · Radiant floors take filtration out of the building which is now mandated for all sectors. · ASHRAE guidance for managing virus air filtration is forthcoming.
Expert C	0%	0%	0%	0%	0%		· Technology is prohibitively expensive for residential MF.
Expert D	0%	1%	2%	4%	5%		· Phase 2: included estimates and updated rationale. · Agree with Expert G, this would have low market share; it is so unique and complicated, builders and buyers will not be accustomed to it.
Expert E	0%	1%	1%	1%	1%		· Phase 2: decreased estimates and updated rationale. · Longer time for market uptake.
Expert F	0%	1%	2%	2%	2%		· Hydronic has merit, but it will take time for Americans to get used to them, and they will be a higher end application . Much more potential in commercial systems. Bulk of what will be done is ducted systems.
Expert G	0%	1%	2%	4%	5%		· Low market share; it is so unique and complicated builders and buyers will not be accustomed to it.
Expert H	1%	3%	3%	4%	5%		· Only applicable in very niche situations: research finding that climate conditions (e.g., drought) affected performance was important and highlighted limitation of technology.
Expert I	0%	0%	0%	0%	0%		· Hydronic radiant heating/cooling systems do not appear to have any meaningful market opportunity. California is moving to a Zero Energy code with heating and cooling loads becoming so small the duct sizing aligns with that for whole-house ventilation. In other words, you have a free distribution system for air source. Further, high-performance new homes will effectively eliminate or minimize thermal bridging so the most significant benefit of radiant systems, better surface temperatures, are substantially mitigated.
Expert J	5%	5%	5%	5%	5%		· New MF is so much harder than SF for these types of technologies because they are developer driven; usually they are conservative when it comes to costs.
Expert K	1%	2%	3%	4%	5%		· Project did not address biggest barriers: high costs and physical limitations to where this could be applied. · Little application in residential space and improving controls does not overcome residential barriers.
Expert L	1%	2%	3%	4%	5%		· Do not see a real market for hydronics- everything is air-based and air-delivered.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

HYDRONIC RADIANT COOLING AND HEATING SYSTEM

Residential MF - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**0%**	**1%**	**1%**	**2%**	**2%**		
Expert A	0%	0%	0%	0%	0%		· Phase 2: updated rationale. · Cooling requires dehumidification which is an obstacle to adoption. · Retrofitting a this technology into an existing building seems very unlikely.
Expert B	0%	0%	0%	0%	0%		· Air to air heat pumps are cheap and effective, and these other technologies are complicated and more expensive. · Radiant floors take filtration out of the building which is now mandated for all sectors. · ASHRAE guidance for managing virus air filtration is forthcoming.
Expert C	0%	0%	0%	0%	0%		· Technology is prohibitively expensive for residential MF.
Expert D	0%	1%	2%	4%	5%		· Phase 2: included estimates and updated rationale. · Agree with Expert G, this would have low market share; it is so unique and complicated, builders and buyers will not be accustomed to it.
Expert E	0%	1%	1%	1%	1%		· Phase 2: decreased estimates and updated rationale. · Longer time for market uptake.
Expert F	0%	0%	0%	0%	0%		· Hydronic has merit, but it will take time for Americans to get used to them, and they will be a higher end application . Much more potential in commercial systems. Bulk of what will be done is ducted systems.
Expert G	0%	1%	2%	4%	5%		· Low market share; it is so unique and complicated builders and buyers will not be accustomed to it.
Expert H	1%	3%	6%	8%	10%		· Phase 2: increased estimates and updated rationale. · Movement is growing for sustainability within residential MF. · Increased ventilation rates are going to be part of COVID-19 response.
Expert I	0%	0%	0%	0%	0%		· Hydronic radiant heating/cooling systems do not appear to have any meaningful market opportunity. California is moving to a Zero Energy code with heating and cooling loads becoming so small the duct sizing aligns with that for whole-house ventilation. In other words, you have a free distribution system for air source. Further, high-performance new homes will effectively eliminate or minimize thermal bridging so the most significant benefit of radiant systems, better surface temperatures, are substantially mitigated.
Expert J	1%	1%	1%	1%	1%		· This approach makes sense for SF residential, new homes.
Expert K	0%	0%	1%	1%	1%		· Project did not address biggest barriers: high costs and physical limitations to where this could be applied. · Little application in residential space and improving controls does not overcome residential barriers, especially for existing.
Expert L	1%	2%	3%	4%	5%		· Phase 2: decreased estimates and updated rationale. · Barriers in existing buildings are too much to see substantial uptake in existing.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

HYDRONIC RADIANT COOLING AND HEATING SYSTEM

Commercial - New

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**1%**	**3%**	**5%**	**6%**	**7%**		
Expert A	5%	10%	15%	20%	25%		· Phase 2: updated rationale. · Built-in dehumidification in commercial buildings provides opportunity for technology. · Non-occupied setback strategy is important for achieving energy savings but this is not possible with this technology. · Moisture management is also difficult, tied to climate zone, and important for achieving energy savings.
Expert B	2%	3%	4%	4%	5%		· Air to air heat pumps are cheap and effective, and these other technologies are complicated and more expensive.
Expert C	0%	0%	0%	0%	0%		· Commercial is daytime occupancy and hydronic relies on steady state temps which means that setback temps during non-occupancy is lost; not appliable to this sector.
Expert D	0%	1%	2%	4%	5%		· Phase 2: included estimates and updated rationale. · Agree with Expert G, this would have low market share; it is so unique and complicated, builders and buyers will not be accustomed to it.
Expert E	0%	1%	2%	3%	4%		· Phase 2: decreased estimates and updated rationale. · Longer time for market uptake.
Expert F	0%	2%	5%	5%	5%		· Hydronic has merit, but it will take time for Americans to get used to them, and they will be a higher end application . Much more potential in commercial systems. Bulk of what will be done is ducted systems.
Expert G	0%	1%	2%	4%	5%		· Low market share; it is so unique and complicated builders and buyers will not be accustomed to it.
Expert H	2%	4%	6%	6%	6%		· Only applicable in very niche situations: research finding that climate conditions (e.g., drought) affected performance was important and highlighted limitation of technology. · More applicable for buildings with static cooling load, not dynamic, but could be relevant for some types of commercial.
Expert I	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert J	5%	5%	5%	5%	5%		· Would need to change ASHRAE definition/assumptions for base cooling to gain market uptake.
Expert K	1%	2%	5%	6%	7%		· Project did not address biggest barriers: high costs and physical limitations to where this could be applied.
Expert L	1%	2%	4%	6%	8%		· Do not see a real market for hydronics- everything is air-based and air-delivered.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

HYDRONIC RADIANT COOLING AND HEATING SYSTEM

Commercial - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**0%**	**1%**	**2%**	**2%**	**3%**		
Expert A	3%	5%	8%	10%	13%		· Phase 2: updated rationale. · Built-in dehumidification in commercial buildings provides opportunity for technology. · Retrofitting a this technology into an existing building seems very unlikely.
Expert B	0%	0%	1%	1%	1%		· Air to air heat pumps are cheap and effective, and these other technologies are complicated and more expensive.
Expert C	0%	0%	0%	0%	0%		· Commercial is daytime occupancy and hydronic relies on steady state temps which means that setback temps during non-occupancy is lost; not appliable to this sector.
Expert D	0%	1%	2%	4%	5%		· Phase 2: included estimates and updated rationale. · Agree with Expert G, this would have low market share; it is so unique and complicated, builders and buyers will not be accustomed to it.
Expert E	0%	1%	1%	1%	1%		· Phase 2: decreased estimates and updated rationale. · Longer time for market uptake.
Expert F	0%	0%	0%	0%	0%		· Hydronic has merit, but it will take time for Americans to get used to them, and they will be a higher end application . Much more potential in commercial systems. Bulk of what will be done is ducted systems.
Expert G	0%	1%	2%	4%	5%		· Low market share; it is so unique and complicated builders and buyers will not be accustomed to it.
Expert H	0%	0%	0%	0%	0%		· Only applicable in very niche situations: research finding that climate conditions (e.g., drought) affected performance was important and highlighted limitation of technology. · More applicable for buildings with static cooling load, not dynamic, but could be relevant for some types of commercial.
Expert I	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert J	1%	1%	1%	1%	1%		· Would need to change ASHRAE definition/assumptions for base cooling to gain market uptake.
Expert K	0%	0%	1%	1%	1%		· Project did not address biggest barriers: high costs and physical limitations to where this could be applied.
Expert L	1%	2%	3%	4%	5%		· Phase 2: decreased estimates and updated rationale. · Barriers in existing buildings are too much to see substantial uptake in existing.

NEXT GENERATION HVAC SYSTEMS DESIGNED FOR CA-SPECIFIC CLIMATES

Climate applicability: Applicable to all CA climate zones.

Residential SF - New

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**5%**	**8%**	**12%**	**17%**	**20%**		
Expert A	5%	10%	20%	40%	40%		· Success of this project is linked to penetration of high-performing building enclosures. · Field evaluation did not seem sufficient for analyzing performance of technology. · Seven technology packaged approach could limit implementation.
Expert B	5%	6%	7%	7%	8%		· Air to air heat pumps are cheap and effective, and these other technologies are complicated and more expensive.
Expert C	0%	0%	0%	0%	0%		· This technology relies on a dual fuel strategy that includes gas, given the state's move towards electrification this technology does not make sense.
Expert D	0%	0%	0%	0%	0%		· All inclusive system is too complicated for the residential market.
Expert E	1%	5%	10%	15%	20%		· Phase 2: increased estimates and updated rationale. · Promising technology, although the packaged approach is difficult.
Expert F	5%	15%	35%	45%	50%		· Absolute right approach – solar ready, multiple fuels ready, DR ready.
Expert G	10%	18%	25%	33%	40%		· This is a promising approach and needed in the market, however it is difficult to see how this would be introduced in the market.
Expert H	10%	13%	15%	18%	20%		· Phase 2: decreased estimates and updated rationale. · The risk associated with this from manufacturers perspective is not small; so this has less potential.
Expert I	1%	1%	1%	1%	1%		· Way too complex a bundle of technologies for a single investment. For example, integrated fault detection and diagnostics by itself is a huge challenge for the HVAC industry currently represented by significant research investments. The best this research can do is impact analysis.
Expert J	20%	23%	23%	23%	23%		· This approach sounds great but first costs will be difficult to overcome.
Expert K	0%	2%	8%	15%	20%		· There is a market need for this type of integrated technology in the residential sector; however unclear how pragmatic this would be in application.
Expert L	1%	2%	4%	8%	12%		· HVAC market is well established, existing manufacturers have more resources and are better able to meet new codes/standards. Likelihood of success will increase if existing manufacturer purchases technology.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

NEXT GENERATION HVAC SYSTEMS DESIGNED FOR CA-SPECIFIC CLIMATES

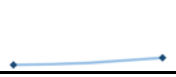
Residential SF - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**4%**	**5%**	**8%**	**10%**	**12%**		
Expert A	10%	15%	25%	35%	40%		· Phase 2: increased estimates and updated rationale. · Retrofitting this technology into an existing building seems very unlikely. · Seven technology packaged approach could limit implementation.
Expert B	5%	6%	7%	7%	8%		· Air to air heat pumps are cheap and effective, and these other technologies are complicated and more expensive.
Expert C	1%	2%	5%	0%	0%		· This technology relies on a dual fuel strategy that includes gas, given the state's move towards electrification this technology does not make sense. · This may see some uptake in existing residential early years, but will be phased out later as electrification goals are met.
Expert D	0%	0%	0%	0%	0%		· All inclusive system is too complicated for the residential market.
Expert E	1%	2%	5%	10%	15%		· Phase 2: increased estimates and updated rationale. · Promising technology, although the packaged approach is difficult.
Expert F	2%	5%	10%	12%	15%		· Absolute right approach – solar ready, multiple fuels ready, DR ready.
Expert G	5%	10%	10%	15%	15%		· Phase 2: decreased estimates and updated rationale. · Higher cost in the existing market will make this more difficult; owners and contractors are sensitive to it.
Expert H	5%	9%	13%	16%	20%		· Phase 2: decreased estimates and updated rationale. · The risk associated with this from manufacturers perspective is not small; so this has less potential.
Expert I	1%	1%	1%	1%	1%		· Too complex for retrofit in particular.
Expert J	10%	10%	10%	10%	10%		· This approach sounds great but first costs will be difficult to overcome.
Expert K	2%	5%	8%	10%	15%		· There is a market need for this type of integrated technology in the residential sector; however unclear how pragmatic this would be in application.
Expert L	1%	1%	2%	4%	6%		· Phase 2: decreased estimates due to clarification that all 7 technologies are packaged together.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

NEXT GENERATION HVAC SYSTEMS DESIGNED FOR CA-SPECIFIC CLIMATES

Residential MF - New

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**3%**	**6%**	**9%**	**11%**	**13%**		
Expert A	10%	20%	25%	25%	25%		· Success of this project is linked to penetration of high-performing building enclosures. · Field evaluation did not seem sufficient for analyzing performance of technology. · Seven technology packaged approach could limit implementation.
Expert B	0%	0%	1%	1%	1%		· Air to air heat pumps are cheap and effective, and these other technologies are complicated and more expensive.
Expert C	0%	0%	0%	0%	0%		· This technology relies on a dual fuel strategy that includes gas, given the state's move towards electrification this technology does not make sense. · Most MF are all electric already, so retrofitting with gas is not likely and is not standard market practice for new MF.
Expert D	0%	0%	0%	0%	0%		· All inclusive system is too complicated for the residential market.
Expert E	1%	5%	7%	15%	20%		· Phase 2: increased estimates and updated rationale. · Promising technology, although the packaged approach is difficult.
Expert F	5%	10%	15%	15%	15%		· Absolute right approach – solar ready, multiple fuels ready, DR ready. However, if people do VRF, they will not use this approach, so there will be a gap in the MF sector.
Expert G	10%	18%	25%	33%	40%		· This is a promising approach and needed in the market, however it is difficult to see how this would be introduced in the market.
Expert H	5%	9%	13%	16%	20%		· Phase 2: decreased estimates and updated rationale. · The risk associated with this from manufacturers perspective is not small; so this has less potential.
Expert I	0%	0%	0%	0%	0%		· Too complex and constrained by split incentive.
Expert J	5%	5%	5%	5%	5%		· This approach sounds great but first costs will be difficult to overcome. Currently can't get just heat pumps into some of these buildings.
Expert K	0%	2%	8%	15%	20%		· There is a market need for this type of integrated technology in the residential sector; however unclear how pragmatic this would be in application.
Expert L	1%	2%	4%	8%	12%		· HVAC market is well established, existing manufacturers have more resources and are better able to meet new codes/standards. Likelihood of success will increase if existing manufacturer purchases technology.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

