Commercial Replacement and Attachment Window Solutions Market Transformation Initiative

Appendix B: Market Forecasting & Cost-Effectiveness Modeling Approach – DRAFT

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Prepared by:
Karen Horkitz, Market Research and Evaluation Lead, CalMTA
Isaac Schultz, Engineering Manager, Resource Innovations
Ashreeta Prasanna, Manager, Resource Innovations
Tom Bougher, Principal, West Monroe

Resource Innovations
719 Main Street, Suite A
Half Moon Bay, CA, 94019
(888) 217-0217
info@calmta.org

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List of Abbreviations

Abbreviation	Definition
ACC	Avoided Cost Calculator
AERC	Attachments Energy Rating Council
AVP	Awareness of the value proposition
BMA	Baseline Market Adoption
BPS	Building Performance Standard
CalMTA	California Market Transformation Administrator
CEDARS	California Energy Data and Reporting System
CEUS	California Commercial End-Use Survey
CET	Cost-Effectiveness Tool
CRAWS	Commercial Replacement and Attachment Window Solutions
CPUC	California Public Utilities Commission
CZ	Climate Zone
CSW	Commercial secondary windows
E3	Energy and Environmental Economics
ESCO	Energy Service Company
eTRM	Electronic Technical Reference Manual
EUL	Effective Useful Life
DEER	Database for Energy Efficiency Resources
GHG	Greenhouse gas
HVAC	Heating, ventilation, and air conditioning
IMC	Incremental Measure Cost
IOU	Investor-owned utility
MPI	Market progress indicator
MUSH	Municipal, university, school, and hospital
NAICS	North American Industry Classification System
NEB	Non-energy benefit
NPV	Net present value
PA	Program administrator
PAC	Program Administrator Cost test
PG&E	Pacific Gas and Electric
PV	Present value
SCE	Southern California Edison
SCT	Societal Cost Test
SDG&E	San Diego Gas and Electric

Abbreviation	Definition
TMA	Total Market Adoption
TRC	Total Resource Cost test
TSB	Total System Benefit
UEI	Unit energy impact
VIG	Vacuum insulated glass

1 Purpose

Market Transformation Initiatives (MTIs) generate energy savings and related benefits by accelerating and increasing market adoption of energy-efficient technologies and practices. Estimating MTI impacts requires a documented market adoption forecast and a transparent method for translating forecasted adoption into incremental system benefits and cost-effectiveness results.

This appendix documents the approach, methods, assumptions, data sources, and key results CalMTA used to estimate incremental impacts resulting from the Commercial Replacement and Attachment Window Solutions (CRAWS) MTI. These methods are consistent with the CalMTA MTI Evaluation Framework.[1]

The CRAWS MTI includes both commercial secondary windows (CSW) and vacuum insulated glass (VIG). This appendix presents the forecasted adoption, Total System Benefit (TSB), and cost-effectiveness results for CSW only. CalMTA chose to model only CSW at this point in time because CSW products are sufficiently mature to forecast market adoption and cost effectiveness: they currently have a better-defined retrofit pathway than VIG, and there is sufficient information available to make reasonable assumptions about CSW per-square-foot adoption, savings, and costs. VIG remains within the CRAWS MTI strategy and theory of market change, and CalMTA plans to model VIG adoption and cost effectiveness when product ratings, cost data, supply-chain information, and field-performance data mature.[2]

For this appendix, "CSW" refers to a secondary window retrofit product installed on the interior or exterior of existing commercial windows without replacing the primary glass or frame. The model's scope focuses on existing commercial buildings with single-pane or double-pane clear windows without low-emissivity (low-e) coatings. These represent the conditions where CSW is expected to provide the strongest combination of energy savings, comfort benefits, and customer economics.[3]

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[1] To learn more about the CalMTA MTI Evaluation Framework, please see CalMTA, Market Transformation Initiative Evaluation Framework, April 2024. Further information is also available in Appendix F: Evaluation Plan.

[2] VIG remains within the CRAWS MTI product scope but this Appendix B model quantifies CSW only. Additional VIG modeling will require more mature information on product ratings, installed costs, supply-chain capacity, field performance, and adoption pathways. For more information, see the CRAWS MTI Plan, Technology Overview and Strategic Interventions sections; Appendix D: Market Characterization, Sections 2.1, 7, and 8; and Appendix F: Evaluation Plan, MPIs related to VIG rating methods and manufacturer participation.

[3] CSWs are retrofit products attached to the interior or exterior of an existing window, creating an insulating layer without replacing the primary window glass or frame. For more information, see Appendix D: Market Characterization, Section 2.1, Product Definitions; and Attachment 1 to Appendix B, Product Information.

The adoption, TSB, and cost-effectiveness forecasts presented in this appendix cover the 2028-2047 modeling period. The CRAWS MTI Plan describes market deployment, awareness-building, and implementation activities that will support the modeled adoption trajectory.

2 Executive summary

To estimate incremental impacts for the CRAWS MTI, CalMTA developed forecasts of Baseline Market Adoption (BMA) and Total Market Adoption (TMA) and, ultimately, the net incremental market adoption achieved by the MTI. Forecasted CSW adoption is a key input to the calculation of TSB and cost-effectiveness ratios: Total Resource Cost (TRC), Program Administrator Cost (PAC), and Societal Cost Test (SCT).

The CRAWS MTI addresses a large and underdeveloped retrofit opportunity in California's existing commercial building stock. Single-pane and double-pane clear windows remain common in commercial buildings, and poor-performing windows can increase HVAC loads, reduce occupant comfort, and make later electrification more expensive if building owners size HVAC equipment before evaluating envelope improvements. CalMTA designed the CRAWS MTI to help the market recognize and act on an "envelope-first" value proposition: improving window performance before or alongside major HVAC investments so that California captures durable energy, peak-load, greenhouse gas (GHG), and resilience benefits rather than locking in oversized HVAC systems.[4]

The adoption forecast that CalMTA describes in this appendix is intentionally narrower than its full CRAWS market vision. The MTI Plan and Evaluation Plan track progress toward broader CSW and VIG market transformation; Appendix B describes CSW adoption only. This treatment is conservative because it excludes potential VIG adoption and does not monetize several non-energy benefits that market actors identify as important purchase drivers, including thermal comfort, noise reduction, reduced occupant disruption, resilience, and potential HVAC downsizing value. As a result, the primary forecast should be interpreted as a CSW-only cost-

[4] For more information about the CRAWS envelope-first theory of market change, see the CRAWS MTI Plan, Executive Summary, Vision, and Strategic Interventions sections; Appendix A: Logic Model; and CRAWS MTI Plan Messaging. The CRAWS Market Characterization Report also describes the market barriers associated with low awareness of window performance, reactive window replacement practices, and HVAC-first retrofit planning.

effectiveness forecast that does not fully represent the value associated with CRAWS market transformation.[5]

2.1 Market adoption forecast

CalMTA developed a statewide CSW adoption forecast using a Gompertz S-curve framework that estimates cumulative CSW adoption over a 20-year forecast period for two scenarios: the BMA scenario estimates adoption absent the CRAWS MTI; the TMA scenario estimates accelerated adoption expected from coordinated market transformation interventions.

BMA represents expected "naturally occurring" adoption under current market, policy, and technology conditions. In the BMA scenario, CSW remains a niche retrofit solution. Adoption growth remains slow because most building owners do not routinely evaluate window performance as part of capital planning or in response to occupant discomfort; many window upgrades occur only when windows fail, and HVAC investments often occur before envelope upgrades are considered. The BMA scenario therefore reflects a market without investment in an MTI strategically designed to catalyze adoption, resulting in low growth throughout the forecast period.

TMA represents adoption in the presence of the CRAWS MTI. The TMA forecast assumes that MTI activities increase awareness of the value proposition, build market actor confidence, support performance-rating and technical-resource infrastructure, strengthen supply-chain and installer capacity, and create a stronger business case for pairing envelope improvements with HVAC planning. In the TMA scenario, the MTI accelerates the pace at which market actors become aware of CSW, understand where it is an economically attractive retrofit option, and choose to install it.[6]

The model separately tracks the municipal, university, school, and hospital (MUSH) segment and the non-MUSH segment. This segmentation reflects the CRAWS strategy that expects MUSH buildings to be a stronger early market because they are more likely to be owner-occupied, have longer ownership horizons, use structured capital planning and Energy Service Company (ESCO) channels, and face stronger pressure to prepare for decarbonization and building-performance

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[5] For more information on CRAWS non-energy benefits (NEBs) and customer value drivers, see Appendix D: Market Characterization, Executive Summary and Sections 6.8, 6.10, 6.11, and 8. NEBs identified through market research include thermal comfort, noise reduction, aesthetics, reduced disruption, and resilience. These benefits are important to the MTI theory of change but are not monetized in the TSB calculation.

[6] For more information on the CRAWS strategic interventions that inform the TMA forecast, see the CRAWS MTI Plan, Section 2.2, Strategic Interventions; Appendix A: Logic Model; and Appendix F: Evaluation Plan, Table 1, CRAWS PTLM outcomes, MPIs, milestones, and current baseline.

requirements. Non-MUSH buildings remain important to long-term transformation, but CalMTA expects a slower CSW adoption rate because decision making is more fragmented and split-incentive constraints are more common within this segment.[7]

The adoption model starts with commercial floor area from the 2022 California Commercial End-Use Survey (CEUS).[8] CalMTA excluded all warehouses and a portion of miscellaneous floor area, mapped the remaining stock to Database for Energy Efficient Resources (DEER) prototype buildings, and converted floor area to window area using DEER prototype geometry assumptions. Because CEUS does not directly identify window type or low-e status, CalMTA used building vintage as a proxy for identifying buildings likely to retain single-pane or clear double-pane windows. This process produced an estimated 445.1 million square feet of technically addressable window area. Applying customer-economics filters for positive net present value and simple payback of eight years or less produced an estimated achievable potential of 145.4 million square feet statewide.

Figure 1 compares cumulative CSW adoption under the BMA and TMA scenarios. The gap between the BMA and TMA curves represents the net incremental CSW adoption that CalMTA attributes to the MTI. In the primary forecast, TMA reaches approximately 44% of the estimated achievable potential and approximately 14% of technical potential by the end of the forecast horizon. The forecast does not assume that the MTI captures the full technical opportunity; substantial addressable stock remains after the forecast period, which makes the estimate more conservative and consistent with the long-run nature of market transformation.

[7] For more information on the initial target market and MUSH focus, see the CRAWS MTI Plan, Executive Summary and Target Market sections; Appendix D: Market Characterization, Section 2.2, Target Market; and Appendix F: Evaluation Plan, MPIs and data sources related to MUSH and CRE market adoption.

[8] California Energy Commission. 2022 California Commercial End-Use Survey Final Report. 2022 California Commercial End-Use Survey (CEUS): Final Report | California Energy Commission.

Figure 1. Cumulative CSW adoption forecast, BMA vs. TMA, 2028-2047

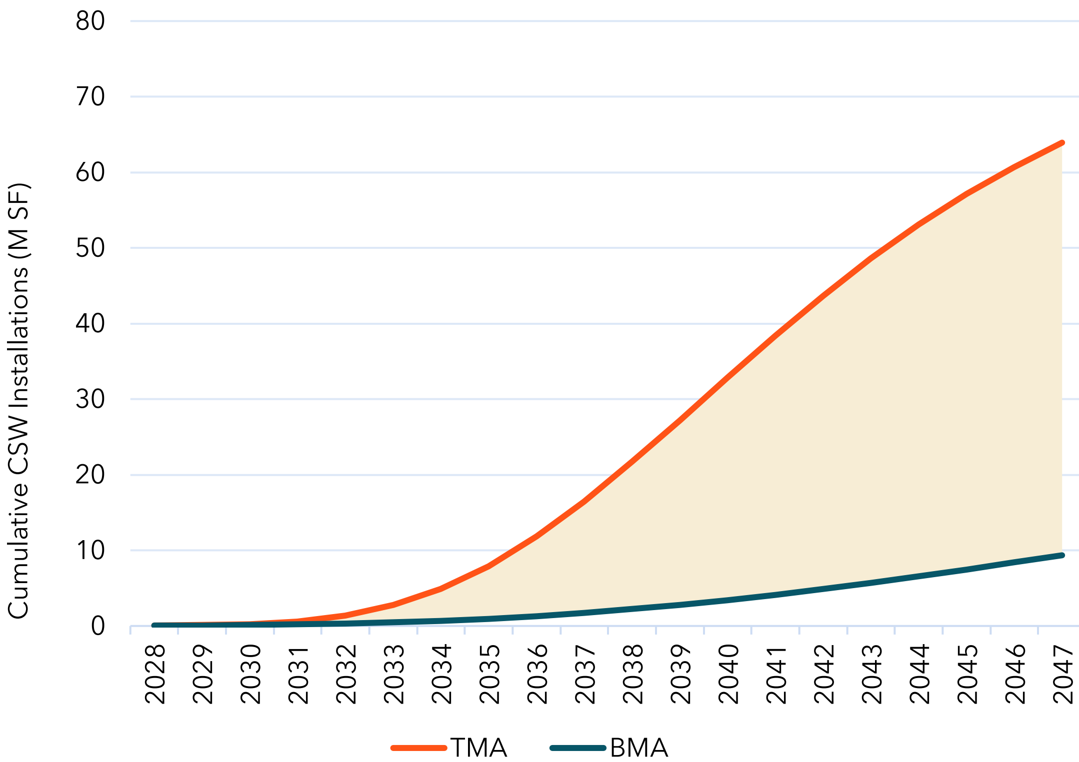

Table 1 summarizes the BMA and TMA market adoption forecast results. Cumulative TMA reaches approximately 63.9 million square feet of CSW installations over the forecast period, compared with 9.4 million square feet under BMA. The difference between the two scenarios represents approximately 54.6 million square feet of statewide incremental adoption.

Consistent with the CalMTA MTI Evaluation Framework, CalMTA makes two adjustments to the statewide incremental adoption forecast before calculating TSB and cost-effectiveness. First, CalMTA excludes the portion of incremental adoption attributed to buildings outside investor-owned utility (IOU) service territories. Second, CalMTA subtracts estimated PA-verified units associated with incremental adoption to avoid double counting with PA-claimed program activity.

For CRAWS, this adjustment is applied by fuel: adoption in gas IOU-only territory is retained for gas avoided-cost benefits, receives zero electric avoided-cost benefits, and includes only an allocated share of incremental measure costs based on the gas share of total electric-plus-gas TSB benefits. After these adjustments, the forecast includes 37.6 million square feet of net incremental CSW adoption for TSB and cost-effectiveness estimation. These adjustments are described in greater detail in Sections 3.5 & 3.6.

Table 1. Forecast of CSW adoption (in millions square feet of window area, 2028-2047)

Segment	TMA	BMA	Total incremental adoption	Estimated PA-verified adoption	Net incremental adoption for TSB and CE estimation
Electric IOU & Gas IOU territory	42.3	6.2	36.1	7.1	29.0
Gas IOU Only territory	12.2	1.6	10.7	2.0	8.6
Non-IOU territory	9.4	1.6	7.8	0.0	NA
Statewide Total	**63.9**	**9.4**	**54.6**	**9.1**	**37.6**

Note: PA-verified units include adoption estimated to be associated with PA programs statewide (Source: CalMTA estimates). Values are cumulative 2028–2047 million square feet of CSW window area. Electric IOU and gas IOU territory receives both electric and gas avoided-cost benefits. Gas IOU-only territory receives gas avoided-cost benefits but zero electric avoided-cost benefits. Non-IOU territory is excluded from the primary TSB and cost-effectiveness calculation. PA-verified adoption is deducted to avoid double counting with PA-claimed program activity. Values may not sum exactly due to rounding.

2.2 Total system benefit and cost-effectiveness forecast

After developing BMA and TMA forecasts, CalMTA translated net incremental CSW adoption into TSB and cost-effectiveness results using avoided costs, per-square-foot unit energy impacts, hourly load shapes, initiative costs, incremental measure costs, and measure-life assumptions. The analysis uses the CPUC Avoided Cost Calculator (ACC) framework, 2024 ACC workbooks, IOU-specific avoided-cost inputs, and CPUC cost-effectiveness test definitions for the TRC, PAC, and SCT.[9]

Table 2 summarizes the value of net incremental TSB, by benefit category and cost-effectiveness test, and

[9] Avoided costs were developed using the CPUC ACC framework and 2024 ACC workbooks. Cost-effectiveness tests are based on CPUC Standard Practice Manual concepts for the TRC, PAC, and SCT tests. For more information, see CPUC, DER Cost-Effectiveness and 2024 ACC Documentation v1b; and CPUC, California Standard Practice Manual.

Table 3 reports the cost-effectiveness ratios.[10] Under the TRC and PAC cost tests, forecast net incremental TSB is $508.8 million, with a TRC ratio of 1.31 and a PAC ratio of 19.2. Table 2 also shows total societal benefits of greater than $990 million, which are higher than the TRC and PAC value because the SCT includes additional societal avoided-cost components (primarily air-quality and methane-leakage adders) and uses a lower societal discount rate. The benefit-cost ratio under the SCT cost test is 1.82 (Table 3).

Table 2. CSW estimated TSB (2028-2047)

Cost Effectiveness Test	TSB ($M)	Energy ($M)	Grid ($M)	GHG ($M)
TRC and PAC	508.8	105.4	63.8	339.6
SCT Base	992.9	186.1	112.3	694.5
SCT High	1,001.3	186.1	112.3	702.9

Source: CalMTA estimates. Values are present value 2024 dollars. GHG values exclude refrigerant benefits because CSW does not change refrigerant type or quantity relative to the baseline condition.

Table 3. CSW cost-effectiveness estimate (2028-2047)

TRC	PAC	Base SCT	High SCT
1.31	19.2	1.82	1.84

Source: CalMTA estimates. Ratios are calculated over the 2028-2047 forecast period using net incremental adoption for TSB and CE estimation.

Although CPUC requires CalMTA to use net incremental benefits to calculate cost effectiveness, CalMTA also reports statewide TSB and "co-created" TSB, which represent the broader market effects of the CRAWS MTI.[11]

[10] All present values in this appendix are reported in 2024 dollars unless otherwise noted. CalMTA uses 2024 as the common present-value base year to ensure results are aligned and to allow for consistent comparisons of results across MTIs. All benefits and costs occurring during the forecast period are discounted back to 2024 dollars for reporting.

[11] The CalMTA MTI Evaluation Framework requires CalMTA to estimate incremental adoption using BMA and TMA forecasts and to avoid double counting with PA-verified savings. Broader incremental TSB results, including IOU-territory co-created TSB and statewide incremental TSB, are shown in Table 11Table 11.