NEXT GENERATION HVAC SYSTEMS DESIGNED FOR CA-SPECIFIC CLIMATES

Residential MF - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**2%**	**3%**	**5%**	**6%**	**8%**		
Expert A	5%	10%	15%	20%	25%		· Phase 2: decreased estimates and updated rationale. · Retrofitting this technology into an existing building seems very unlikely. · Seven technology packaged approach could limit implementation.
Expert B	1%	1%	2%	2%	2%		· Air to air heat pumps are cheap and effective, and these other technologies are complicated and more expensive.
Expert C	0%	0%	0%	0%	0%		· This technology relies on a dual fuel strategy that includes gas, given the state's move towards electrification this technology does not make sense. · Most MF are all electric already, so retrofitting with gas is not likely and is not standard market practice for new MF.
Expert D	0%	0%	0%	0%	0%		· All inclusive system is too complicated for the residential market.
Expert E	1%	2%	4%	5%	10%		· Phase 2: increased estimates and updated rationale. · Promising technology, although the packaged approach is difficult.
Expert F	1%	2%	3%	4%	5%		· Absolute right approach – solar ready, multiple fuels ready, DR ready. However, if people do VRF, they will not use this approach, so there will be a gap in the MF sector.
Expert G	5%	7%	10%	15%	17%		· Phase 2: decreased estimates and updated rationale. · Higher cost in the existing market will make this more difficult; owners and contractors are sensitive to it.
Expert H	5%	9%	13%	16%	20%		· Phase 2: decreased estimates and updated rationale. · The risk associated with this from manufacturers perspective is not small; so this has less potential.
Expert I	0%	0%	0%	0%	0%		· Too complex and constrained by split incentive.
Expert J	1%	1%	1%	1%	1%		· This approach sounds great but first costs will be difficult to overcome. Currently can't get just heat pumps into some of these buildings.
Expert K	2%	5%	8%	10%	15%		· There is a market need for this type of integrated technology in the residential sector; however unclear how pragmatic this would be in application.
Expert L	1%	1%	2%	4%	6%		· Phase 2: decreased estimates due to clarification that all 7 technologies are packaged together.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

LOW-COST HELICAL COIL GROUND HEAT EXCHANGER

Climate applicability: Applicable to all CA climate zones.

Residential SF - New

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**1%**	**2%**	**2%**	**2%**	**3%**		
Expert A	0%	0%	0%	0%	0%		· Due to large scale of technology, this is not well-suited to SF.
Expert B	5%	4%	4%	3%	2%		· Air to air heat pumps are cheap and effective, and these other technologies are complicated and more expensive.
Expert C	0%	0%	0%	0%	0%		· Technology is not viable, it is too expensive, unreliable, and climate-specific.
Expert D	0%	0%	0%	0%	0%		· Ground source heat pump technologies are unreliable due to soil conditions and this project also had these issues; this will not affect the market.
Expert E	1%	1%	1%	1%	1%		· Technology is very application-specific; needs a lot of space, and often need to tear up yards to do the work. You need to have enough buildings to amortize costs; best applied on large campuses or military installations.
Expert F	1%	2%	3%	3%	3%		· No specific comments.
Expert G	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert H	2%	3%	4%	5%	6%		· Competition from less expensive and more reliable air sourced system is a substantial market barrier.
Expert I	2%	2%	3%	3%	3%		· GCHP have an increasing challenge competing with advanced inverter driven, variable-speed, ultra-high efficient air source heat pumps achieving 22+ SEER and 5 COP. With efficiency benefits disappearing, biggest advantage is ability to have indoor compressor for durability. Also concerned about scaling technology with site variations on ground soil heat exchange characteristics; do not expect significant market penetration.
Expert J	5%	6%	6%	6%	6%		· Uptake would be suburban/rural only given land required, generally uptake will be hindered by amount of space needed.
Expert K	0%	1%	2%	2%	3%		· Installation cost is prohibitively expensive and needs a lot space for implementation.
Expert L	1%	2%	3%	4%	5%		· These systems take up a lot of space and you can't just hire an HVAC contractor to install them; you need to hire another contractor to dig up a large area of property first. · HVAC market is well established, existing manufacturers have more resources and are better able to meet new codes/standards. Likelihood of success will increase if existing manufacturer purchases technology.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

LOW-COST HELICAL COIL GROUND HEAT EXCHANGER

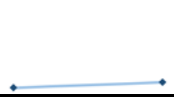
Residential SF - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**1%**	**2%**	**2%**	**2%**	**3%**		
Expert A	0%	0%	0%	0%	0%		· Due to large scale of technology, this is not well-suited to SF.
Expert B	2%	3%	4%	4%	5%		· Air to air heat pumps are cheap and effective, and these other technologies are complicated and more expensive.
Expert C	0%	0%	0%	0%	0%		· Technology is not viable, it is too expensive, unreliable, and climate-specific.
Expert D	0%	0%	0%	0%	0%		· Ground source heat pump technologies are unreliable due to soil conditions and this project also had these issues; this will not affect the market.
Expert E	1%	1%	1%	1%	1%		· Cost premium higher than for builder-discounted SF.
Expert F	0%	0%	0%	0%	0%		· There is no market for GSHP in existing buildings.
Expert G	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert H	2%	3%	4%	5%	6%		· Competition from less expensive and more reliable air sourced system is a substantial market barrier.
Expert I	1%	1%	2%	2%	2%		· GCHP have an increasing challenge competing with advanced inverter driven, variable-speed, ultra-high efficient air source heat pumps achieving 22+ SEER and 5 COP. With efficiency benefits disappearing, biggest advantage is ability to have indoor compressor for durability. Also concerned about scaling technology with site variations on ground soil heat exchange characteristics. As a result, don't expect significant market penetration.
Expert J	10%	10%	10%	10%	10%		· Uptake would be suburban/rural only given land required, generally uptake will be hindered by amount of space needed.
Expert K	0%	0%	1%	1%	1%		· Phase 2: decreased estimates and updated rationale. · Installation cost is prohibitively expensive and needs a lot space for implementation. · Very unlikely in existing due to invasive nature of installation.
Expert L	1%	2%	3%	4%	5%		· These systems take up a lot of space and you can't just hire an HVAC contractor to install them; you need to hire another contractor to dig up a large area of property first. · HVAC market is well established, existing manufacturers have more resources and are better able to meet new codes/standards. Likelihood of success will increase if existing manufacturer purchases technology.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

LOW-COST HELICAL COIL GROUND HEAT EXCHANGER

Residential MF - New

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**1%**	**2%**	**3%**	**4%**	**4%**		
Expert A	0%	5%	5%	10%	10%		· First costs are a substantial barrier to market penetration. · Performance of technology is highly dependent on soil moisture content which makes this climate dependent and unreliable.
Expert B	1%	2%	3%	4%	5%		· Air to air heat pumps are cheap and effective, and these other technologies are complicated and more expensive.
Expert C	0%	0%	0%	0%	0%		· Technology is not viable, it is too expensive, unreliable, and climate-specific.
Expert D	0%	0%	0%	0%	0%		· Ground source heat pump technologies are unreliable due to soil conditions and this project also had these issues; this will not affect the market.
Expert E	1%	1%	1%	1%	1%		· Cost premium lower than residential renovation, but more than SF.
Expert F	1%	5%	10%	10%	10%		· Phase 2: decreased estimates due to arguments from other panelists.
Expert G	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert H	2%	4%	6%	8%	10%		· Phase 2: decreased estimates and updated rationale. · Agree with other experts' rationale; aligning estimates to be in line with others. · Competition from less expensive and more reliable air sourced system is a substantial market barrier. · More relevant to MF sector since footprint is larger.
Expert I	0%	0%	0%	0%	0%		· GCHP have an increasing challenge competing with advanced inverter driven, variable-speed, ultra-high efficient air source heat pumps achieving 22+ SEER and 5 COP. With efficiency benefits disappearing, biggest advantage is ability to have indoor compressor for durability. Also concerned about scaling technology with site variations on ground soil heat exchange characteristics. As a result, don't expect significant market penetration.
Expert J	2%	2%	2%	2%	2%		· Uptake would be suburban/rural only given land required, generally uptake will be hindered by amount of space needed.
Expert K	0%	1%	2%	2%	3%		· Installation cost is prohibitively expensive and needs a lot space for implementation.
Expert L	1%	2%	3%	4%	5%		· These systems take up a lot of space and you can't just hire an HVAC contractor to install them; you need to hire another contractor to dig up a large area of property first. · HVAC market is well established, existing manufacturers have more resources and are better able to meet new codes/standards. Likelihood of success will increase if existing manufacturer purchases technology.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

LOW-COST HELICAL COIL GROUND HEAT EXCHANGER

Residential MF - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**0%**	**1%**	**1%**	**2%**	**2%**		
Expert A	1%	2%	3%	4%	5%		· Phase 2: decreased estimates since previous estimates were too high. · First costs are a substantial barrier to market penetration. · Performance of technology is highly dependent on soil moisture content which makes this climate dependent and unreliable.
Expert B	0%	0%	1%	1%	1%		· Air to air heat pumps are cheap and effective, and these other technologies are complicated and more expensive.
Expert C	0%	0%	0%	0%	0%		· Technology is not viable, it is too expensive, unreliable, and climate-specific.
Expert D	0%	0%	0%	0%	0%		· Ground source heat pump technologies are unreliable due to soil conditions and this project also had these issues; this will not affect the market.
Expert E	1%	1%	1%	1%	1%		· More price sensitive than new construction.
Expert F	0%	0%	0%	0%	0%		· There is no market for GSHP in existing buildings.
Expert G	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert H	2%	4%	6%	8%	10%		· Phase 2: decreased estimates and updated rationale. · Agree with other experts' rationale; aligning estimates to be in line with others. · Competition from less expensive and more reliable air sourced system is a substantial market barrier. · More relevant to MF sector since footprint is larger.
Expert I	0%	0%	0%	0%	0%		· GCHP have an increasing challenge competing with advanced inverter driven, variable-speed, ultra-high efficient air source heat pumps achieving 22+ SEER and 5 COP. With efficiency benefits disappearing, biggest advantage is ability to have indoor compressor for durability. Also concerned about scaling technology with site variations on ground soil heat exchange characteristics. As a result, don't expect significant market penetration.
Expert J	0%	0%	0%	0%	0%		· Uptake would be suburban/rural only given land required, generally uptake will be hindered by amount of space needed.
Expert K	0%	0%	1%	1%	1%		· Phase 2: decreased estimates and updated rationale. · Installation cost is prohibitively expensive and needs a lot space for implementation. · Very unlikely in existing due to invasive nature of installation.
Expert L	1%	2%	3%	4%	5%		· These systems take up a lot of space and you can't just hire an HVAC contractor to install them; you need to hire another contractor to dig up a large area of property first. · HVAC market is well established, existing manufacturers have more resources and are better able to meet new codes/standards. Likelihood of success will increase if existing manufacturer purchases technology.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

LOW-GWP, HIGH-EFFICIENCY HEAT PUMP AND AIR CONDITIONER

Climate applicability: Applicable to all CA climate zones.

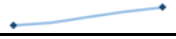
Residential SF - New

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**1%**	**3%**	**7%**	**9%**	**11%**		
Expert A	5%	10%	20%	30%	30%		· Simplicity of technology and installation process makes this easy for consumers. · Lower costs also make this competitive especially compared to ductless mini-splits.
Expert B	1%	5%	8%	12%	15%		· Does not see this being popular in new SF market.
Expert C	0%	0%	0%	0%	0%		· Overall technology and savings seem promising, however this would not be applied in new construction since other whole-house approaches would be applied.
Expert D	0%	0%	0%	0%	0%		· There is no market for this technology in new residential since HVAC will be included in new residential.
Expert E	0%	2%	4%	5%	7%		· Phase 2: updated rationale. · Concept is appealing but has concerns: lack of cost and lab data is troublesome; excessive marketing without data is indicative of ideas that do not deliver; propane as a coolant has flammability issues and therefore regulatory issues.
Expert F	1%	3%	5%	5%	5%		· This approach is not really for new homes, but if it is better and cheaper than window units, will probably be popular in existing homes.
Expert G	0%	10%	20%	30%	40%		· Phase 2: updated rationale. · Acknowledges high estimates, but affirms this is an impressive technology with promising savings.
Expert H	0%	1%	2%	3%	4%		· Promising technology if it provides a cheaper alternative; however currently do not have manufacturer for technology.
Expert I	1%	2%	3%	3%	3%		· Significant improvement to conventional window AC, but a small market in new CA SF homes, so market penetration is low.
Expert J	3%	4%	4%	4%	4%		· If price point gets down to $300, this will have very high market uptake. · Concerned about use of propane, a fossil fuel, as the coolant.
Expert K	0%	0%	5%	10%	15%		· Likely to be substantial portion of market share since it replaces window units and is easily retrofittable.
Expert L	2%	4%	8%	12%	15%		· This technology is promising but has not been fully tested since the next step is to produce 300/year in the near future. · HVAC market is well established, existing manufacturers have more resources and are better able to meet new codes/standards. Likelihood of success will increase if existing manufacturer purchases technology.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