The results presented in this Appendix are the product of these conservative modeling assumptions:

- The primary forecast includes CSW only and excludes potential VIG adoption.
- CalMTA excludes monetized non-energy benefits (NEBs).[12]
- CalMTA does not include additional avoided costs that could arise if CSW enables HVAC downsizing during future equipment replacement.
- The cost-effectiveness calculation removes adoption outside IOU territories and PA-verified units, even though those installations are likely to grow as a result of the MTI and contribute to broader statewide market transformation and California policy goals.

3 Market adoption forecast

This section describes the framework CalMTA used to estimate statewide CSW adoption over the 2028-2047 forecast period and to calculate the net incremental adoption attributed to the CRAWS MTI. This document expresses adoption in square feet of installed CSW window area because window area is the common unit used for stock sizing, unit energy impacts, incremental measure cost, and avoided cost calculations.

This framework separates the physical and economic size of the market from the pace at which the market is likely to act. The model does not assume that all technically addressable buildings will install CSW. Instead, it first narrows the market to buildings where CSW appears economically plausible, then estimates how much of that market becomes aware and engaged and adopts CSW under BMA and TMA conditions.

Throughout this appendix, the term "primary forecast" refers to CalMTA's central set of adoption, cost, avoided cost, and cost-effectiveness assumptions for the CRAWS MTI. Section 6 presents sensitivity cases that vary selected assumptions to test how results change under alternate market, cost, policy, and adoption conditions.

3.1 Model structure

CalMTA used a Gompertz S-curve framework to forecast cumulative CSW adoption. This framework is appropriate for an emerging commercial retrofit technology because it estimates

[12] Because the TSB calculation includes only avoided-cost benefits, the cost-effectiveness ratios understate the value building owners may perceive from CSW in applications where thermal comfort, noise reduction, occupant disruption, resilience, or future HVAC right-sizing are important purchase drivers.

adoption to occur slowly at first, then accelerate as awareness, professional recommendation, field evidence, and market infrastructure build, and finally taper as the most accessible portion of the market is served.

The model estimates cumulative adoption in year t as:

$$Adoption_t = AVP_t * M * e^{-e^{-r(t-t_0)}}$$

Where:

> $Adoption_t$ = cumulative CSW adoption in year t, expressed as square feet of installed CSW window area
> AVP_t= awareness of the value proposition multiplier in year t
>
> M = the Gompertz model maximum, which CalMTA approximates using the estimated achievable potential described in Section 3.2.3, expressed as square feet of window area
>
> r = growth rate, which determines the steepness of the adoption curve
>
> t = forecast year
> t_0 = inflection year, when annual adoption reaches its maximum
> e = exponential function

The Gompertz parameters translate the estimated achievable potential into an annual adoption trajectory. For this analysis, CalMTA uses estimated achievable potential as the model's practical upper bound because it reflects the portion of technical potential that passes both the positive-net-present-value and the simple-payback filters. This approach does not imply that the full technical market is unavailable or that all remaining buildings could never adopt CSW. Rather, it provides a conservative proxy for the portion of the market for which CSW retrofits are likely to offer a strong value proposition.[13]

After estimating the Gompertz adoption trajectory, CalMTA applies an additional awareness-of-the-value-proposition (AVP) constraint. AVP represents the share of the economically attractive market that is sufficiently aware of CSW and its value proposition to consider CSW as a potential

[13] CalMTA previously used a Gompertz S-curve framework in the Room Heat Pumps MTI, Appendix B, because the model structure can be linked to MTI market interventions and milestones. For additional diffusion-modeling context, see Geroski, P.A. 2000. "Models of Technology Diffusion," Research Policy 29(4-5): 603-625; Meade, N. and Islam, T. 2006. "Modelling and Forecasting the Diffusion of Innovation: A 25-year Review," International Journal of Forecasting 22(3): 519-545; and Lee, J.C., Lu, K.W., and Horng, S.C. 1992. "Technological Forecasting with Nonlinear Models," Journal of Forecasting 11(3): 195-206.

retrofit solution. Market actors cannot evaluate CSW as an option if they are not aware of the product category, do not understand the problems it can solve, or do not have enough confidence in its performance and installation pathway. See Sections 3.3 & 0 for additional details on the AVP constraint.[14]

3.2 Inputs and assumptions

The BMA and TMA forecasts use the same underlying building stock, technical-potential, customer-economics, and geography assumptions. They differ in the assumed pace and extent of market engagement, including the AVP trajectory and adoption growth-rate assumptions. These differences reflect the expected effect of CRAWS MTI activities on awareness, confidence, market infrastructure, and adoption over time.

3.2.1 Market size and segmentation

The forecast begins with 2022 CEUS commercial floor space data. CEUS is the most current California-specific commercial building stock source available for this analysis and provides floor space by building type, utility territory, and building vintage. CalMTA used CEUS because the adoption model must allocate the building stock to IOU territories and building types in a way that can be reconciled with energy impacts and cost-effectiveness calculations.[15]

The CRAWS model uses CEUS as the primary stock basis for market sizing, window-area estimation, and utility-territory allocation. This approach keeps the stock, adoption, unit energy impact, and avoided cost calculations reconciled to a common framework. The model also maintains separate electric and gas IOU indicators so that benefits and associated costs can be assigned appropriately to buildings in each of three IOU segments, as described in Section 3.5

CalMTA excluded warehouse floor area and part of the miscellaneous category before calculating addressable stock. CalMTA excluded warehouses because they typically have low window-to-floor-area ratios and therefore limited CSW opportunity relative to floor area. Additionally, CalMTA excluded 50% of the miscellaneous building category because it contains a heterogeneous mix of uses, some of which are expected to have limited addressable window

[14] AVP is a CalMTA modeling construct representing awareness of the value proposition. It is used to reflect non-price barriers such as information gaps, lack of product familiarity, limited professional recommendation, limited availability of decision-support tools, and lack of routine envelope evaluation in building retrofit planning. For supporting market barriers and MPIs, see Appendix D: Market Characterization, Findings 3 through 5 and Sections 6.7 through 6.11; Appendix A: Logic Model; and Appendix F: Evaluation Plan, Table 1.

[15] The 2022 CEUS final report states that CEUS estimates commercial floor stocks, fuel shares, energy use, and hourly whole-building load profiles by commercial building type and electric utility service area.

area or limited relevance to the CRAWS value proposition. These assumptions are conservative because they reduce the modeled stock before the adoption forecast.[16]

The remaining floor area was divided into two market segments: MUSH and non-MUSH. The MUSH segment includes municipal, university, school, hospital, and related institutional building types, represented by the DEER education, hospital, nursing home, assembly, and library prototypes. The non-MUSH segment includes the remaining targeted commercial stock. This segmentation aligns the adoption model with the MTI strategy, which identifies owner-occupied and institutionally managed buildings as the likely early market for CRAWS because these buildings have longer investment horizons, greater ability to capture operational benefits, and stronger channels for ESCO and public-sector engagement.[17]

3.2.2 Addressable stock and prototype mapping

CEUS does not directly identify window type, pane count, or low-e coating status, but does track building vintage in categories. CalMTA therefore used building vintage as a proxy for identifying addressable stock. Buildings constructed before 1997 are included in the addressable stock because they are more likely to retain single-pane or clear double-pane windows without low-e coatings. Buildings constructed from 1998 onward are excluded from the addressable stock because they are more likely to have been built with, or subsequently upgraded to, higher-performing glazing. Screening for building vintage is consistent with the CRAWS target market of pre-2000 commercial buildings with single-pane or double-pane clear windows and is also conservative because it excludes post-1998 buildings, even though some may still contain poor-performing windows.[18]

After identifying addressable floor area, CalMTA mapped CEUS building categories to DEER commercial prototype buildings. Each CEUS category maps to one or more DEER prototypes, and DEER floor-area weights were used to split floor area across prototypes where needed. Using DEER prototypes provides a common geometry basis for the adoption, savings, cost, and avoided

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[16] Warehouse and miscellaneous-category exclusions are CalMTA modeling assumptions based on expected limited addressable window area and the heterogeneous composition of miscellaneous commercial floor space. For the modeling presentation of this assumption, see May 6, 2026, MTAB Presentation, CRAWS Market Adoption Forecast slides on commercial floor space and exclusions.

[17] For more information on owner-occupied and institutional market prioritization, see the CRAWS MTI Plan, Target Market and Strategic Interventions sections; Appendix D: Market Characterization, Section 2.2; and Appendix F: Evaluation Plan, Table 1.

[18] Appendix D: Market Characterization identifies the CRAWS target market as commercial buildings constructed before 2000 that have single-pane or double-pane clear windows. The market characterization also shows that low-e coatings are much less common in older building vintages and that post-2000 buildings are substantially more likely to have low-e coatings.

cost calculations. This is important because the model converts commercial floor area into window area, applies per-square-foot unit energy impacts, and calculates incremental measure costs on the same per-square-foot window-area basis.

Each DEER prototype has a window-to-floor-area ratio. CalMTA applies those ratios to the filtered CEUS floor area to estimate addressable window area. This process produced an estimated 445.1 million square feet of technically addressable CSW window area statewide.

3.2.3 Estimated achievable potential

CalMTA applies sequential filters to move from technical potential to the estimated achievable potential. These filters are intended to approximate the practical decision screens that commercial building owners use when evaluating discretionary envelope investments.

The first filter identifies technical potential: existing commercial window area that is physically addressable based on building type, vintage, and window-area assumptions. This step estimates where CSW could plausibly be installed before considering customer economics.