LOW-GWP, HIGH-EFFICIENCY HEAT PUMP AND AIR CONDITIONER

Residential SF - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**2%**	**5%**	**9%**	**13%**	**16%**		
Expert A	10%	20%	30%	33%	33%		· Simplicity of technology and installation process makes this easy for consumers. · Lower costs also make this competitive especially compared to ductless mini-splits. · Most appealing to the existing market sector.
Expert B	1%	8%	16%	23%	30%		· These are inexpensive and easier to integrate into the building but offer low quality filtration.
Expert C	0%	1%	5%	15%	30%		· Phase 2: increased estimates and updated rationale. · Uptake likely to increase in climates where temperatures are rising and no cooling available.
Expert D	1%	2%	3%	3%	3%		· Phase 2: included estimates and updated rationale. · Significant improvement to conventional window AC, but a small market in new California SF existing homes, so market penetration is low, agree with Expert I.
Expert E	0%	1%	3%	5%	7%		· Phase 2: updated rationale. · Concept is appealing but has concerns: lack of cost and lab data is troublesome; excessive marketing without data is indicative of ideas that do not deliver; propane as a coolant has flammability issues and therefore regulatory issues.
Expert F	2%	5%	10%	10%	10%		· This approach is not really for new homes, but if it is better and cheaper than window units, will probably be popular in existing homes.
Expert G	0%	10%	20%	30%	40%		· Phase 2: updated rationale. · Acknowledges high estimates, but affirms this is an impressive technology with promising savings.
Expert H	0%	1%	2%	3%	4%		· Promising technology if it provides a cheaper alternative; however currently do not have manufacturer for technology.
Expert I	1%	2%	3%	3%	3%		· Significant improvement to conventional window AC, but a small market in new CA SF existing homes, so market penetration is low.
Expert J	5%	5%	5%	5%	5%		· This is a great idea for retrofit. If they can really get the price point down to $300, this will have very high market uptake. Dislikes use of propane, a fossil fuel, as the coolant.
Expert K	0%	0%	5%	10%	15%		· Likely to be substantial portion of market share since it replaces window units and is easily retrofittable.
Expert L	2%	4%	8%	12%	15%		· This technology is promising but has not been fully tested since the next step is to produce 300/year in the near future. · HVAC market is well established, existing manufacturers have more resources and are better able to meet new codes/standards. Likelihood of success will increase if existing manufacturer purchases technology.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

LOW-GWP, HIGH-EFFICIENCY HEAT PUMP AND AIR CONDITIONER

Residential MF - New

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**4%**	**7%**	**11%**	**15%**	**19%**		
Expert A	15%	25%	35%	40%	40%		· Simplicity of technology and installation process makes this easy for consumers. · Lower costs also make this competitive especially compared to ductless mini-splits.
Expert B	10%	15%	20%	25%	30%		· These are inexpensive and easier to integrate into the building but offer low quality filtration.
Expert C	0%	0%	0%	0%	0%		· Overall technology and savings seem promising, however this would not be applied in new construction since other whole-house approaches would be applied.
Expert D	1%	3%	5%	10%	15%		· Phase 2: included estimates and updated rationale. · Significant improvement to conventional window AC and a larger market than SF homes, but with significant split incentive barrier. Thus, market penetration is low, but higher than SF existing homes.
Expert E	0%	3%	5%	10%	15%		· Phase 2: increased estimates and updated rationale. · Concept is appealing but has concerns: lack of cost and lab data is troublesome; excessive marketing without data is indicative of ideas that do not deliver; propane as a coolant has flammability issues and therefore regulatory issues. · MF is a likely niche for this product.
Expert F	5%	10%	20%	22%	25%		· This approach is not really for new homes, but if it is better and cheaper than window units, will probably be popular in existing homes.
Expert G	0%	10%	20%	30%	40%		· Phase 2: updated rationale. · Acknowledges high estimates, but affirms this is an impressive technology with promising savings.
Expert H	0%	1%	2%	3%	4%		· Promising technology if it provides a cheaper alternative; however currently do not have manufacturer for technology.
Expert I	1%	3%	5%	10%	15%		· Significant improvement to conventional window AC and a larger market than SF homes, but with significant split incentive barrier. Thus, market penetration is low, but higher than SF existing homes.
Expert J	10%	10%	10%	10%	10%		· This is a great idea for retrofit. If they can really get the price point down to $300, this will have very high market uptake. · Concerned about use of propane, a fossil fuel, as the coolant.
Expert K	0%	0%	5%	10%	15%		· Likely to be substantial portion of market share since it replaces window units and is easily retrofittable.
Expert L	2%	4%	8%	12%	15%		· This technology is promising but has not been fully tested since the next step is to produce 300/year in the near future. · HVAC market is well established, existing manufacturers have more resources and are better able to meet new codes/standards. Likelihood of success will increase if existing manufacturer purchases technology.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

LOW-GWP, HIGH-EFFICIENCY HEAT PUMP AND AIR CONDITIONER

Residential MF - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**5%**	**8%**	**12%**	**17%**	**23%**		
Expert A	20%	30%	35%	40%	40%		· Simplicity of technology and installation process makes this easy for consumers. · Lower costs also make this competitive especially compared to ductless mini-splits. · Most appealing to the existing market sector.
Expert B	20%	25%	30%	35%	40%		· These are inexpensive and easier to integrate into the building but offer low quality filtration.
Expert C	0%	1%	5%	20%	50%		· Overall technology and savings seem promising, however this would not be applied in new construction since other whole-house approaches would be applied.
Expert D	1%	3%	5%	10%	15%		· Phase 2: included estimates and updated rationale. · Significant improvement to conventional window AC, but a small market in new California SF existing homes, so market penetration is low, agree with Expert I.
Expert E	0%	1%	3%	4%	5%		· Phase 2: increased estimates and updated rationale. · Concept is appealing but has concerns: lack of cost and lab data is troublesome; excessive marketing without data is indicative of ideas that do not deliver; propane as a coolant has flammability issues and therefore regulatory issues. · MF is a likely niche for this product.
Expert F	5%	10%	15%	20%	20%		· This approach is not really for new homes, but if it is better and cheaper than window units, will probably be popular in existing homes.
Expert G	0%	10%	20%	30%	40%		· Phase 2: updated rationale. · Acknowledges high estimates, but affirms this is an impressive technology with promising savings.
Expert H	0%	2%	4%	6%	8%		· Phase 2: increased estimates and updated rationale. · This offers flexibility for existing buildings
Expert I	1%	3%	5%	10%	15%		· Significant improvement to conventional window AC and a larger market than SF homes, but with significant split incentive barrier. Thus, market penetration is low, but higher than SF existing homes.
Expert J	5%	5%	5%	5%	5%		· This is a great idea for retrofit. If they can really get the price point down to $300, this will have very high market uptake. · Concerned about use of propane, a fossil fuel, as the coolant.
Expert K	0%	0%	5%	10%	15%		· Likely to be substantial portion of market share since it replaces window units and is easily retrofittable.
Expert L	2%	5%	10%	15%	20%		· Phase 2: increased estimates due to rationale provided by other experts.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

RADIATIVE SKY COOLING-ENABLED EFFICIENCY IMPROVEMENTS ON COMMERCIAL COOLING SYSTEMS

Climate applicability: Applicable to all CA climate zones, but approximately 23% higher savings in hot and dry climates.

Commercial - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**3%**	**5%**	**7%**	**10%**	**14%**		
Expert A	3%	5%	8%	10%	13%		· Potential for associated moisture management benefit in some climates makes this more appealing. · May compete with Solar PV for roof space which could limit market uptake.
Expert B	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert C	1%	2%	5%	10%	25%		· Phase 2: decreased estimates and updated rationale. · Competition with roof space solar panels will lower uptake.
Expert D	1%	1%	1%	1%	1%		· Technology seems compatible with existing chiller and radiant cooling systems however battery storage and ice storage tends to be far more efficient than chilled water systems due to size constraints.
Expert E	1%	2%	3%	4%	5%		· Phase 2: increased estimates and updated rationale. · Solar application is appealing to consumers, but overall market is small since this is a weak chiller.
Expert F	2%	4%	6%	8%	10%		· Space is a constraint- lots of competition for roof space, or it will cut into parking. It is also definitely additive. Limited penetration because it will not be in code.
Expert G	0%	1%	2%	4%	5%		· May not be applicable to most California climates since radiant cooling systems are depending not just on air temperature but how much the sky radiates the cold. · Researchers also discuss a "specialized film" without providing details; lack of transparency makes it difficult to assess technology.
Expert H	2%	4%	4%	6%	6%		· Phase 2: increased estimates and updated rationale. · Previously underestimated applicability; level of savings could be more of a driver for market share.
Expert I	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert J	15%	23%	31%	39%	47%		· Has enormous potential because inexpensive and technology is unlikely to break; it's not complicated and requires very little maintenance. · Will need some good marketing and consumer education around it. Love to see it on low income MF family.
Expert K	0%	1%	3%	4%	5%		· Technology seems feasible but it does not seem commercially available for a long time.
Expert L	2%	5%	10%	15%	20%		· Phase 2: decreased estimates due to rationale provided by other experts.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

SCALE-UP OF MAGNETOCALORIC MATERIALS FOR HIGH EFFICIENCY MAGNETIC REFRIGERATION

Climate applicability: Applicable to all CA climate zones.

Commercial - New

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**0%**	**1%**	**2%**	**4%**	**6%**		
Expert A	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert B	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert C	0%	1%	2%	4%	8%		· Many technological challenges remain before this could see market uptake: still need early adopter customers for manufacturing equipment and it is unclear how this would be operationalized.
Expert D	0%	1%	1%	3%	5%		· Technology is still nascent and developing and will likely take some time to develop. · Market uptake the same for existing and new since locations will replace their systems at the end of useful life.
Expert E	0%	1%	3%	5%	7%		· Phase 2: updated rationale. · This is a great technology- silent, small, and no coolants and their associated GWP problems. However, 2045 is unlikely, technology still needs to be proven at the manufacture ring level.
Expert F	0%	0%	1%	3%	5%		· If this technology suits the cooling load, then by 2035, we should see NC starting to try it.
Expert G	N.R.	N.R.	N.R.	N.R.	N.R.		· Not enough information on technology to provide assessment.
Expert H	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert I	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert J	0%	1%	1%	1%	1%		· Science does not seem proven and is clearly military research. · Concerned about environmental impacts of mining rare earth minerals needed for this technology (e.g., gadolinium).
Expert K	0%	2%	3%	4%	5%		· There is market need for alternative to typical refrigerants however scaling this technology to mainstream with limited MCE materials will be an issue.
Expert L	1%	2%	4%	6%	8%		· While promising, seems like an expensive solution to this problem. · Technology also faces barrier to acquiring materials needed for manufacturing at scale.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

SCALE-UP OF MAGNETOCALORIC MATERIALS FOR HIGH EFFICIENCY MAGNETIC REFRIGERATION

Commercial - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**0%**	**1%**	**1%**	**2%**	**3%**		
Expert A	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert B	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert C	0%	1%	1%	3%	5%		· Phase 2: decreased estimates and updated rationale. · Uptake would be slower compared to new since replacement rates are lower. · Many technological challenges remain: still need early adopter customers for manufacturing equipment and it is unclear how this would be operationalized.
Expert D	0%	1%	1%	3%	5%		· Technology is still nascent and developing and will likely take some time to develop. · Market uptake the same for existing and new since locations will replace their systems at the end of useful life.
Expert E	0%	1%	1%	2%	3%		· Phase 2: updated rationale. · This is a great technology- silent, small, and no coolants and their associated GWP problems. However, 2045 is unlikely, technology still needs to be proven at the manufacture ring level.
Expert F	0%	0%	0%	0%	0%		· Capital cycle on a chiller is 20 years; will not be considered.
Expert G	N.R.	N.R.	N.R.	N.R.	N.R.		· Not enough information on technology to provide assessment.
Expert H	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert I	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert J	0%	0%	0%	0%	0%		· Science does not seem proven and is clearly military research. · Concerned about environmental impacts of mining rare earth minerals needed for this technology (e.g., gadolinium).
Expert K	0%	1%	1%	2%	3%		· There is market need for alternative to typical refrigerants however scaling this technology to mainstream with limited MCE materials will be an issue. · Implementing in existing buildings will be more difficult than new.
Expert L	1%	2%	4%	6%	8%		· While promising, seems like an expensive solution to this problem. · Technology also faces barrier to acquiring materials needed for manufacturing at scale.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

MEMS-BASED ULTRASONIC ANEMOMETER

Climate applicability: Applicable to all CA climate zones.

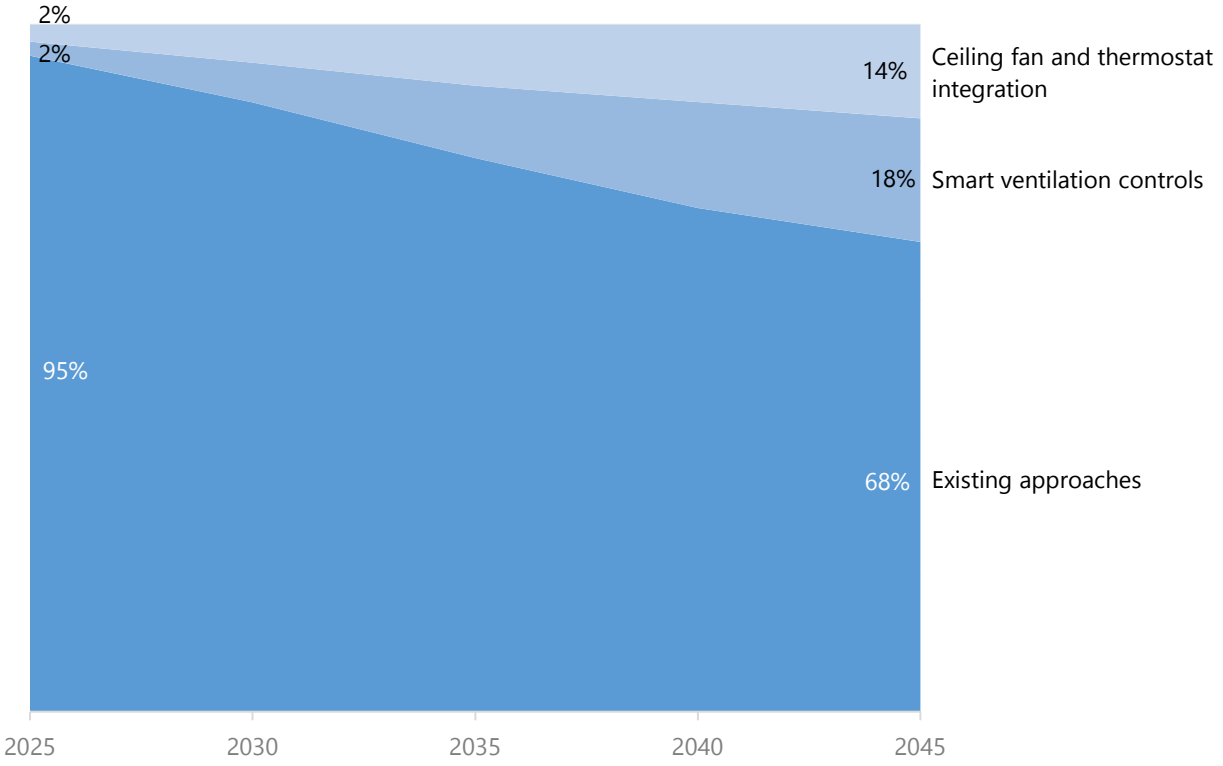
Commercial - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**3%**	**8%**	**15%**	**22%**	**30%**		
Expert A	0%	10%	20%	30%	40%		· Technology aims to address some key gaps of existing technologies. · Needs to be improved to control the effects of light, temperature, and humidity on technology performance.
Expert B	10%	28%	45%	63%	80%		· Commercial HVAC equipment doesn't get replaced until absolutely necessary- slower than residential. But by 2045, if these work, and they are not expensive, this will be a hit.
Expert C	N.R.	N.R.	N.R.	N.R.	N.R.		· Phase 2: removed estimates, unknown if duct testing is mandated.
Expert D	0%	0%	2%	4%	5%		· There is a market need for a good anemometer. · Current barrier to technology is that it is battery powered; since anemometers are embedded in system they need to be energy harvesting.
Expert E	0%	5%	10%	20%	30%		· Phase 2: increased estimates and updated rationale. · Any manufacturer can take this to market, not just the current one. This is an easy way to improve performance, which will be needed as California moves forward with ZNE policy.
Expert F	0%	0%	0%	0%	0%		· Phase 2: updated rationale. · If technology is cheaper as stated, it would already be in the market. There is a market need for this, so if it is superior, it would already be in the market. · Market barrier is lack of trust in sensors, so alternative testing will still occur.
Expert G	0%	5%	17%	28%	40%		· There is a historical market need for better sensor; but previous alternatives have failed. · estimates assume that product addresses barriers and state continues to embrace ZNE.
Expert H	2%	5%	10%	20%	30%		· Large market need for this technology; ease of installation is a plus. · Researchers need to make the data emerging from this technology useful for users.
Expert I	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert J	20%	25%	30%	35%	40%		· Great potential for existing buildings, is effective and inexpensive and does not need to be calibrated which eases maintenance concerns. Although small building savings, high adoption rate will increase total savings. · In COVID-19 era, new regulations on air changes will increase energy use, but having more accurate air flow measurements will reduce this impact.
Expert K	0%	0%	2%	4%	5%		· This could be an alternative to more expensive duct flow testing; however technology still has accuracy issues, indicating the market readiness is far off. · Application may also be limited because building operators need to understand the technology and how to make decisions based on data from this technology.
Expert L	2%	5%	10%	15%	25%		· Phase 2: decreased estimates due to rationale provided by other experts.

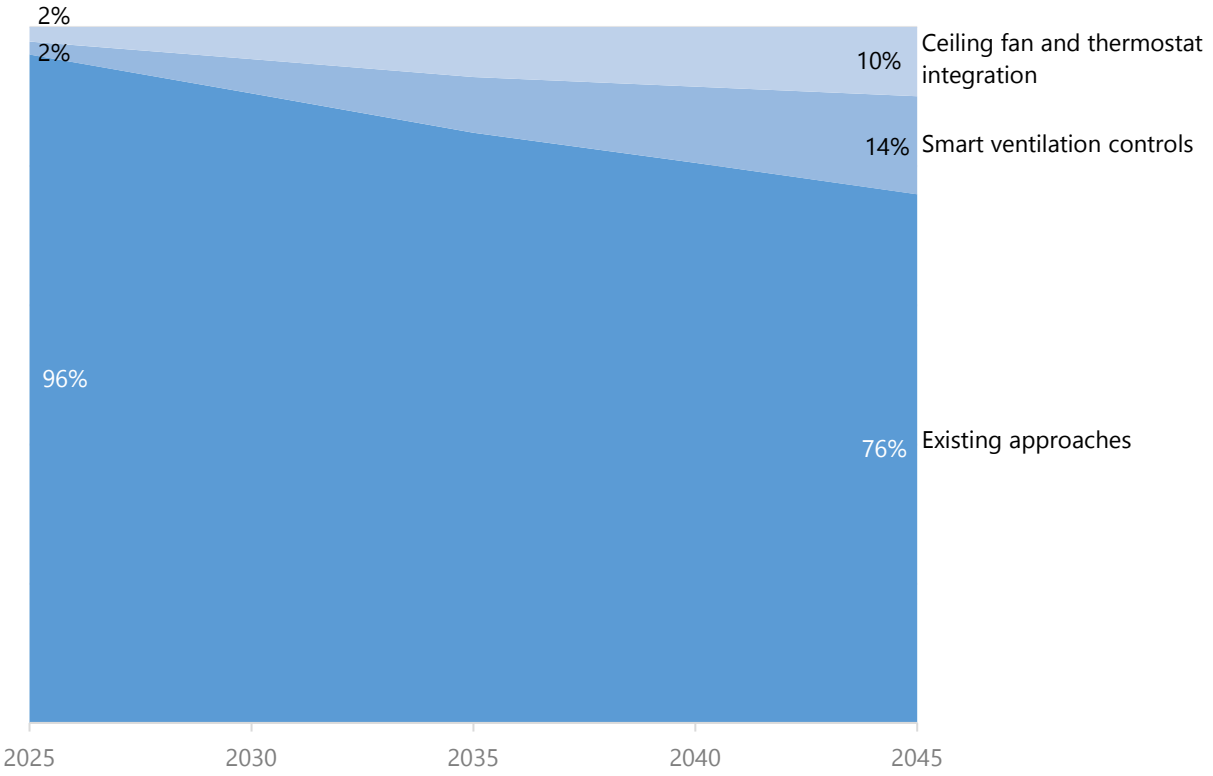
Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

HVAC - CONTROLS

Residential SF - Existing



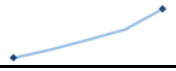
Residential MF - Existing



SMART VENTILATION CONTROLS

Climate applicability: Applicable to all CA climate zones, but twice the energy savings in hot and dry climates than in climates experiencing regular rain with cooler winters.

Residential SF - New

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**3%**	**9%**	**15%**	**23%**	**30%**		
Expert A	5%	10%	15%	20%	25%		· Ventilation will continue to increase in its importance has building envelopes become tighter.
Expert B	10%	15%	20%	25%	30%		· Phase 2: increased estimates and updated rationale. · COVID-19 concerns will increase public's interest in ventilation.
Expert C	0%	5%	8%	12%	15%		· Phase 2: increased estimates and updated rationale. · A lot of potential benefits; the institutional barriers are the primary barriers. · If a major brand purchases this, could see a lot of market share.
Expert D	5%	16%	28%	39%	50%		· This technology exists; project was focused on providing data that could inform ASHRAE standard; if ASHRAE does not accept this technology it will not substantially impact the market, estimates assume it is accepted.
Expert E	1%	5%	10%	20%	25%		· Phase 2: increased estimates and updated rationale. · Any manufacturer may take these to market, which could increase share. · Smart controls needs more demonstrations and cost reduction R&D. This project found highly variable outcomes, so much more work is needed. Also will need to comply with ASHRAE, or change ASHRAE standard. Assume code change 2035 for new homes.
Expert F	0%	10%	25%	50%	50%		· Post-pandemic, this is going to get into code because of health and safety reasons. However, there are competitors in this space- Dyson has a competing technology.
Expert G	0%	5%	8%	12%	15%		· Overall low potential: makes mechanical system more complicated.
Expert H	5%	15%	20%	25%	25%		· Phase 2: increased estimates and updated rationale. · Higher market share since COVID-19 will require increased ventilation, and this uptake will happen quickly.
Expert I	1%	5%	10%	25%	50%		· Provides both energy and health benefits and is cost-effective; anticipate substantial market adoption.
Expert J	5%	7%	7%	7%	7%		· Developers will take time to adopt this approach.
Expert K	0%	3%	10%	12%	15%		· Phase 2: updated rationale. · While T-24 requirements for continuous ventilation is energy inefficient, adjusting ventilation rates seasonally doesn't address the core purpose of adjusting ventilation rates based on IAQ. Using a better proxy for indoor pollutant levels would make more sense
Expert L	2%	10%	20%	30%	50%		· COVID-19 concerns will increase likelihood of market share. · New construction has lower barriers to adoption if packaged with a required ventilation system. Assumes ventilation required for all in code.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

SMART VENTILATION CONTROLS

Residential SF - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**2%**	**6%**	**11%**	**15%**	**18%**		
Expert A	5%	10%	15%	20%	25%		· Ventilation will continue to increase in its importance has building envelopes become tighter.
Expert B	5%	10%	15%	20%	25%		· Phase 2: increased estimates and updated rationale. · COVID-19 concerns will increase public's interest in ventilation.
Expert C	N.R.	N.R.	N.R.	N.R.	N.R.		· Biggest barrier facing this technology is acceptance with ASHRAE; but this may be a road block since there is controversy regarding ventilation rates. · estimates were provided but assume the HVAC-control markets are exclusive; estimates for the 2025 - 2045 time frame: 0%; 0%; 0%; 1%; 3%.
Expert D	N.R.	N.R.	N.R.	N.R.	N.R.		· This technology exists; project was focused on providing data that could inform ASHRAE standard; if ASHRAE does not accept this technology it will not substantially impact the market, estimates assume it is accepted. · It will be more difficult to integrate this into existing buildings than new buildings. · estimates were provided but assume the HVAC-control markets are exclusive; estimates for the 2025 - 2045 time frame: 1%; 4.5%; 8%; 11.5%; 15%.
Expert E	1%	3%	7%	10%	10%		· Phase 2: increased estimates and updated rationale. · Any manufacturer may take these to market, which could increase share. · First cost is an issue for ventilation strategy. · Homeowners less likely to use ventilation controls strategy.
Expert F	0%	10%	25%	50%	50%		· Estimates assume that code will not apply to renovations.
Expert G	0%	5%	8%	12%	15%		· Overall low potential: makes mechanical system more complicated.
Expert H	5%	10%	16%	16%	16%		· Phase 2: increased estimates and updated rationale. · Higher market share since COVID-19 will require increased ventilation, and this uptake will happen quickly.
Expert I	1%	3%	5%	8%	15%		· Phase 2: increased estimates. · Provides both energy and health benefits and is cost-effective; anticipate substantial market adoption.
Expert J	3%	4%	5%	6%	7%		· Will appeal to certain type of homeowner, Silicone Valley types, but consumer education is needed for both adoption and to teach people to use the tech correctly. Also this approach is harder in existing homes
Expert K	0%	1%	5%	6%	7%		· Phase 2: updated rationale. · While T-24 requirements for continuous ventilation is energy inefficient, adjusting ventilation rates seasonally doesn't address the core purpose of adjusting ventilation rates based on IAQ. Using a better proxy for indoor pollutant levels would make more sense
Expert L	1%	2%	4%	7%	10%		· COVID-19 concerns will increase likelihood of market share.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

SMART VENTILATION CONTROLS

Residential MF - New

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**2%**	**6%**	**11%**	**18%**	**24%**		
Expert A	5%	10%	15%	20%	25%		· Ventilation will continue to increase in its importance has building envelopes become tighter.
Expert B	1%	6%	11%	15%	20%		· Phase 2: increased estimates and updated rationale. · COVID-19 concerns will increase public's interest in ventilation.
Expert C	0%	0%	1%	3%	10%		· Biggest barrier facing this technology is acceptance with ASHRAE; but this may be a road block since there is controversy regarding ventilation rates.
Expert D	1%	5%	8%	12%	15%		· This technology exists; project was focused on providing data that could inform ASHRAE standard; if ASHRAE does not accept this technology it will not substantially impact the market, estimates assume it is accepted. · It will be less likely this will be taken up by multifamily than single family.
Expert E	1%	2%	6%	10%	10%		· Phase 2: increased estimates and updated rationale. · Any manufacturer may take these to market, which could increase share. · Code change may help to drive smart ventilation for MF.
Expert F	0%	10%	25%	50%	50%		· Post-pandemic, this is going to get into code because of health and safety reasons. However, there are competitors in this space- Dyson has a competing technology.
Expert G	0%	5%	8%	12%	15%		· Overall low potential: makes mechanical system more complicated.
Expert H	5%	10%	16%	16%	16%		· Phase 2: increased estimates and updated rationale. · Higher market share since COVID-19 will require increased ventilation, and this uptake will happen quickly.
Expert I	1%	5%	10%	25%	50%		· Provides both energy and health benefits and is cost-effective; anticipate substantial market adoption. · Split-incentive with MF owners will result in lower market share.
Expert J	5%	7%	7%	7%	7%		· Anticipated change in ventilation standard will help this technology.
Expert K	0%	3%	10%	12%	15%		· Phase 2: updated rationale. · While T-24 requirements for continuous ventilation is energy inefficient, adjusting ventilation rates seasonally doesn't address the core purpose of adjusting ventilation rates based on IAQ. Using a better proxy for indoor pollutant levels would make more sense
Expert L	2%	10%	20%	30%	50%		· COVID-19 concerns will increase likelihood of market share. · New construction has lower barriers to adoption if packaged with a required ventilation system. Assumes ventilation required for all in code.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