The second filter identifies economic potential: the subset of technical potential that produces positive net present value using a 10% customer discount rate. The 10% rate is intended to reflect a private-sector investment perspective rather than a utility or societal cost-effectiveness perspective. Commercial building owners often evaluate envelope retrofits against competing capital uses, including deferred maintenance, tenant improvements, HVAC replacement, and other operational investments. Using a higher customer discount rate in the adoption model is therefore conservative relative to the lower discount rates used in TRC and SCT calculations.[19]

The third filter identifies the subset of economic potential with simple payback of eight years or less. This filter recognizes that a project can be cost effective over its life but still fail to meet the shorter investment horizon many commercial building owners use for discretionary envelope improvements. CalMTA selected an eight-year threshold as a moderate screen to represent projects with a credible near- to medium-term business case within the MTI horizon, while still being more conservative than a lifetime NPV test alone. Buildings that clear the NPV test but fail

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[19] The 10% customer discount rate is a CalMTA modeling assumption intended to approximate private-sector commercial investment screening rather than public-sector or utility cost-effectiveness discounting. For related commercial retrofit decision-making literature, see Anderson, S.T. and Newell, R.G. 2004. "Information Programs for Technology Adoption: The Case of Energy-Efficiency Audits," Resource and Energy Economics 26(1): 27-50; Jones, C.B. and Bogus, S.M. 2010. "Decision Process for Energy Efficient Building Retrofits: The Owner's Perspective," Journal of Green Building 5(3): 131-146; and Kontokosta, C.E. 2016. "Modeling the Energy Retrofit Decision in Commercial Office Buildings," Energy and Buildings 131: 1-20.

the payback screen may still be viable under stronger policy, financing, incentive, or non-energy benefit conditions.[20]

These three screening filters reduce total existing window area to 445.1 million square feet of technical potential, 165.9 million square feet of economic potential, and 145.4 million square feet of estimated achievable potential. The model uses the 145.4 million square feet value as a conservative proxy for the Gompertz M parameter in both BMA and TMA. In other words, BMA and TMA use the same estimated achievable potential; the MTI accelerates how much of that market is reached within the forecast period.

Table 4. Stages used to derive estimated achievable potential for CSW

Filter stage	Description	Window area (million square feet)
0	Existing windows in commercial buildings	620.0
1	Technical potential / addressable stock	445.1
2	Economic potential (positive NPV at 10% discount rate)	165.9
3	Achievable potential (payback <= 8 years)	145.4

Source: CalMTA estimates. Values represent window area in million square feet. Technical potential reflects and achievable potential apply customer-economics screens to the technical potential.

3.3 Baseline market adoption

BMA represents expected CSW adoption in the absence of the CRAWS MTI. The BMA forecast assumes that the CSW market grows slowly because the market remains constrained by information gaps, limited performance-rating visibility, limited professional recommendation, reactive window replacement practices, and competition for capital from other building improvements.

The BMA scenario assumes that without coordinated market transformation, most building owners continue their current practice of addressing windows only when a failure, tenant complaint, historic preservation need, or isolated project opportunity arises. As such, market adoption remains low and does not reach a natural inflection point (when annual adoption reaches its maximum) within the forecast period.

[20] The eight-year simple-payback screen is a CalMTA modeling assumption used to represent a moderate commercial decision threshold for discretionary envelope investments. It is intended to identify the subset of positive-NPV projects with a strong enough customer value proposition to support adoption within the MTI horizon.

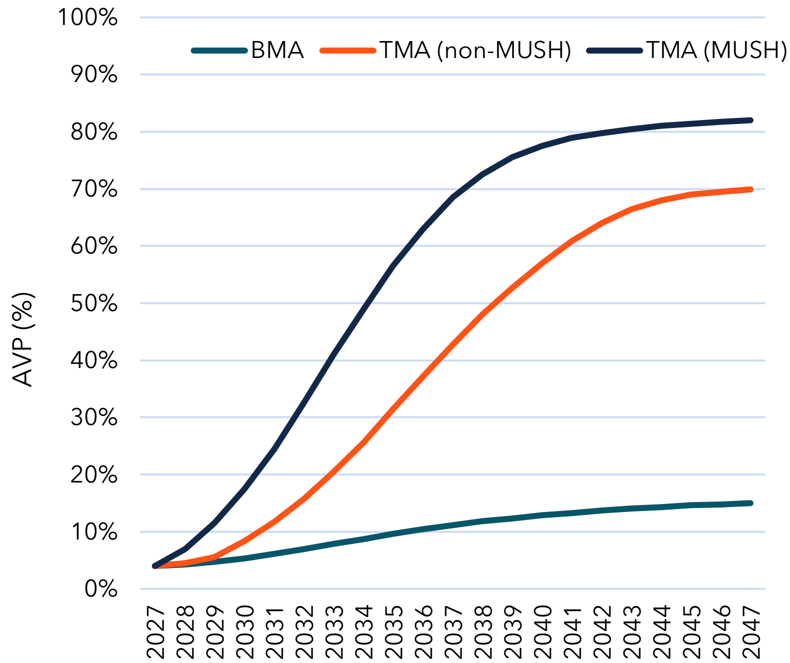
CalMTA modeled BMA using a growth rate of 0.07 and an inflection year of 2050.[21] Because the inflection year falls after the 2028-2047 forecast period, annual BMA adoption remains in the pre-inflection accelerating growth phase throughout the full duration of the modeled period, and cumulative adoption does not enter the rapid middle stage of the S-curve before the end of the forecast period. CalMTA selected this slow-growth trajectory because CSW has existed in the market for years without achieving broad commercial uptake, while market characterization findings found that CSW remains a niche retrofit option with limited owner awareness, largely reactive adoption, and little evidence of the professional recommendation, policy pressure, or delivery-channel maturity needed for broad market acceleration.[22]

Figure 2 shows the BMA AVP trajectory which starts at approximately 1% and rises slowly to approximately 5% by 2047. The BMA AVP trajectory is deliberately above zero. This avoids overstating MTI impact by recognizing that some adoption is likely to occur naturally as awareness of building decarbonization, building performance standards, and high-performance retrofit solutions increases over time.

[21] In the Gompertz S-curve model, the growth rate is a curve-shape parameter that controls how quickly adoption ramps up over time. A lower growth rate produces a flatter adoption curve, meaning adoption increases gradually from year to year. A higher growth rate produces a steeper curve, meaning adoption accelerates more quickly as the market approaches its inflection year. The inflection year is the point when annual adoption reaches its highest level, not the point when adoption stops.

[22] For baseline market barriers, see Appendix D: Market Characterization, Finding 5 and Sections 6.7 through 6.11. The report describes reactive replacement practices, information-source patterns, limited use of tools and calculators, limited incentive awareness, and the importance of quantifying benefits beyond energy savings.

Figure 2. AVP trajectories by scenario and segment, 2028-2047



Note: AVP values) represent a constraint on market adoption – not market adoption; an AVP of 0% implies that zero potential purchasers are sufficiently aware of CSW to consider it as a solution, and an AVP of 80% implies that 80% of potential purchasers are sufficiently aware to consider CSW.

3.4 Total market adoption

TMA represents the CSW adoption trajectory expected in the presence of coordinated CRAWS MTI interventions. Relative to BMA, TMA assumes faster growth, earlier inflection, and a higher AVP trajectory because the MTI is designed to reduce the non-price barriers that keep economically attractive CSW projects from being identified, recommended, financed, and installed.

Under TMA, the market transformation effect is modeled through three linked mechanisms. First, MTI activities increase market awareness of the CSW value proposition. Second, field demonstrations, technical resources, product ratings, and training increase confidence among market actors who influence building owner decisions, including ESCOs, architects, specifiers, HVAC designers, and installers. Third, integration with external programs, building decarbonization planning, and potential building performance standards makes envelope evaluation more routine during major retrofit and HVAC decision points.[23]

CalMTA modeled TMA using growth rates of 0.18 for non-MUSH and 0.22 for MUSH, with inflection years of 2038 and 2036, respectively. The higher MUSH growth rate and earlier MUSH inflection reflect the expectation that institutional procurement channels, ESCO delivery models, public-sector planning, and longer ownership horizons allow MUSH adoption to accelerate sooner once the value proposition is demonstrated. Table 5 summarizes the corresponding model inputs.

Table 5. Key adoption forecast parameters by scenario and segment

Scenario	Segment	Growth Rate	Inflection Year
BMA	MUSH and Non-MUSH	0.07	2050
TMA	MUSH	0.22	2036
TMA	Non-MUSH	0.18	2038

Source: CalMTA estimates.

Figure 2 shows the AVP trajectories used in the BMA and TMA forecasts. These values represent the share of the economically attractive market that is aware enough of CSW and its value proposition to *consider* CSW as a potential retrofit solution.

The difference between the BMA and TMA parameter sets reflects CalMTA's theory of market change. In BMA, CSW remains a niche solution that grows slowly as the market responds to general decarbonization and retrofit pressures. In TMA, targeted interventions accelerate awareness, increase confidence among market actors who influence building decisions, and help make envelope evaluation a more routine part of retrofit and HVAC planning.

3.5 IOU territory and program-administrator-verified units

CalMTA applies two sequential adjustments to forecast statewide incremental adoption before calculating MTI TSB and cost-effectiveness.