SMART VENTILATION CONTROLS

Residential MF - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**2%**	**5%**	**8%**	**11%**	**14%**		
Expert A	5%	10%	15%	20%	25%		· Ventilation will continue to increase in its importance has building envelopes become tighter.
Expert B	1%	8%	16%	23%	30%		· Phase 2: increased estimates and updated rationale. · COVID-19 concerns will increase public's interest in ventilation.
Expert C	N.R.	N.R.	N.R.	N.R.	N.R.		· Biggest barrier facing this technology is acceptance with ASHRAE; but this may be a road block since there is controversy regarding ventilation rates. · May be more accepted in MF existing than SF since there are more concerns about ventilation quality in MF. · estimates were provided but assume the HVAC-control markets are exclusive; estimates for the 2025 - 2045 time frame: 0%; 0%; 1%; 3%; 10%.
Expert D	N.R.	N.R.	N.R.	N.R.	N.R.		· This technology exists; project was focused on providing data that could inform ASHRAE standard; if ASHRAE does not accept this technology it will not substantially impact the market, estimates assume it is accepted. · It will be more difficult to integrate this into existing buildings than new buildings. · estimates were provided but assume the HVAC-control markets are exclusive; estimates for the 2025 - 2045 time frame: 1%; 4.5%; 8%; 11.5%; 15%.
Expert E	1%	6%	9%	12%	15%		· Phase 2: increased estimates and updated rationale. · Any manufacturer may take these to market, which could increase share.
Expert F	5%	8%	10%	10%	10%		· This will not be mandated in code and only a certain portion of consumers want ceiling fans, which will limit market uptake.
Expert G	0%	5%	8%	12%	15%		· Overall low potential: makes mechanical system more complicated.
Expert H	5%	7%	10%	12%	15%		· Phase 2: increased estimates and updated rationale. · Higher market share since COVID-19 will require increased ventilation, and this uptake will happen quickly.
Expert I	1%	1%	2%	5%	10%		· Phase 2: increased estimates. · Provides both energy and health benefits and is cost-effective; anticipate substantial market adoption. · Split-incentive with MF owners will result in lower market share.
Expert J	0%	1%	2%	3%	4%		· Anticipated change in ventilation standard will help this technology.
Expert K	0%	1%	5%	6%	7%		· Phase 2: updated rationale. · While T-24 requirements for continuous ventilation is energy inefficient, adjusting ventilation rates seasonally doesn't address the core purpose of adjusting ventilation rates based on IAQ. Using a better proxy for indoor pollutant levels would make more sense
Expert L	1%	2%	4%	7%	10%		· COVID-19 concerns will increase likelihood of market share.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

SMART CEILING FANS AND SMART THERMOSTAT INTEGRATION

Climate applicability: Applicable to all CA climate zones.

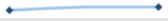
Residential SF - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**2%**	**6%**	**9%**	**11%**	**14%**		
Expert A	5%	10%	15%	20%	25%		· Difficult to use ceiling fans to effectively contribute to heating savings. · Effectiveness relies on internal climate: if moisture is high, then there is lower savings.
Expert B	5%	10%	15%	15%	15%		· Phase 2: increased estimates and updated rationale. · Potential for early adoption, with capping at 15%. · Ceiling fans will be extra expense tacked onto another type of AC systems.
Expert C	N.R.	N.R.	N.R.	N.R.	N.R.		· Cost is relatively high for implementing in existing SF so expect a slower diffusion. · Needs acceptance by ASHRAE to see large market uptake. · estimates were provided but assume the HVAC-control markets are exclusive; estimates for the 2025 - 2045 time frame: 0%; 1%; 2%; 4%; 8%.
Expert D	N.R.	N.R.	N.R.	N.R.	N.R.		· Integration of ceiling fans with thermostats is a logical approach; believes this will be accepted by the market. · estimates were provided but assume the HVAC-control markets are exclusive; estimates for the 2025 - 2045 time frame: 5%; 10%; 15%; 17.5%; 20%.
Expert E	1%	5%	10%	10%	10%		· Technology needs more development but has high promise particularly for the lower income market. Some components of this technology is in the market already, although this is more sophisticated. estimates assume this technology helps meet 2030 code.
Expert F	0%	0%	0%	5%	10%		· This will not be mandated in code and only a certain portion of consumers want ceiling fans, which will limit market uptake.
Expert G	0%	5%	8%	12%	15%		· Overall, low potential: integrating ceiling fans with thermostats seems like they may be working against each other. · Smart thermostats are regularly misused and adding another complicated mechanism seems unlikely to help.
Expert H	2%	5%	10%	10%	10%		· Fans are an underutilized resource and integration makes sense; complementary addition to smart homes. · Market accessible through home improvement stores.
Expert I	0%	0%	0%	0%	0%		· Savings estimates seem substantially overstated. Technology concept is faulty, ceiling fans cool people, not spaces, there is too much chance for unacceptable comfort variations experienced within the home.
Expert J	10%	15%	20%	25%	30%		· Consumer education is key on the fans, the rotation of the fan or blade direction is really critical - if fans pull up it is much more comfortable as opposed to if they push the air down no one likes air blowing on their head. Ceiling heights can be a limiting factor.
Expert K	0%	0%	1%	1%	1%		· Generally not optimistic about this technology since it was based on assumption that occupant would perceive improved comfort regardless of temperature.
Expert L	2%	5%	10%	15%	20%		· Fans make a lot of sense, especially if integrated with cooling system.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

SMART CEILING FANS AND SMART THERMOSTAT INTEGRATION

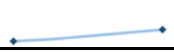
Residential MF - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**2%**	**5%**	**7%**	**9%**	**10%**		
Expert A	8%	13%	18%	23%	28%		· Difficult to use ceiling fans to effectively contribute to heating savings. · Effectiveness relies on internal climate: if moisture is high, then there is lower savings. · Fans are more likely in MF since there are typically more rooms without operating windows.
Expert B	1%	3%	6%	8%	10%		· May be a better market opportunity here- low cost alternative to renovating with additional cooling.
Expert C	N.R.	N.R.	N.R.	N.R.	N.R.		· Fans provide a low-cost comfort improvement to buildings without AC; these are more likely in MF. · Needs acceptance by ASHRAE to see large market uptake. · estimates were provided but assume the HVAC-control markets are exclusive; estimates for the 2025 - 2045 time frame: 0%; 1%; 5%; 20%; 40%.
Expert D	N.R.	N.R.	N.R.	N.R.	N.R.		· Integration of ceiling fans with thermostats is a logical approach; believes this will be accepted by the market. · estimates were provided but assume the HVAC-control markets are exclusive; estimates for the 2025 - 2045 time frame: 5%; 10%; 15%; 17.5%; 20%.
Expert E	1%	5%	10%	10%	10%		· Technology needs more development but has high promise particularly for the lower income market. Some components of this technology is in the market already, although this is more sophisticated. estimates assume this technology helps meet 2030 code.
Expert F	5%	8%	10%	10%	10%		· This will not be mandated in code and only a certain portion of consumers want ceiling fans, which will limit market uptake.
Expert G	0%	5%	8%	12%	15%		· Overall, low potential: integrating ceiling fans with thermostats seems like they may be working against each other. · Smart thermostats are regularly misused and adding another complicated mechanism seems unlikely to help.
Expert H	2%	5%	10%	10%	10%		· Fans are an underutilized resource and integration makes sense; complementary addition to smart homes. · Market accessible through home improvement stores.
Expert I	0%	0%	0%	0%	0%		· Savings estimates seem substantially overstated. Technology concept is faulty, ceiling fans cool people, not spaces, there is too much chance for unacceptable comfort variations experienced within the home. · Split-incentive with MF owners will result in lower market share.
Expert J	3%	3%	3%	3%	3%		· Great low income strategy for retrofit; can be done by anyone. Consumer education is key on the fans, the rotation of the fan or blade direction is really critical- if fans pull up it is much more comfortable as opposed to if they push the air down no one likes air blowing on their head. Ceiling heights can be a limiting factor. · Landlords will not implement this unless mandated.
Expert K	0%	0%	1%	1%	1%		· Generally not optimistic about this technology since it was based on assumption that occupant would perceive improved comfort regardless of temperature.
Expert L	2%	4%	7%	10%	13%		· Phase 2: decreased estimates and updated rationale. · Fans make a lot of sense, especially if integrated with cooling system but will be more difficult in MF.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

SMART CEILING FANS AND SMART THERMOSTAT INTEGRATION

Commercial - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**2%**	**5%**	**8%**	**10%**	**14%**		
Expert A	5%	10%	15%	20%	25%		· Difficult to use ceiling fans to effectively contribute to heating savings. · Effectiveness relies on internal climate: if moisture is high, then there is lower savings.
Expert B	5%	11%	18%	24%	30%		· This kind of technology is already in use in commercial buildings.
Expert C	0%	0%	1%	1%	1%		· Phase 2: decreased estimates and updated rationale. · Ceiling fans are really uncommon in commercial, so unlikely to see this uptake in the market.
Expert D	N.R.	N.R.	N.R.	N.R.	N.R.		· Does not have a sense for the prevalence of ceiling fans in the commercial market, no estimates provided.
Expert E	1%	5%	10%	10%	15%		· Phase 2: increased estimates. · Entry and exit and associated air exchange dynamics makes this less helpful here. Not as concerned with energy savings from this market (often renters pay utilities on building).
Expert F	0%	0%	0%	0%	0%		· Big Ass Fans has the market share of commercial buildings that want ceiling fans.
Expert G	0%	5%	8%	12%	15%		· Overall, low potential: integrating ceiling fans with thermostats seems like they may be working against each other. · Smart thermostats are regularly misused and adding another complicated mechanism seems unlikely to help.
Expert H	2%	4%	5%	7%	8%		· Phase 2: increased estimates due to previous underestimates of market potential in commercial setting.
Expert I	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert J	5%	8%	11%	14%	20%		· Phase 2: increased estimates. · Have seen a similar strategy work successfully in institutional buildings.
Expert K	0%	0%	1%	1%	1%		· Generally not optimistic about this technology since it was based on assumption that occupant would perceive improved comfort regardless of temperature.
Expert L	2%	5%	10%	15%	20%		· Fans make a lot of sense, especially if integrated with cooling system.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

ULTRA-THIN FLEXIBLE LED LIGHTING PANELS

Climate applicability: Applicable to all CA climate zones.

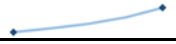
Commercial - New

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**4%**	**10%**	**17%**	**25%**	**39%**		
Expert A	10%	20%	30%	40%	50%		· Technology offers a new aesthetic expression for lighting which will be very appealing to architects and designers.
Expert B	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert C	0%	1%	5%	20%	60%		· Technological challenge of increasing panel size remains, but assuming technology can be scaled up, this is very promising.
Expert D	1%	8%	15%	23%	30%		· Technology provides opportunity for more uniform ceiling look in commercial retail that is better than linear tube lighting. · There is more competition in new construction for alternative approaches (e.g., daylighting techniques) so uptake may be lower compared to existing.
Expert E	1%	3%	5%	10%	15%		· Grantee does not provide data to support lower cost claims. Technology still needs to develop for larger sizes. However, maintaining uniformity and efficacy at larger sizes has always been a challenge for LEDs. · Market share estimates provided are specific to the current manufacturer, IEc intended for experts to focus on total market share of the technology or approach.
Expert F	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert G	10%	23%	35%	48%	60%		· Existing solutions seem adequate for the market; but assuming this can be done cheaply this will have uptake.
Expert H	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert I	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert J	8%	11%	14%	17%	24%		· Phase 2: increased estimates due to clarification that these can re-use existing fixtures.
Expert K	0%	5%	10%	15%	20%		· Provides a very interesting architectural alternative and may be very attractive on the market.
Expert L	2%	10%	20%	30%	50%		· Phase 2: decreased estimates due to previous overestimates.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

ULTRA-THIN FLEXIBLE LED LIGHTING PANELS

Commercial - Existing

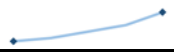
Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**3%**	**8%**	**15%**	**23%**	**35%**		
Expert A	10%	20%	30%	40%	50%		· Technology offers a new aesthetic expression for lighting which will be very appealing to architects and designers.
Expert B	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert C	0%	1%	5%	20%	60%		· Technological challenge of increasing panel size remains, but assuming technology can be scaled up, this is very promising.
Expert D	1%	11%	20%	30%	40%		· Technology provides opportunity for more uniform ceiling look in commercial retail that is better than linear tube lighting.
Expert E	0%	1%	3%	5%	10%		· Harder to retrofit than new. Thin flexible is good option however. New technologies evolving all the time
Expert F	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert G	10%	23%	35%	48%	60%		· Existing solutions seem adequate for the market; but assuming this can be done cheaply this will have uptake.
Expert H	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert I	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert J	1%	2%	5%	7%	10%		· Phase 2: increased estimates due to clarification that these can re-use existing fixtures.
Expert K	0%	3%	5%	8%	10%		· Provides an interesting architectural alternative which makes it attractive on the market.
Expert L	2%	8%	15%	25%	40%		· Phase 2: decreased estimates due to difficulty retrofitting in existing buildings.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

FLEXIBLE, NETWORKED LIGHTING CONTROL SYSTEMS

Climate applicability: Applicable to all CA climate zones.

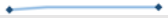
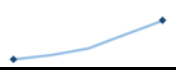
Commercial - New

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**3%**	**5%**	**11%**	**15%**	**22%**		
Expert A	N.R.	N.R.	N.R.	N.R.	N.R.		· Unable to predict market uptake since the identified challenge (lack of multi-vendor interoperability in the market) is not addressed by the technological aspects of the project.
Expert B	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert C	0%	1%	5%	10%	25%		· Phase 2: decreased estimates and updated rationale. · Agree with comments from Expert E, control complexity and desk personalization is not always desired.
Expert D	10%	15%	20%	30%	40%		· This technology allows for individual and local control which is appealing to consumers.
Expert E	1%	5%	10%	15%	25%		· Phase 2: increased estimates and updated rationale. · Any manufacturer may take these to market, which could increase share. · Competition from OLEDs may limit market share.
Expert F	0%	0%	20%	20%	20%		· Effectively addresses market issue that different lighting systems cannot "talk." · User customization and control is important. · Market share is limited to open office concepts where users are stable and sit in the same place for a while.
Expert G	1%	5%	5%	5%	5%		· Phase 2: increased estimates due to rationale provided by other experts that this does fix a problem.
Expert H	5%	10%	15%	20%	20%		· Mechanisms in which this is incentivized in the market are complicated to manage but the technology has merit.
Expert I	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert J	1%	2%	3%	4%	5%		· Unclear if this can be integrated into an existing EMS system. Everyone loves the idea of lighting controls but facilities/maintenance people cannot stand them - they always need to be tinkered with. They would rather have occupancy/vacancy standards so you don't need access to software.
Expert K	0%	1%	2%	5%	10%		· There is a need for a more standard interface for networked systems and connecting this to national standards is important.
Expert L	5%	10%	20%	30%	50%		· Phase 2: decreased estimates due to rationale provided by other experts.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

FLEXIBLE, NETWORKED LIGHTING CONTROL SYSTEMS

Commercial - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**2%**	**5%**	**10%**	**14%**	**16%**		
Expert A	N.R.	N.R.	N.R.	N.R.	N.R.		· Unable to predict market uptake since the identified challenge (lack of multi-vendor interoperability in the market) is not addressed by the technological aspects of the project.
Expert B	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert C	N.R.	N.R.	N.R.	N.R.	N.R.		· Phase 2: removed estimates, could not comment on underlying assumptions in this sector.
Expert D	5%	8%	10%	15%	20%		· This technology allows for individual and local control which is appealing to consumers. · Will be more difficult to implement in existing buildings since it requires updating the existing lighting and this increases cost of adaptation.
Expert E	0%	10%	15%	20%	20%		· Phase 2: increased estimates and updated rationale. · Any manufacturer may take these to market, which could increase share. · Competition from OLEDs may limit market share.
Expert F	0%	0%	20%	20%	20%		· Effectively addresses market issue that different lighting systems cannot "talk" to each other. · User customization and control is important. · Market share is limited to open office concepts where users are stable and sit in the same place for a while.
Expert G	1%	5%	5%	5%	5%		· Phase 2: increased estimates due to rationale provided by other experts that this does fix a problem.
Expert H	5%	10%	15%	20%	20%		· Mechanisms in which this is incentivized in the market are complicated to manage but the technology has merit.
Expert I	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert J	1%	2%	3%	4%	5%		· Unclear if this can be integrated into an existing EMS system. Everyone loves the idea of lighting controls but facilities/maintenance people cannot stand them - they always need to be tinkered with. They would rather have occupancy/vacancy standards so you don't need access to software.
Expert K	0%	0%	1%	4%	7%		· There is a need for a more standard interface for networked systems and connecting this to national standards is important.
Expert L	2%	5%	10%	20%	30%		· Harder to get into existing buildings than new construction, but tenants will want it in the future. Also security/safety benefits and benefits to occupants (can count # of occupants in a room). If you have a fire, you know how many people are in the building and need to get out. Some of these also have temperature sensors and HVAC integration.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

ENERGY EFFICIENT PLUG LOAD DESIGNS

Climate applicability: Applicable to all CA climate zones.

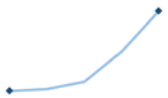
Residential SF - New

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**4%**	**7%**	**11%**	**18%**	**26%**		
Expert A	0%	3%	5%	8%	10%		· Benefits of technology will only materialize if CA adopts the industry technology standard proposed by the project; market uptake estimates assume it does before 2030.
Expert B	N.R.	N.R.	N.R.	N.R.	N.R.		· Did not provide market estimates. · Typically, people do not think about plug loads, so if these technologies are adopted into standards or EnergyStar, they will have substantial adoption, otherwise they will not. Additionally, if the technology restricts ease of use of everyone's gadgets, it will fail.
Expert C	1%	3%	10%	40%	80%		· Success is dependent on integration into EnergyStar; estimates assume this happens. · Commercial uptake would be faster since use of computers in this sector occurs faster than in residential. · Fast growth in market share aligns with adoption curves for electronics.
Expert D	0%	0%	0%	0%	0%		· Appliances that are focus of research will be obsolete by the time standards are developed for them; there is no market for this.
Expert E	1%	1%	1%	1%	1%		· No federal standard can be written for these because they are developed by product, and the per product energy savings is not good enough to justify a standard. · Manufacturers resist these components because of cost concerns. · Potential for customer dissatisfaction as well.
Expert F	2%	5%	0%	0%	0%		· Largely irrelevant given that we are going from desktop to cloud computing for digital processing, which has massive energy benefits.
Expert G	10%	20%	30%	40%	50%		· Is promising because it is complementary to CEC and other agency's electronic efficiency efforts.
Expert H	10%	15%	20%	25%	25%		· Since approach is not targeting a specific vendor, but the industry overall, it could increase market uptake if integrated in EnergyStar standard.
Expert I	2%	5%	15%	25%	35%		· Energy efficient plug loads are easy to integrate if there is a standard, and this work effectively addresses that challenge.
Expert J	15%	20%	25%	30%	35%		· Cost, consumer education will be key to uptake.
Expert K	0%	3%	10%	12%	15%		· Technological reliability needs to improve; estimates provided assuming performance is improved.
Expert L	1%	5%	10%	20%	30%		· Given it's relatively low cost and impact, it is likely these technologies will be incorporated into Title 24 for new construction codes and standards

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

ENERGY EFFICIENT PLUG LOAD DESIGNS

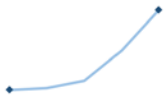
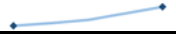
Residential SF - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**4%**	**7%**	**10%**	**16%**	**23%**		
Expert A	0%	3%	5%	8%	10%		· Benefits of technology will only materialize if CA adopts the industry technology standard proposed by the project; market uptake estimates assume it does before 2030.
Expert B	N.R.	N.R.	N.R.	N.R.	N.R.		· Did not provide market estimates. · Typically, people do not think about plug loads, so if these technologies are adopted into standards or EnergyStar, they will have substantial adoption, otherwise they will not. Additionally, if the technology restricts ease of use of everyone's gadgets, it will fail.
Expert C	1%	3%	10%	40%	80%		· Success is dependent on integration into EnergyStar; estimates assume this happens. · Commercial uptake would be faster since use of computers in this sector occurs faster than in residential. · Fast growth in market share aligns with adoption curves for electronics.
Expert D	0%	0%	0%	0%	0%		· Appliances that are focus of research will be obsolete by the time standards are developed for them; there is no market for this.
Expert E	1%	1%	1%	1%	1%		· No federal standard can be written for these because they are developed by product, and the per product energy savings is not good enough to justify a standard. · Manufacturers resist these components because of cost concerns. · Potential for customer dissatisfaction as well.
Expert F	2%	5%	0%	0%	0%		· Largely irrelevant given that we are going from desktop to cloud computing for digital processing, which has massive energy benefits.
Expert G	10%	20%	30%	40%	50%		· Is promising because it is complementary to CEC and other agency's electronic efficiency efforts.
Expert H	10%	15%	20%	25%	25%		· Since approach is not targeting a specific vendor, but the industry overall, it could increase market uptake if integrated in EnergyStar standard.
Expert I	1%	3%	8%	13%	25%		· Energy efficient plug loads are easy to integrate if there is a standard, and this work effectively addresses that challenge.
Expert J	15%	20%	25%	30%	35%		· Cost, consumer education will be key to uptake.
Expert K	0%	3%	10%	12%	15%		· Technological reliability needs to improve; estimates provided assuming performance is improved.
Expert L	1%	3%	5%	8%	12%		· No specific comments.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

ENERGY EFFICIENT PLUG LOAD DESIGNS

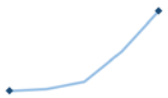
Residential MF - New

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**4%**	**7%**	**11%**	**18%**	**25%**		
Expert A	0%	3%	5%	8%	10%		· Benefits of technology will only materialize if CA adopts the industry technology standard proposed by the project; market uptake estimates assume it does before 2030.
Expert B	N.R.	N.R.	N.R.	N.R.	N.R.		· Did not provide market estimates. · Typically, people do not think about plug loads, so if these technologies are adopted into standards or EnergyStar, they will have substantial adoption, otherwise they will not. Additionally, if the technology restricts ease of use of everyone's gadgets, it will fail.
Expert C	1%	3%	10%	40%	80%		· Success is dependent on integration into EnergyStar; estimates assume this happens. · Commercial uptake would be faster since use of computers in this sector occurs faster than in residential. · Fast growth in market share aligns with adoption curves for electronics.
Expert D	0%	0%	0%	0%	0%		· Appliances that are focus of research will be obsolete by the time standards are developed for them; there is no market for this.
Expert E	1%	1%	1%	1%	1%		· No federal standard can be written for these because they are developed by product, and the per product energy savings is not good enough to justify a standard. · Manufacturers resist these components because of cost concerns. · Potential for customer dissatisfaction as well.
Expert F	2%	5%	0%	0%	0%		· Largely irrelevant given that we are going from desktop to cloud computing for digital processing, which has massive energy benefits.
Expert G	10%	20%	30%	40%	50%		· Is promising because it is complementary to CEC and other agency's electronic efficiency efforts.
Expert H	10%	15%	20%	25%	25%		· Since approach is not targeting a specific vendor, but the industry overall, it could increase market uptake if integrated in EnergyStar standard.
Expert I	1%	3%	8%	13%	25%		· Energy efficient plug loads are easy to integrate if there is a standard, and this work effectively addresses that challenge. · Longer timeframe for adoption due to split incentive.
Expert J	20%	25%	30%	35%	40%		· Cost, consumer education will be key to uptake.
Expert K	0%	3%	10%	12%	15%		· Technological reliability needs to improve; estimates provided assuming performance is improved.
Expert L	1%	5%	10%	20%	30%		· Given it's relatively low cost and impact, it is likely these technologies will be incorporated into Title 24 for new construction codes and standards.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

ENERGY EFFICIENT PLUG LOAD DESIGNS

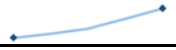
Residential MF - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**3%**	**5%**	**8%**	**14%**	**20%**		
Expert A	0%	3%	5%	8%	10%		· Benefits of technology will only materialize if CA adopts the industry technology standard proposed by the project; market uptake estimates assume it does before 2030.
Expert B	N.R.	N.R.	N.R.	N.R.	N.R.		· Did not provide market estimates. · Typically, people do not think about plug loads, so if these technologies are adopted into standards or EnergyStar, they will have substantial adoption, otherwise they will not. Additionally, if the technology restricts ease of use of everyone's gadgets, it will fail.
Expert C	1%	3%	10%	40%	80%		· Success is dependent on integration into EnergyStar; estimates assume this happens. · Commercial uptake would be faster since use of computers in this sector occurs faster than in residential. · Fast growth in market share aligns with adoption curves for electronics.
Expert D	0%	0%	0%	0%	0%		· Appliances that are focus of research will be obsolete by the time standards are developed for them; there is no market for this.
Expert E	1%	1%	1%	1%	1%		· No federal standard can be written for these because they are developed by product, and the per product energy savings is not good enough to justify a standard. · Manufacturers resist these components because of cost concerns. · Potential for customer dissatisfaction as well.
Expert F	2%	5%	0%	0%	0%		· Largely irrelevant given that we are going from desktop to cloud computing for digital processing, which has massive energy benefits.
Expert G	10%	20%	30%	40%	50%		· Is promising because it is complementary to CEC and other agency's electronic efficiency efforts.
Expert H	10%	15%	20%	25%	25%		· Since approach is not targeting a specific vendor, but the industry overall, it could increase market uptake if integrated in EnergyStar standard.
Expert I	1%	3%	8%	13%	25%		· Energy efficient plug loads are easy to integrate if there is a standard, and this work effectively addresses that challenge. · Longer timeframe for adoption due to split incentive.
Expert J	3%	3%	3%	3%	3%		· Cost, consumer education will be key to uptake.
Expert K	0%	3%	10%	12%	15%		· Technological reliability needs to improve; estimates provided assuming performance is improved.
Expert L	1%	3%	5%	10%	15%		· Phase 2: decreased estimates due to rationale provided by other experts.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

ENERGY EFFICIENT PLUG LOAD DESIGNS

Commercial - New

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**5%**	**8%**	**13%**	**20%**	**27%**		
Expert A	0%	3%	5%	8%	10%		· Benefits of technology will only materialize if CA adopts the industry technology standard proposed by the project; market uptake estimates assume it does before 2030.
Expert B	N.R.	N.R.	N.R.	N.R.	N.R.		· Did not provide market estimates. · Typically, people do not think about plug loads, so if these technologies are adopted into standards or EnergyStar, they will have substantial adoption, otherwise they will not. Additionally, if the technology restricts ease of use of everyone's gadgets, it will fail.
Expert C	2%	5%	20%	60%	100%		· Success is dependent on integration into EnergyStar; estimates assume this happens. · Commercial uptake would be faster since use of computers in this sector occurs faster than in residential. · Fast growth in market share aligns with adoption curves for electronics.
Expert D	0%	0%	0%	0%	0%		· Appliances that are focus of research will be obsolete by the time standards are developed for them; there is no market for this.
Expert E	1%	1%	1%	1%	1%		· No federal standard can be written for these because they are developed by product, and the per product energy savings is not good enough to justify a standard. · Manufacturers resist these components because of cost concerns. · Potential for customer dissatisfaction as well.
Expert F	2%	5%	0%	0%	0%		· Largely irrelevant given that we are going from desktop to cloud computing for digital processing, which has massive energy benefits.
Expert G	10%	20%	30%	40%	50%		· Is promising because it is complementary to CEC and other agency's electronic efficiency efforts.
Expert H	10%	15%	20%	25%	25%		· Since approach is not targeting a specific vendor, but the industry overall, it could increase market uptake if integrated in EnergyStar standard.
Expert I	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert J	20%	25%	30%	35%	40%		· Trades and skilled labor outreach will be critical for new construction uptake. Cost, consumer education will be key to uptake.
Expert K	0%	3%	10%	12%	15%		· Technological reliability needs to improve; estimates provided assuming performance is improved.
Expert L	1%	5%	10%	20%	30%		· Phase 2: decreased estimates due to rationale provided by other experts. · Given its relatively low cost and impact, it is likely these technologies will be incorporated into Title 24 for new construction codes and standards

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

ENERGY EFFICIENT PLUG LOAD DESIGNS

Commercial - Existing

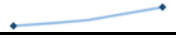
Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**5%**	**8%**	**12%**	**19%**	**25%**		
Expert A	0%	3%	5%	8%	10%		· Benefits of technology will only materialize if CA adopts the industry technology standard proposed by the project; market uptake estimates assume it does before 2030.
Expert B	N.R.	N.R.	N.R.	N.R.	N.R.		· Did not provide market estimates. · Typically, people do not think about plug loads, so if these technologies are adopted into standards or EnergyStar, they will have substantial adoption, otherwise they will not. Additionally, if the technology restricts ease of use of everyone's gadgets, it will fail.
Expert C	2%	5%	20%	60%	100%		· Success is dependent on integration into EnergyStar; estimates assume this happens. · Commercial uptake would be faster since use of computers in this sector occurs faster than in residential. · Fast growth in market share aligns with adoption curves for electronics.
Expert D	0%	0%	0%	0%	0%		· Appliances that are focus of research will be obsolete by the time standards are developed for them; there is no market for this.
Expert E	1%	1%	1%	1%	1%		· No federal standard can be written for these because they are developed by product, and the per product energy savings is not good enough to justify a standard. · Manufacturers resist these components because of cost concerns. · Potential for customer dissatisfaction as well.
Expert F	2%	5%	0%	0%	0%		· Largely irrelevant given that we are going from desktop to cloud computing for digital processing, which has massive energy benefits.
Expert G	10%	20%	30%	40%	50%		· Is promising because it is complementary to CEC and other agency's electronic efficiency efforts.
Expert H	10%	15%	20%	25%	25%		· Since approach is not targeting a specific vendor, but the industry overall, it could increase market uptake if integrated in EnergyStar standard.
Expert I	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert J	20%	25%	30%	35%	40%		· For renovations, the ground fault circuit interrupters are often changed without a permit, they shouldn't be but they, are so it will be hard to predict market uptake for commercial.
Expert K	0%	3%	10%	12%	15%		· Technological reliability needs to improve; estimates provided assuming performance is improved.
Expert L	1%	3%	5%	8%	12%		· No specific comments.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

ZERO NET ENERGY PLUG LOADS

Climate applicability: Applicable to all CA climate zones.