3.5.1 IOU service territory adjustment

First, CalMTA identifies the portion of statewide incremental adoption that is applicable to IOU TSB and cost-effectiveness calculations. The CRAWS MTI is statewide in strategy and market

[23] For TMA causal logic, see the CRAWS MTI Plan, Strategic Interventions section; Appendix A: Logic Model; and Appendix F: Evaluation Plan, Table 1. These materials link MTI activities to awareness-building, market actor recommendations, technical-resource development, installer training, product ratings, municipal policy integration, and envelope-HVAC integration.

impact, but formal cost-effectiveness calculations are based on IOU-applicable benefits. Because CRAWS affects both electricity and natural gas consumption, the model applies the IOU-territory adjustment separately by fuel rather than removing all adoption outside electric IOU territory.

The model classifies adoption into three utility-territory segments:

1) Adoption in territory served by both electric and gas IOUs receives both electric and gas avoided-cost benefits and associated incremental measure costs.
2) Adoption in territory served by a gas IOU only receives gas avoided-cost benefits, zero electric avoided-cost benefits, and an allocated share of incremental measure costs.[24]
3) Adoption in territory served by neither an electric or gas IOU is excluded from the net incremental adoption used for the primary TSB and cost-effectiveness forecast.

Table 1 shows forecast adoption in each of these three segments.

CEUS provides the commercial floor-space foundation used for market sizing and electric utility territory assignment.[25] To estimate commercial floor space served by a gas IOU that is not served by an electric IOU, CalMTA made the simplifying assumption that buildings identified by CEUS as being served by SMUD or LADWP are also served by Pacific Gas and Electric Company (PG&E) or Southern California Gas Company, respectively. The CRAWS forecasting model represents incremental adoption in gas-only IOU service territory separately, so that these areas are not incorrectly excluded from gas benefits. This approach is particularly important for CRAWS because the measure produces both electric and gas impacts.

Operationally, the TSB calculation applies avoided costs by fuel: electric avoided costs are applied only to adoption in electric IOU territory, while gas avoided costs are applied to adoption

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[24] For adoption in gas IOU-only territory, the model includes only the portion of incremental measure costs associated with the gas benefits counted in the TSB and cost-effectiveness calculation. The cost allocation is based on the relative share of gas TSB benefits compared with total electric-plus-gas TSB benefits for the same adoption segment. For example, if gas avoided-cost benefits represent 70% of total electric-plus-gas TSB benefits for units in the gas IOU-only segment, the model includes 70% of the incremental measure costs for that segment. This approach aligns the included costs with the portion of benefits retained in the primary cost-effectiveness calculation.

[25] CalMTA reviewed EIA electric and natural gas data as an independent reasonableness check because prior CalMTA Appendix B models often used EIA-based customer, sales, or revenue data to estimate IOU and non-IOU allocation. For CRAWS, CEUS was retained as the primary allocation source because the model is built from commercial floor space and window area, and using CEUS consistently avoids mixing floor-space data from one source with allocation factors from another source. The EIA comparison was generally consistent with the CEUS-derived IOU/non-IOU allocation and did not indicate that a blended allocation was warranted.

in gas IOU territory, including gas IOU-only areas.[26] The non-IOU segment is retained separately in the forecasting model for transparency but is excluded from the primary TSB and cost-effectiveness calculation. Broader statewide and co-created impacts are reported separately in Section 4.3.

3.5.2 Program-administrator-verified units adjustment

Second, CalMTA removes estimated PA-verified units. PA-verified units represent the portion of incremental adoption estimated to be reported as verified savings by Program Administrators. CalMTA subtracts these units from the incremental adoption estimated in IOU service territories to avoid double counting benefits that are forecast to be claimed through PA programs. This treatment does not mean that PA-supported installations are unrelated to the MTI. Rather, it means that for formal IOU cost-effectiveness accounting, CalMTA removes units expected to be claimed by PA programs and presents broader influenced benefits separately in the co-created TSB results in Table 11.[27]

For the primary forecast, CalMTA assumes that PA-verified units represent 10% of incremental IOU-territory CSW installations during the early years of Phase III, rise to 40% during the medium term as utility CSW program activity increases, and decline to zero by the end of the forecast period as CSW market infrastructure matures and adoption becomes less dependent on program support. This assumption is based on CalMTA's expected program-availability timeline for CSW. In the short term (2027-2030), CalMTA assumes a 10% share because no PA programs currently incentivize CSW and the measure is expected to be added to the eTRM during this period. In the medium term (2030-2035), CalMTA assumes the PA-verified share rises to 40% as programs that include CSW become more widely available. In the later period (2035-2047), CalMTA assumes the PA-verified share tapers to zero as the technology matures and a declining share of installations is expected to occur through utility programs. CalMTA will update this assumption annually based on actual data, including PA activity, eTRM status, incentive offerings, and California Energy Data and Reporting System (CEDARS)-reported units.

3.6 Net incremental market adoption

After developing the BMA and TMA forecasts, CalMTA calculated net incremental adoption for use in the TSB and cost-effectiveness forecasts, using the equation below:

[26] "Gas IOU-only territory" refers to areas outside electric IOU service territory where the model assigns gas impacts to an IOU gas territory. These areas receive gas avoided-cost benefits only. Electric avoided-cost benefits are not applied unless the adoption occurs in PG&E, SCE, or SDG&E electric territory.

[27] To avoid double counting, the CalMTA MTI Evaluation Framework requires PA-verified units associated with incremental adoption to be subtracted from MTI-attributed net incremental adoption used for TSB and cost-effectiveness.

$$Y^{N.incremental} = Y^{TMA} - Y^{BMA} - Y^{non-IOU} - Y^{PA}$$

Where:

$Y^{N.incremental}$ = net incremental adoption used for TSB and cost-effectiveness

Y^{TMA} = Total Market Adoption

Y^{BMA} = Baseline Market Adoption

$Y^{non-IOU}$ = incremental adoption attributed to buildings outside IOU service territories

Y^{PA} = PA-verified units associated with incremental adoption

The order of subtraction does not change the result; the equation is written to match the order in which the adjustments are described above. Table 6 reports net incremental adoption by segment. Under the primary forecast, after excluding adoption attributed to non-IOU territory and the estimated PA-verified units, the net incremental adoption used for TSB and cost effectiveness is shown in the right-most column of Table 6.

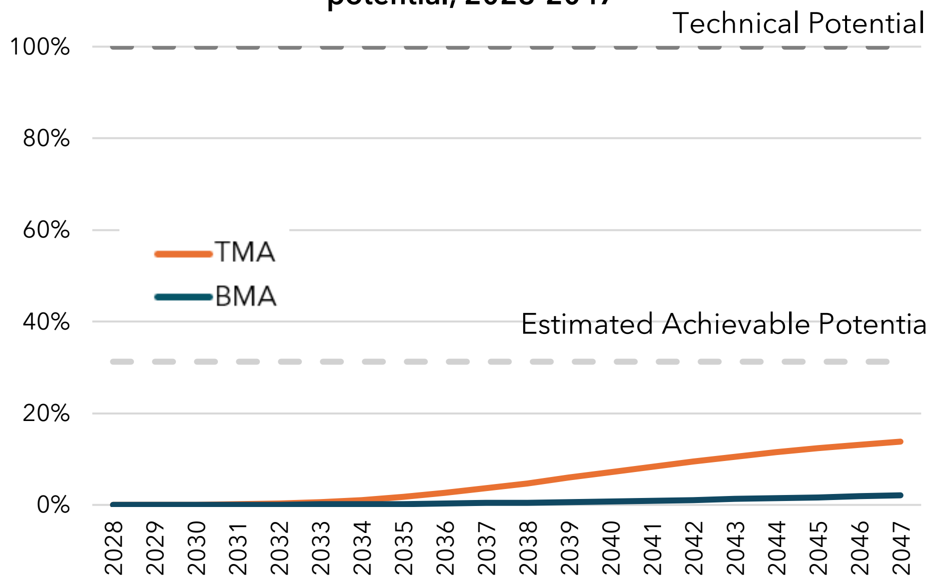
Table 6. Net incremental adoption, million square feet of CSW window area

Segment	Statewide incremental units	Adoption attributed to non-IOU territory	PA-verified units	Net incremental adoption for TSB and CE estimation
MUSH buildings	9.9	1.9	2.2	5.8
Non-MUSH buildings	44.7	5.9	6.9	31.8
Total	54.6	7.8	9.1	37.6

Source: CalMTA estimates. Values are cumulative 2028-2047 million square feet of CSW window area. Values may not sum exactly due to rounding.

Figure 3 shows the modeled TMA trajectory relative to both technical potential and estimated achievable potential. The forecast does not assume that the MTI reaches the full technical opportunity. Instead, adoption remains constrained by the economic-potential and payback filtering screens described in Section 3.2.3, as well as the AVP and Gompertz diffusion assumptions.

Figure 3. CSW adoption as a proportion of technical potential and estimated achievable potential, 2028-2047



3.7 Load shapes

CalMTA used hourly electric and gas savings shapes developed from building energy simulations of baseline and proposed CSW cases. These hourly profiles capture the seasonal and time-of-use patterns of CSW-related electricity and gas savings and are used to weight avoided costs from the 2024 ACC workbooks. This approach allows the TSB calculation to reflect annual energy savings and also the time-dependent value of those savings to the electric and gas systems.

CalMTA expresses the load shapes on a per-square-foot-of-window-area basis and are weighted by building type, climate zone, IOU territory, and modeled installation case. Attachment 1 documents the energy-modeling methods, case definitions, climate-zone weighting, and avoided cost calculations used for this MTI.[28]

3.8 Unit energy impacts

CalMTA expresses unit energy impacts on a per-square-foot-of-window-area basis and includes both electricity and natural gas impacts. CRAWS has a single modeled installation condition: installation of CSW on an existing commercial single-pane or clear double-pane window, relative to the equipment baseline of leaving the existing window in place. This "do-nothing" installation

[28] For detailed load-shape development methods, see Appendix B, Attachment 1: Documentation of Unit Energy Savings and Avoided Cost Calculations for Commercial Replacement and Attachment Window Solutions, Energy Modeling Software, Building Models, Climate Zones, Avoided Cost Calculations, and Weighting Factors sections.

condition reflects the fact that CSW is modeled as a retrofit attachment to an existing window rather than as a full window replacement

These per-square-foot unit energy impacts are used in two places in the model. First, they are used to calculate NPV and payback periods in the estimation of achievable market potential. Second, they are used in the TSB calculation to translate net incremental CSW adoption into electric, gas, grid, and GHG benefits. Using one common savings unit across the adoption and cost-effectiveness models ensures that stock, savings, costs, and avoided costs reconcile to a consistent window-area basis.[29]

DEER prototype building simulations do not include additional savings that may result from reduced air infiltration after CSW installation. This exclusion results in a conservative estimate of unit energy impacts because secondary windows can reduce uncontrolled air leakage in some buildings. CalMTA's current modeling follows the draft measure framework and does not claim additional benefits in the primary UEI values.[30]

3.9 Effective useful life

CalMTA uses a 30-year effective useful life (EUL) for CSW installations in the primary forecast, consistent with the value CPUC staff recently recommended CSW measure package.[31] The 30-year EUL is applied consistently in the TSB and cost-effectiveness calculations and reflects the expected duration over which installed CSW products produce energy and system benefits.

4 Total system benefits

CalMTA calculated TSB as the present value (2024 dollars) of avoided electric, gas, and GHG impacts associated with net incremental CSW adoption. TSB is calculated by pairing annual net incremental adoption with per-square-foot unit energy impacts, hourly load shapes, and avoided-

[29] For UEI methodology, see Appendix B, Attachment 1. Energy modeling was performed using EnergyPlus and DEER commercial prototype building models. The modeling compares existing window baseline cases with proposed CSW cases and expresses results on a per-square-foot-of-window-area basis.

[30] Attachment 1 notes that CSWs can reduce air infiltration in some cases, but the energy modeling did not include reduced infiltration benefits. Excluding infiltration savings is a conservative modeling treatment because the primary UEI values include only the modeled thermal-performance improvement associated with the CSW cases. Attachment 1 cites Henderson et al. 2007, "Mitigating the Impacts of Uncontrolled Air Flow on Indoor Environmental Quality and Energy Demand in Non-Residential Buildings," Final Report DOE Project No. DE-FC-36-02GO12012, as supporting evidence that uncontrolled air leakage can affect nonresidential building energy demand.

[31] Measure SWBE012-01 draft high efficiency window commercial measure; Biermayer, P. Email message to Jeff Mitchell, May 15, 2026.

cost values. The analysis uses net incremental adoption to calculate IOU cost-effectiveness. CalMTA also reports co-created and statewide TSB estimates to provide a fuller view of market impacts.

TSB includes avoided energy, grid, and GHG benefits to the energy system calculated using standard avoided-cost methods, in accordance with the CPUC ACC.[32] It does not include monetized customer non-energy benefits such as thermal comfort, noise reduction, reduced disruption, resilience, or improved ability to right-size HVAC equipment during future replacements. As a result, the TSB and cost-effectiveness results likely understate the full value that some building owners may derive from CSW, particularly in applications where comfort, acoustics, resilience, or HVAC planning benefits are important drivers of adoption.

TSB is a function of the inputs described in earlier sections: net incremental adoption, unit energy impacts, hourly load shapes, avoided costs, measure life, and discounting assumptions. For CRAWS, TSB is driven by avoided electric, gas, grid, and GHG benefits. Refrigerant benefits and costs are not included because CSW does not change refrigerant type or quantity relative to the baseline condition.

$$TSB = (Electric\ Benefits + Gas\ Benefits)$$

$$- (Electric\ Supply\ Cost + Gas\ Supply\ Costs)$$

CalMTA categorized the avoided cost components into three categories: energy benefits, grid benefits, and GHG benefits. Table 7 lists the ACC workbook factors from the electric and gas models by the three categories for reporting.

Table 7. Avoided cost components by category

Category	Electric Model	Gas Model
Energy	Energy	Market (commodity)
Grid	Generation capacity	Transmission and distribution
	Transmission capacity	
	Distribution capacity	
	Ancillary Services	
	Losses	
GHG	Cap and trade	Environment (CO_2 and NO_X emission)
	GHG adder	Upstream methane leakage
	GHG rebalancing	Behind-the-meter methane leakage
	Methane leakage	Gas air quality adder
	Air quality adder	N/A

[32] California Public Utilities Commission, *2024 Avoided Cost Calculator Documentation, Version 1b*; see also CPUC DER Cost-Effectiveness Tools and Updates.

Source: CalMTA summary of 2024 ACC V1b electric and gas avoided-cost components. Refrigerant avoided costs are not applicable to CSW.

4.1 Avoided costs

CalMTA developed measure-specific avoided-cost values using the CPUC ACC framework and the 2024 Distributed Energy Resources ACC workbooks developed by Energy and Environmental Economics (E3), Version 2024 V1b. CalMTA used IOU-specific electric and gas avoided-cost inputs for PG&E, SCE, and SDG&E and included avoided costs through the final year needed to capture the full benefit stream from installations occurring during the 2028–2047 adoption forecast period. For CSW benefits extending beyond the final year available in the ACC workbook, CalMTA used the final available avoided-cost year as a proxy. Avoided cost inputs used for TSB calculations are shown in Table 8.

Table 8. Avoided-cost inputs

Input	Assumption
Avoided-cost framework	CPUC ACC
ACC version	2024 ACC workbooks, Version 2024 V1b
Electric avoided costs	PG&E, SCE, SDG&E
Gas avoided costs	PG&E, SCE, SDG&E
Refrigerant avoided costs	Not Applicable
Installation years	2028–2047
Post-2054 avoided-costs	2054 avoided-cost values used as proxy
TRC / PAC discounting	Average nominal discount rate of 7.30%
SCT discounting	3% real (5.06% nominal)
Representative climate zones	PG&E-CZ12, SDG&E-CZ7, SCE-CZ10

Source: 2024 ACC Guidance. Average discount rate reflects the simple average of the PG&E, SCE, and SDG&E nominal discount rates used in the cost-effectiveness model.

Table 9 shows the discount rates per IOU used in avoided cost and TSB calculations.

Table 9. Discount rate by IOU

IOU	Discount Rate
PG&E	7.27%
SCE	7.44%
SDGE	7.18%
Average discount rate	7.30%

For the SCT, CalMTA applies the base and high SCT-specific avoided-cost values from the ACC to incremental adoption for PG&E, SCE, and SDG&E. As with the TRC and PAC analyses, CalMTA aggregated and discounted these benefits to estimate base and high SCT benefits in 2024 dollars.

Avoided-cost benefits are applied by fuel and utility-territory segment. Electric avoided-cost benefits are applied only to adoption in electric IOU territory using the applicable PG&E, SCE, or SDG&E electric avoided-cost values. For adoption in gas IOU-only territory, the model assigns zero electric avoided-cost benefits but applies gas avoided-cost benefits using the applicable mapped gas utility territory. Adoption outside both electric and gas IOU territory is excluded from the primary TSB and cost-effectiveness calculation. This treatment allows the model to count gas benefits in portions of the state served by a gas IOU but not an electric IOU, while preserving the CPUC cost-effectiveness convention of excluding non-IOU electric benefits from the primary cost-effectiveness result.

4.2 TSB results

Table 10 shows estimated TSB by cost-test basis and benefit category for the 2028-2047 forecast period. Under the TRC/PAC basis, total TSB is estimated at $508.8 million, consisting of energy, grid, and GHG benefits. Under the SCT basis, total societal benefits are higher because the SCT includes additional societal avoided-cost components and applies societal discounting.

Table 10. TRC, PAC, base SCT, and high SCT TSB estimates, 2028-2047

MTI Approach	TSB ($M)[33]	Energy ($M)	Grid ($M)	GHG non-refrigerant ($M)
TRC	508.8	105.4	63.8	339.6
SCT base	992.9	186.1	112.3	694.5
SCT high	1,001.3	186.1	112.3	702.9

[33] TSB refers to Total System Benefits for the TRC test and Total Societal benefits for the SCT.

4.3 Co-created and statewide TSB

The TSB value reported for cost effectiveness uses net incremental IOU-territory adoption after removing PA-verified units. This is the appropriate value for CPUC cost-effectiveness testing, but it does not fully represent the statewide market impact of the CRAWS MTI. The distinction between the primary cost-effectiveness result and the broader statewide result is especially relevant for CRAWS because some adoption outside electric IOU territory will still produce gas benefits in gas IOU territory, and additional adoption outside IOU territory may contribute to broader statewide market transformation even though it is not included in the primary cost-effectiveness calculation.