Residential SF - New

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**3%**	**6%**	**9%**	**14%**	**21%**		
Expert A	3%	5%	8%	10%	13%		· Associated benefits for safety and resilience will drive substantial market uptake for this product.
Expert B	N.R.	N.R.	N.R.	N.R.	N.R.		· Did not provide market estimates. · A customer who hires an architect/builder for a net zero home will utilize this technology, but this is a very niche/small market.
Expert C	5%	10%	20%	40%	80%		· Phase 2: increased estimates and updated rationale. · Agree with Expert G rationale.
Expert D	N.R.	N.R.	N.R.	N.R.	N.R.		· Project does not seem relevant to estimating market adoption since it did not focus on a marketable technology.
Expert E	1%	1%	1%	1%	2%		· Market is too niche: only buildings with DC circuit, PV on the roof, and battery backup needed for medical. · Health/safety issues need to be addressed as well.
Expert F	0%	0%	0%	0%	0%		· DC plug load makes technology complicated and unlikely to be adopted. · Home medical market may be too small.
Expert G	5%	5%	10%	10%	10%		· Phase 2: decreased estimates and updated rationale. · Negative will still outweigh positive. · Plug loads will become more important as ZNE takes hold; so these smaller efforts to minimize load will become more important. However switching appliances from AC to DC may be difficult.
Expert H	5%	5%	5%	5%	5%		· Only applicable to niche market; only for ZNE buildings.
Expert I	2%	5%	15%	25%	35%		· Phase 2: updated rationale. · 80% of equipment uses DC power now. We will get there, and it needs to happen since it provides a more resilient option since we need battery backup for grid-interactive capabilities and resiliency reasons.
Expert J	5%	20%	25%	30%	35%		· Phase 2: decreased estimates and updated rationale. · Uptake is going to be code driven but will not be updated in early years.
Expert K	0%	1%	1%	2%	2%		· Cost to connect this to a PV system with DC power option is barrier to substantial uptake.
Expert L	1%	5%	10%	20%	30%		· Given it's relatively low cost and impact, it is likely these technologies will be incorporated into Title 24 for new construction codes and standards

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

ZERO NET ENERGY PLUG LOADS

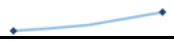
Residential SF - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**2%**	**2%**	**4%**	**5%**	**7%**		
Expert A	3%	5%	8%	10%	13%		· Associated benefits for safety and resilience will drive substantial market uptake for this product.
Expert B	N.R.	N.R.	N.R.	N.R.	N.R.		· Did not provide market estimates. · A customer who hires an architect/builder for a net zero home will utilize this technology, but this is a very niche/small market.
Expert C	0%	0%	1%	2%	5%		· Phase 2: increased estimates and updated rationale. · Agree with Expert G rationale; update will still be relatively low in existing buildings.
Expert D	N.R.	N.R.	N.R.	N.R.	N.R.		· Project does not seem relevant to estimating market adoption since it did not focus on a marketable technology.
Expert E	0%	1%	1%	1%	2%		· Expensive rewiring makes ZNE plug load approach too costly for existing residential.
Expert F	0%	0%	0%	0%	0%		· DC plug load makes technology complicated and unlikely to be adopted. · Home medical market may be too small.
Expert G	5%	5%	10%	10%	10%		· Phase 2: decreased estimates and updated rationale. · Negative will still outweigh positive. · Plug loads will become more important as ZNE takes hold; so these smaller efforts to minimize load will become more important. However switching appliances from AC to DC may be difficult.
Expert H	5%	5%	5%	5%	5%		· Only applicable to niche market; only for ZNE buildings.
Expert I	1%	1%	3%	7%	12%		· Phase 2: increased estimates and updated rationale. · 80% of equipment uses DC power now. We will get there, and it needs to happen since it provides a more resilient option since we need battery backup for grid-interactive capabilities and resiliency reasons.
Expert J	5%	5%	10%	10%	10%		· Phase 2: decreased estimates and updated rationale. · Prior estimates were too high.
Expert K	0%	0%	0%	0%	0%		· Cost to connect this to a PV system with DC power option is barrier to substantial uptake, not applicable to existing buildings at all.
Expert L	1%	3%	5%	8%	12%		· No specific comments.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

ZERO NET ENERGY PLUG LOADS

Residential MF - New

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**3%**	**4%**	**11%**	**16%**	**23%**		
Expert A	3%	5%	8%	10%	13%		· Associated benefits for safety and resilience will drive substantial market uptake for this product.
Expert B	N.R.	N.R.	N.R.	N.R.	N.R.		· Did not provide market estimates. · A customer who hires an architect/builder for a net zero home will utilize this technology, but this is a very niche/small market.
Expert C	5%	10%	20%	40%	80%		· Phase 2: increased estimates and updated rationale. · Agree with Expert G rationale.
Expert D	N.R.	N.R.	N.R.	N.R.	N.R.		· Project does not seem relevant to estimating market adoption since it did not focus on a marketable technology.
Expert E	0%	0%	1%	1%	1%		· Market is too niche: only buildings with DC circuit, PV on the roof, and battery backup needed for medical. · Health/safety issues need to be addressed as well.
Expert F	0%	0%	0%	0%	0%		· DC plug load makes technology complicated and unlikely to be adopted. · Home medical market may be too small.
Expert G	5%	5%	10%	10%	10%		· Phase 2: decreased estimates and updated rationale. · Negative will still outweigh positive. · Plug loads will become more important as ZNE takes hold; so these smaller efforts to minimize load will become more important. However switching appliances from AC to DC may be difficult.
Expert H	5%	5%	5%	5%	5%		· Only applicable to niche market; only for ZNE buildings.
Expert I	2%	5%	15%	25%	35%		· Phase 2: increased estimates and updated rationale. · 80% of equipment uses DC power now. We will get there, and it needs to happen since it provides a more resilient option since we need battery backup for grid-interactive capabilities and resiliency reasons.
Expert J	5%	5%	40%	45%	50%		· Phase 2: decreased estimates and updated rationale. · Uptake is going to be code driven but will not be updated in early years.
Expert K	0%	1%	1%	2%	2%		· Cost to connect this to a PV system with DC power option is barrier to substantial uptake.
Expert L	1%	5%	10%	20%	30%		· Given it's relatively low cost and impact, it is likely these technologies will be incorporated into Title 24 for new construction codes and standards

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

ZERO NET ENERGY PLUG LOADS

Residential MF - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**2%**	**2%**	**4%**	**5%**	**6%**		
Expert A	3%	5%	8%	10%	13%		· Associated benefits for safety and resilience will drive substantial market uptake for this product.
Expert B	N.R.	N.R.	N.R.	N.R.	N.R.		· Did not provide market estimates. · A customer who hires an architect/builder for a net zero home will utilize this technology, but this is a very niche/small market.
Expert C	1%	3%	5%	8%	12%		· Phase 2: increased estimates and updated rationale. · Agree with Expert G rationale; update will still be relatively low in existing buildings.
Expert D	N.R.	N.R.	N.R.	N.R.	N.R.		· Project does not seem relevant to estimating market adoption since it did not focus on a marketable technology.
Expert E	0%	0%	1%	1%	1%		· Expensive rewiring makes ZNE plug load approach too costly for existing residential.
Expert F	0%	0%	0%	0%	0%		· DC plug load makes technology complicated and unlikely to be adopted. · Home medical market may be too small.
Expert G	5%	5%	10%	10%	10%		· Phase 2: decreased estimates and updated rationale. · Negative will still outweigh positive. · Plug loads will become more important as ZNE takes hold; so these smaller efforts to minimize load will become more important. However switching appliances from AC to DC may be difficult.
Expert H	5%	5%	5%	5%	5%		· Only applicable to niche market; only for ZNE buildings.
Expert I	0%	0%	1%	3%	5%		· Phase 2: updated rationale. · 80% of equipment uses DC power now. We will get there, and it needs to happen since it provides a more resilient option since we need battery backup for grid-interactive capabilities and resiliency reasons.
Expert J	3%	3%	3%	3%	3%		· Uptake is going to be code driven.
Expert K	0%	0%	0%	0%	0%		· Cost to connect this to a PV system with DC power option is barrier to substantial uptake, not applicable to existing buildings at all.
Expert L	1%	3%	5%	8%	12%		· No specific comments.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

ZERO NET ENERGY PLUG LOADS

Commercial - New

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**3%**	**6%**	**9%**	**14%**	**20%**		
Expert A	5%	10%	15%	20%	25%		· Associated benefits for safety and resilience will drive substantial market uptake for this product; particularly in hospital settings.
Expert B	N.R.	N.R.	N.R.	N.R.	N.R.		· Did not provide market estimates. · A customer who hires an architect/builder for a net zero home will utilize this technology, but this is a very niche/small market.
Expert C	5%	10%	20%	40%	80%		· Phase 2: increased estimates and updated rationale. · Agree with Expert G rationale.
Expert D	N.R.	N.R.	N.R.	N.R.	N.R.		· Project does not seem relevant to estimating market adoption since it did not focus on a marketable technology.
Expert E	0%	1%	1%	2%	2%		· Phase 2: increased estimates and updated rationale. · A few buildings will put in DC circuits with batteries, but still small niche.
Expert F	0%	0%	0%	0%	0%		· DC plug load makes technology complicated and unlikely to be adopted. · Home medical market may be too small.
Expert G	5%	5%	10%	10%	10%		· Phase 2: decreased estimates and updated rationale. · Negative will still outweigh positive. · Plug loads will become more important as ZNE takes hold; so these smaller efforts to minimize load will become more important. However switching appliances from AC to DC may be difficult.
Expert H	5%	5%	5%	5%	5%		· Only applicable to niche market; only for ZNE buildings.
Expert I	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert J	10%	15%	20%	25%	30%		· Uptake is going to be code driven.
Expert K	0%	1%	1%	2%	2%		· Cost to connect this to a PV system with DC power option is barrier to substantial uptake.
Expert L	1%	5%	10%	20%	30%		· Given it's relatively low cost and impact, it is likely these technologies will be incorporated into Title 24 for new construction codes and standards