CalMTA therefore also presents co-created and statewide TSB estimates. Co-created TSB includes PA-verified units within IOU service territories because those installations may be influenced by the MTI even if the verified savings are claimed through PA programs. Statewide co-created TSB includes statewide incremental adoption, including adoption outside IOU service territories, and applies population-weighted average avoided costs where IOU-specific avoided-cost values are not available. These supplemental results show the broader statewide benefits of market transformation while preserving the narrower net incremental value for formal cost-effectiveness tests.[34] Table 11 compares the narrower IOU-territory TSB used for formal cost-effectiveness testing with broader co-created and statewide TSB estimates that include additional influenced adoption.

Table 11. Co-created and statewide TSB

TSB Basis	TSB ($M)
Net incremental TSB used for cost effectiveness (IOU service territory, excluding PA-verified units)	508.8
Incremental co-created TSB (IOU service territory, including PA-verified units)	650.2
Incremental statewide TSB (statewide, including PA-verified units and non-IOU territory)	774.9

Source: CalMTA estimates. Values are present value 2024 dollars. Co-created IOU TSB includes PA-verified units within IOU territory. Co-created statewide TSB includes PA-verified units and adoption outside IOU territories.

[34] For co-created and statewide TSB framing, see the CalMTA MTI Evaluation Framework and Appendix F: Evaluation Plan. Co-created TSB includes PA-verified units influenced by the MTI; statewide TSB includes adoption outside IOU service territories to provide context on broader California market effects.

5 Cost effectiveness

CalMTA estimated cost effectiveness by combining the net incremental CSW adoption forecast with avoided costs, unit energy impacts, load shapes, initiative costs, and incremental measure costs. The analysis reports TRC, PAC, and SCT ratios consistent with CPUC cost-effectiveness practice. The TRC and SCT include participant incremental measure costs and CalMTA initiative costs. The PAC includes CalMTA initiative costs but excludes participant incremental measure costs.

5.1 Initiative costs

Initiative costs represent the cost of implementing the CRAWS MTI over the forecast period, including MTI management, research and evaluation, field demonstrations, marketing and awareness-building, technical-resource development, and market engagement. CalMTA used the initiative-cost forecast included in the CRAWS MTI Plan. These costs total approximately $44.9 million in nominal dollars, equivalent to approximately $26.5 million in 2024 dollars (Table 12).[35]

Table 12. Initiative costs

Cost Type	Total Initiative Costs ($M)
Nominal	44.9
Present Value (2024 dollars)	26.5

5.2 Incremental measure cost

Incremental measure cost (IMC) represents the total incremental cost to the purchaser of installing an MTI measure relative to the applicable baseline condition. CRAWS has one modeled installation condition, as described in Section 3.8: installing CSW on an existing commercial single-pane or clear double-pane window relative to the equipment baseline of leaving the existing window in place. Because CSW is modeled as a retrofit add-on to existing windows, the baseline cost is zero and the full installed cost of CSW is treated as incremental. CalMTA's primary forecast uses an installed cost of approximately $34 per square foot of CSW window area.[36]

The CalMTA primary forecast assumes that IMC does not decline over the MTI period. This is conservative relative to the MTI theory that supply-chain development, installer training, product standardization, and market scale may reduce soft costs over time. The model therefore gives the

[35] Initiative costs are based on the CRAWS MTI Plan lifecycle cost forecast.

[36] The primary installed-cost assumption is $34.1 per square foot of CSW window area based on the measure cost listed in draft measure SWBE012-01 from the California electronic technical reference manual. See Appendix D: Market Characterization, Section 8, which discusses CSW cost data limitations and installed-cost information from field studies, case studies, pilot projects, and industry sources for more information on CSW costs.

MTI credit for accelerating adoption, but not for reducing installed costs in the primary forecast. Total incremental measure costs total approximately $363.1 million in 2024 dollars.

5.3 Total resource cost test

The TRC test compares lifecycle benefits delivered by the MTI to the costs borne by both the PA and participating customers. For this analysis, the TRC numerator is the present value of avoided-cost benefits from net incremental CSW adoption. The TRC denominator includes present-value initiative costs, excluding future direct implementation costs where applicable, and present-value incremental measure costs.

$$TRC = (Electric\ Benefits + Gas\ Benefits + Other\ Benefits) \ /\ TRC\ Cost$$

5.4 Program administrator cost test

The PAC test compares lifecycle benefits to costs from the PA perspective. For this MTI analysis, the PAC numerator is the present value of avoided-cost benefits from net incremental CSW adoption, and the PAC denominator is the present value of CalMTA initiative costs. Participant incremental measure costs are not included in the PAC denominator because the PAC test reflects costs incurred by the PA, not costs paid by participating building owners.

$$PAC = (Electric\ Benefits + Gas\ Benefits + Other\ Benefits) \ /\ PAC\ Cost$$

5.5 Societal cost test

The SCT compares lifecycle benefits and costs from the broader societal perspective. Like the TRC, it includes participant incremental measure costs and initiative costs, but it applies societal avoided-cost assumptions and societal discounting. The societal framework places greater weight on long-term public benefits, including GHG and other societal avoided-cost components, than the TRC framework. Because CRAWS produces long-lived building envelope savings, the SCT is sensitive to the discount rate and to the treatment of long-term avoided emissions and grid benefits. Lower societal discounting generally increases the present value of benefits that occur later in the measure life.

$$SCT_{base} = (Base\ SCT\ Electric\ Benefits + Base\ SCT\ Gas\ Benefits + Other\ Benefits) \ /\ SCT\ Cost$$

The high SCT ratio is calculated as:

$$SCT_{high} = (High\ SCT\ Electric\ Benefits + High\ SCT\ Gas\ Benefits + Other\ Benefits) \ /\ SCT\ Cost$$

5.6 Cost-effectiveness results

Table 13 provides the MTI cost-effectiveness estimates over the 2028-2047 forecast period. These results indicate that the CSW-only forecast is cost effective under the TRC, PAC, and SCT tests, even before monetizing several non-energy benefits, potential infiltration savings, potential HVAC downsizing benefits, or potential VIG adoption.

Table 13. MTI cost-effectiveness estimates, 2028-2047

TRC	PAC	Base SCT	High SCT
1.31	19.19	1.82	1.84

5.7 Cost-effectiveness schedule

Table 14 shows cumulative TSB, cost-effectiveness estimates, and incremental investment at five-year intervals. MTI cost-effectiveness is properly assessed over the full MTI lifecycle rather than at interim points because MTIs typically require the greatest investment during early years to address market barriers, but they accrue the bulk of benefits in later years as removal of market barriers enable growth in awareness, development of market infrastructure, and changes in standard practice. CalMTA presents this schedule to show the expected timing of benefits and investment rather than to indicate that early-year cost effectiveness should be used to assess actual MTI cost-effectiveness.

Table 14. Incremental Investment and Cost effectiveness, at five-year timepoints

Estimated incremental investment required over period	2027-2031	2032-2036	2037-2041	2042-2047
Nominal dollars ($M)	16.0	17.9	5.4	1.4
Cost-Effectiveness Forecast at time point	**2032**	**2037**	**2042**	**2047**
TSB ($M)	10.6	133.8	361.6	508.8
TRC ratio	0.39	1.00	1.22	1.31
PAC ratio	0.61	5.35	13.77	19.19

6 Sensitivity analysis

CalMTA conducted sensitivity analysis to test the robustness of the primary forecast results to changes in key assumptions. These sensitivity scenarios show which assumptions have the largest effect on adoption, TSB, and cost-effectiveness, and show how the result changes under plausible alternative assumptions. The sensitivity scenarios are not probability-weighted scenarios.

The sensitivity scenarios test five types of uncertainty: measure life, installed cost, policy environment, awareness of the value proposition, and the rate of adoption. The scenario with the lowest incremental adoption and TSB is the higher-cost case, which confirms that installed cost is an important downside risk. The 20-year EUL scenario results in significantly lower TSB and TRC, confirming that measure life is a key parameter in assessing CSW cost-effectiveness. Table 15 summarizes the sensitivity scenarios that CalMTA tested, including the resulting TRC ratio, TSB, and net incremental adoption.

Table 15. Sensitivity analysis results

#	Sensitivity scenario	TRC ratio	TSB ($M)	Net incremental adoption (M sq ft)
NA	Primary forecast	1.31	508.8	37.6
1	20-year EUL	1.09	413.2	37.6
2	Higher CSW costs	1.22	408.7	27.9
3	Lower CSW costs	1.30	663.3	59.3
4	Building performance standard	1.32	669.4	48.7
5	Lower AVP in TMA	1.30	451.1	33.7
6	Slower growth rate in TMA	1.29	455.1	33.7
7	Faster growth rate in TMA	1.31	551.6	40.7

6.1 20-year effective useful life

The 20-year EUL scenario reduces the benefit life from 30 years to 20 years while holding adoption and costs constant. This decreases the number of years over which each CSW installation produces avoided-cost benefits, leading to significantly lower TSB and TRC values. These results demonstrate that the forecast is materially affected by the measure-life assumption and that the 30-year EUL is a key model parameter. The results for this analysis are shown in Table 16.

Table 16. Sensitivity scenario #1 results

Model Run	TRC ratio	TSB ($M)	Net incremental adoption (M sq ft)
Primary Forecast	1.31	508.8	37.6
Sensitivity Scenario #1	1.09	413.2	37.6

6.2 Higher CSW costs

The higher-cost scenario increases installed CSW per square foot from $34.1 to $40.0 (Table 17). Higher costs reduce the share of the addressable market that clears the payback filter, lowering net incremental adoption. Higher costs also increase the cost side of the TRC test. The combined effect reduces incremental adoption, TSB, and TRC. The results for this scenario are shown in Table 18.