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

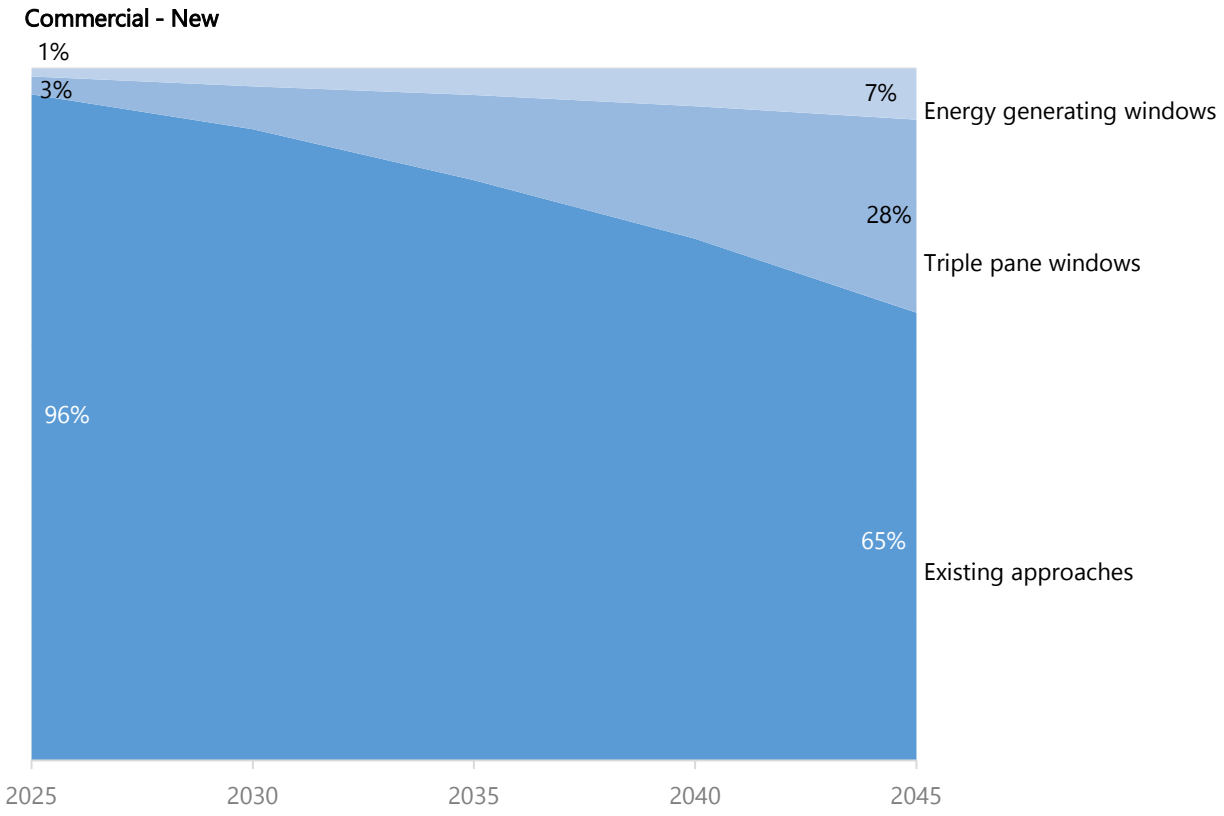
ZERO NET ENERGY PLUG LOADS

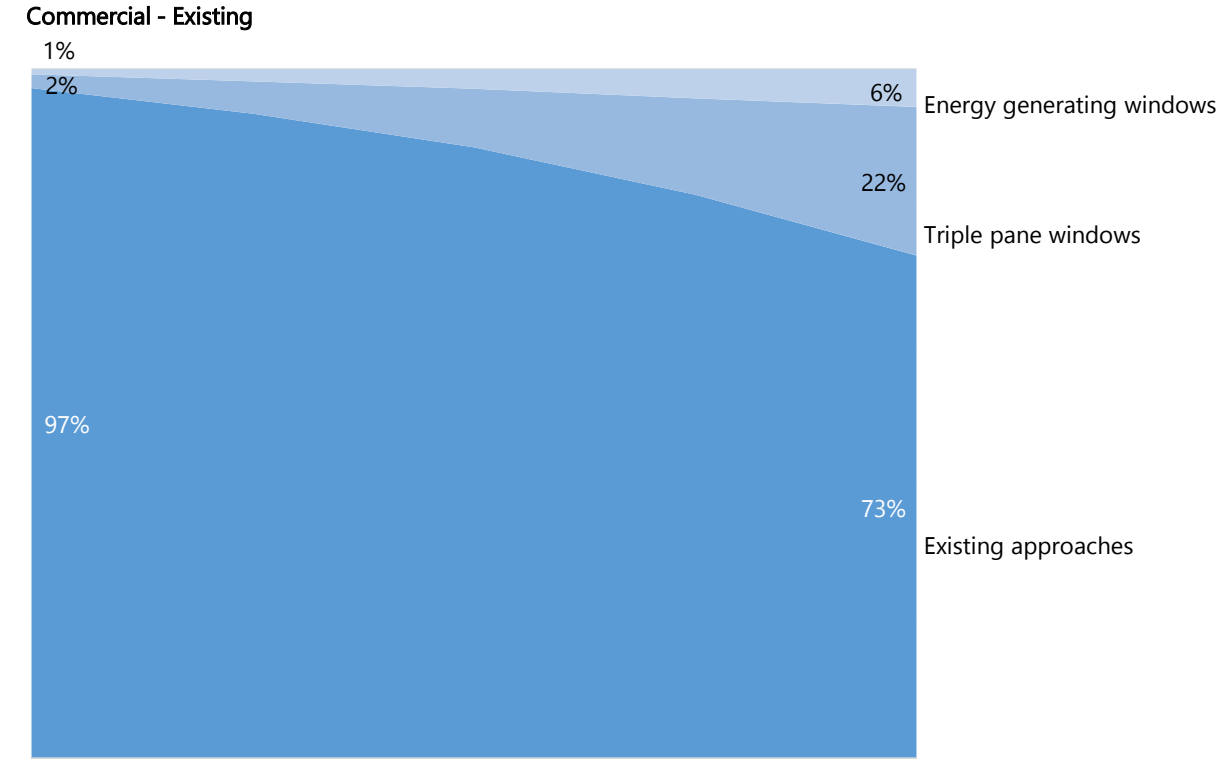
Commercial - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**3%**	**4%**	**6%**	**8%**	**10%**		
Expert A	5%	10%	15%	20%	25%		· Associated benefits for safety and resilience will drive substantial market uptake for this product; particularly in hospital settings.
Expert B	N.R.	N.R.	N.R.	N.R.	N.R.		· Did not provide market estimates. · A customer who hires an architect/builder for a net zero home will utilize this technology, but this is a very niche/small market.
Expert C	0%	1%	2%	5%	10%		· Phase 2: increased estimates and updated rationale. · Agree with Expert G rationale; update will still be relatively low in existing buildings.
Expert D	N.R.	N.R.	N.R.	N.R.	N.R.		· Project does not seem relevant to estimating market adoption since it did not focus on a marketable technology.
Expert E	0%	1%	1%	1%	1%		· Market is too niche: only buildings with DC circuit, PV on the roof, and battery backup needed for medical. · Health/safety issues need to be addressed as well.
Expert F	0%	0%	0%	0%	0%		· DC plug load makes technology complicated and unlikely to be adopted. · Home medical market may be too small.
Expert G	5%	5%	10%	10%	10%		· Phase 2: decreased estimates and updated rationale. · Negative will still outweigh positive. · Plug loads will become more important as ZNE takes hold; so these smaller efforts to minimize load will become more important. However switching appliances from AC to DC may be difficult.
Expert H	5%	5%	5%	5%	5%		· Only applicable to niche market; only for ZNE buildings.
Expert I	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert J	10%	15%	20%	25%	30%		· Uptake is going to be code driven.
Expert K	0%	0%	0%	0%	0%		· Cost to connect this to a PV system with DC power option is barrier to substantial uptake, not applicable to existing buildings at all.
Expert L	1%	3%	5%	8%	12%		· No specific comments.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

WINDOWS

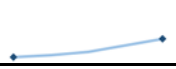

Commercial - New
1%
3%
7%
Energy generating windows
28%
Triple pane windows
96%
65%
Existing approaches
2025
2030
2035
2040
2045


Commercial - Existing
1%
2%
6%
Energy generating windows
22%
Triple pane windows
97%
73%
Existing approaches

TRIPLE PANE INSULATING GLASS WITH LOW-CONDUCTANCE ALUMINUM FRAME

Climate applicability: Applicable to all CA climate zones.

Commercial - New

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**3%**	**6%**	**12%**	**19%**	**28%**		
Expert A	5%	10%	20%	25%	30%		· Phase 2: increased estimates and updated rationale. · Huge industry breakthrough. Double pane low E tops out at R4, and triple panes from Europe are heavy and expensive and top out at R8. This 1 inch triple pane is the bridge between the two, and the first bridge that we have.
Expert B	1%	16%	31%	45%	60%		· Subset of building owners will put in better windows for HVAC savings and code points, however these windows are not a good option.
Expert C	1%	2%	5%	20%	40%		· Technologies that account for user input in a commercial setting will be well received. · Savings potential looks promising.
Expert D	1%	3%	5%	5%	5%		· No specific comments.
Expert E	1%	3%	10%	15%	25%		· Expensive alternative, but market currently produces TVs with this glass which has dropped the price. Real world energy savings and persistence not demonstrated yet, but likely will be, and an anticipated code change around 2030 will help. · Market share estimates provided are specific to the current manufacturer, IEc intended for experts to focus on total market share of the technology or approach.
Expert F	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert G	5%	5%	10%	20%	40%		· Phase 2: decreased estimates and updated rationale. · Agreed with other experts' rationale that California climate may reduce cost-effectiveness of technology.
Expert H	2%	5%	7%	10%	12%		· Phase 2: increased estimates and updated rationale. · There will be a number of buildings seeking ZNE, where this would make sense.
Expert I	1%	2%	3%	4%	5%		· Phase 2: included estimates and updated rationale. · Commercial buildings are load dominated. · This is only effective in very cold climates, which is not majority of California.
Expert J	10%	15%	25%	35%	45%		· Phase 2: increased estimates due to focus on just triple pane technology. · Passive technology like this that does not require maintenance and calibration are key factors. However, cost need to come down and/or code needs to mandate this kind of approach to really take off.
Expert K	0%	3%	10%	12%	15%		· Fitting a triple pane window in same space as double pane makes this appealing. · Technology still needs to be proven at large scale.
Expert L	2%	5%	10%	20%	30%		· Phase 2: decreased estimates and updated rationale. · Cost-effectiveness an issue and influenced by other experts' rationale.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

TRIPLE PANE INSULATING GLASS WITH LOW-CONDUCTANCE ALUMINUM FRAME

Commercial - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**2%**	**5%**	**9%**	**14%**	**22%**		
Expert A	10%	15%	20%	25%	30%		· Phase 2: increased estimates and updated rationale. · Technological innovation for 1-inch wide triple-pane window has substantial positive implications for commercial, particularly existing sector because of the 1-to-1 swap out.
Expert B	1%	16%	31%	45%	60%		· Subset of building owners will put in better windows for HVAC savings and code points, however these windows are not a good option.
Expert C	1%	2%	5%	20%	40%		· Technologies that account for user input in a commercial setting will be well received. · Savings potential looks promising.
Expert D	1%	3%	5%	5%	5%		· No specific comments.
Expert E	1%	1%	5%	10%	20%		· Triple pane windows expected to lag behind new for a while, but once costs and code changes come into play, this will shift to par. Also expect other similar fenestrations to take market share
Expert F	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert G	5%	5%	10%	20%	40%		· Phase 2: decreased estimates and updated rationale. · Agreed with other experts' rationale that California climate may reduce cost-effectiveness of technology.
Expert H	2%	5%	7%	10%	12%		· Phase 2: increased estimates and updated rationale. · There will be a number of buildings seeking deep retrofits, where this would make sense.
Expert I	0%	0%	1%	1%	2%		· Phase 2: included estimates and updated rationale. · Unlikely that windows will be updated in existing commercial buildings.
Expert J	1%	2%	3%	4%	5%		· Passive technology like this that does not require maintenance and calibration are key factors. However, cost need to come down and/or code needs to mandate this kind of approach to really take off.
Expert K	0%	1%	1%	2%	3%		· Fitting a triple pane window in same space as double pane makes this appealing. · Technology still needs to be proven at large scale. · Less likelihood of retrofits doing this as a replacement.
Expert L	1%	3%	6%	12%	20%		· New construction more likely to take off than retrofits, so lower estimates here.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

ADVANCED ENERGY EFFICIENT AND ENERGY GENERATING WINDOWS (CLEARVIEW)

Climate applicability: Applicable to all CA climate zones.

Commercial - New

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**1%**	**3%**	**4%**	**5%**	**7%**		
Expert A	3%	5%	8%	10%	13%		· No specific comments.
Expert B	0%	5%	10%	15%	20%		· Expect a lot of adoption resistance due to complexity, maintenance, and control issues. But if it proves to work and is not a maintenance nightmare, it will ultimately have a high adoption rate.
Expert C	N.R.	N.R.	N.R.	N.R.	N.R.		· Phase 2: removed estimates. · Not area of expertise.
Expert D	0%	0%	0%	0%	1%		· Efficiency is low for this technology, may have more applicability to smart watches. · Minimal market uptake anticipated, only in buildings aiming to implement niche technologies.
Expert E	0%	1%	1%	1%	1%		· Great concept, challenge is getting energy from window to building system. Needs to be an inverter somewhere given DC power. Big price premium likely.
Expert F	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert G	5%	6%	8%	9%	10%		· Consumer acceptance and performance challenges are barriers to this technology.
Expert H	1%	2%	2%	2%	2%		· There are cheaper ways to generate electricity than via windows; this may only be applicable where other on-site generation is not possible.
Expert I	1%	1%	1%	1%	2%		· Phase 2: included estimates and updated rationale. · This will result in loss of visual transmittance; reduce views and daylight.
Expert J	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert K	0%	1%	1%	2%	3%		· Scientifically possible and appealing to have energy generation where it would be used, but this technology is not market ready.
Expert L	1%	3%	5%	10%	15%		· Phase 2: decreased estimates. · Unclear how you collect and use the energy generated. Likely reliability and service challenges over the life of these windows given their complexity.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.

ADVANCED ENERGY EFFICIENT AND ENERGY GENERATING WINDOWS (CLEARVIEW)

Commercial - Existing

Expert	2025	2030	2035	2040	2045	Trend	Rationale
Average	**1%**	**2%**	**3%**	**4%**	**6%**		
Expert A	0%	1%	2%	3%	4%		· Technology less likely in existing buildings.
Expert B	0%	5%	10%	15%	20%		· Expect a lot of adoption resistance due to complexity, maintenance, and control issues. But if it proves to work and is not a maintenance nightmare, it will ultimately have a high adoption rate.
Expert C	N.R.	N.R.	N.R.	N.R.	N.R.		· Phase 2: removed estimates. · Not area of expertise.
Expert D	0%	0%	0%	0%	0%		· Efficiency is low for this technology, may have more applicability to smart watches. · This will not be implemented in existing buildings at all.
Expert E	0%	0%	1%	1%	1%		· Rewiring costs make this unlikely to take off.
Expert F	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert G	5%	6%	8%	9%	10%		· Consumer acceptance and performance challenges are barriers to this technology.
Expert H	1%	2%	2%	2%	2%		· There are cheaper ways to generate electricity than via windows; this may only be applicable where other on-site generation is not possible.
Expert I	0%	0%	0%	1%	1%		· Phase 2: included estimates and updated rationale. · Not cost effective to replace glazing; this will result in loss of visual transmittance; reduce views and daylight.
Expert J	N.R.	N.R.	N.R.	N.R.	N.R.		· Not area of expertise.
Expert K	0%	0%	0%	0%	0%		· Scientifically possible and appealing to have energy generation where it would be used, but this technology is not market ready. · Would not work in retrofit buildings.
Expert L	1%	2%	4%	8%	12%		· Unclear how you collect and use the energy generated. Likely reliability and service challenges over the life of these windows given their complexity.

Data are highlighted if they are the lowest (yellow), or highest (green) for each year.