Table 17. CSW Costs used in sensitivity scenario #2

Growth rate (r)	CSW Cost
Primary Forecast	$34.1 per square foot
Sensitivity Scenario #2	$40.0 per square foot

Table 18. Sensitivity scenario #2 results

Model Run	TRC ratio	TSB ($M)	Net incremental adoption (M sq ft)
Primary Forecast	1.31	508.8	37.6
Sensitivity Scenario #2	1.22	408.7	27.9

6.3 Lower CSW costs

The lower-cost scenario reduces installed CSW per square foot from $34.1 to $30.0 (Table 19). Lower costs increase the share of the market that clears the payback filter, increasing net incremental adoption and TSB. The TRC ratio remains approximately the same as in the primary forecast as the increase in benefits is partially offset by the additional measure costs associated with greater adoption, and the lowered cost changes the population of buildings included in the estimated achievable potential. This result shows that lower costs expand market reach and total benefits even if the benefit-cost ratio does not increase materially. The results for this scenario are shown in Table 20.

Table 19. CSW Costs used in sensitivity scenario #3

Growth rate (r)	CSW Cost
Primary Forecast	$34.1 per square foot
Sensitivity Scenario #3	$30.0 per square foot

Table 20. Sensitivity scenario #3 results

Model Run	TRC ratio	TSB ($M)	Net incremental adoption (M sq ft)
Primary Forecast	1.31	508.8	37.6
Sensitivity Scenario #3	1.30	663.3	59.3

6.4 Building performance standard

The building performance standard scenario models a policy environment in which commercial building owners face stronger requirements to evaluate and improve building performance. This scenario assumes that a California building performance standard (BPS) or similar policy increases both the awareness of the value proposition and the adoption growth rates earlier and faster in both BMA and TMA compared to the primary forecast. [37]

In this scenario, the BPS policy signal and the MTI compound: the policy creates a stronger reason for building owners to evaluate envelope improvements, while the MTI increases the likelihood that CSW is recognized, recommended, and specified as part of that evaluation. To reflect this effect, the BPS scenario includes a steep increase in AVP in all model scenarios and segments beginning around 2032, which is when CalMTA estimates a BPS policy could likely be in effect. The AVP values and growth rates used in this scenario are shown in Figure 4 and Table 21, respectively. See Figure 2 for the AVP values used in the primary forecast. The results for this scenario are shown in Table 22.

[37] The building performance standard sensitivity is a policy-environment sensitivity and is not included in the primary forecast. For CRAWS policy context, see the CRAWS MTI Plan, Energy Policy Landscape and Strategic Interventions sections; Appendix D: Market Characterization, Section 5.3; and Appendix F: Evaluation Plan MPIs related to policy, market actor awareness, and envelope-first planning.

Figure 4. AVP values in sensitivity scenario #4

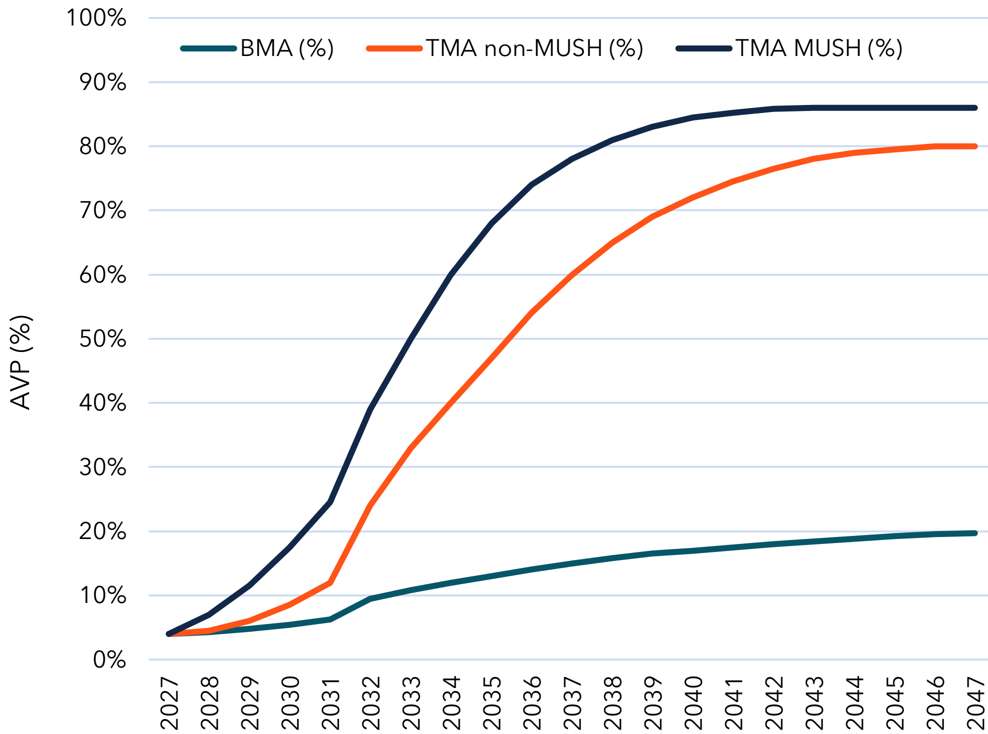


Table 21. Growth rates used in sensitivity scenario #4

Growth rate (r)	BMA	TMA non-MUSH	TMA MUSH
Primary Forecast	0.07	0.18	0.22
Sensitivity Scenario #4	0.08	0.20	0.24

Table 22. Sensitivity scenario #4 results

Model Run	TRC ratio	TSB ($M)	Net incremental adoption (M sq ft)
Primary Forecast	1.31	508.8	37.6
Sensitivity Scenario #4	1.32	669.4	48.7

6.5 Lower AVP in TMA

The lower-AVP scenario assumes that MTI interventions are less effective at building market-actor awareness and confidence than assumed in the primary forecast. The TMA awareness trajectory still increases over time but remains lower throughout the forecast period. Figure 5 shows the

AVP values used in this scenario, and the results are shown in Table 23. See Figure 2 for the AVP values used in the primary forecast. The result remains cost effective, suggesting that the primary forecast is not highly sensitive to moderate reductions in awareness growth.

Figure 5. AVP values used for sensitivity scenario #5

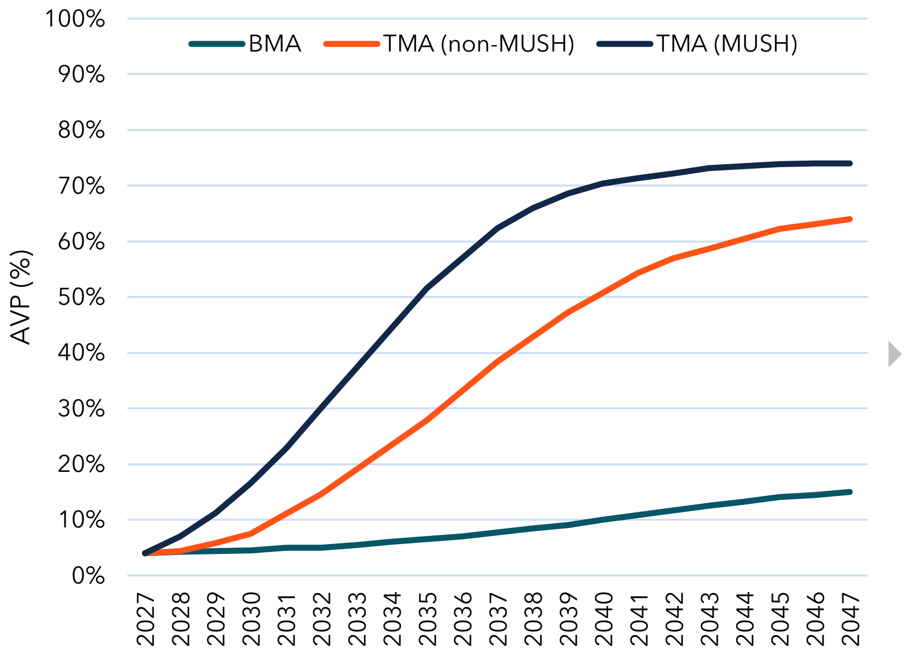


Table 23. Sensitivity scenario #5 results

Model Run	TRC ratio	TSB ($M)	Net incremental adoption (M sq ft)
Primary Forecast	1.31	508.8	37.6
Sensitivity Scenario #5	1.30	451.1	33.7

6.6 Slower growth rate in TMA

In this scenario, CalMTA lowers the TMA growth-rate assumptions for both non-MUSH and MUSH, relative to primary forecast values. This reflects slower market diffusion compared to the primary forecast, such as if installer training, supply-chain development, or ESCO integration takes longer than expected. Table 24 shows the growth rate values used in this scenario, and the results are shown in Table 25. The result remains cost effective, suggesting that moderate delays in market acceleration do not fundamentally change the cost-effectiveness conclusion.

Table 24. Growth rates used in sensitivity scenario #6

Growth rate (r)	BMA	TMA non-MUSH	TMA MUSH
Primary Forecast	0.07	0.18	0.22
Sensitivity Scenario #6	0.07	0.15	0.19

Table 25. Sensitivity scenario #6 results

Model Run	TRC ratio	TSB ($M)	Net incremental adoption (M sq ft)
Primary Forecast	1.31	508.8	37.6
Sensitivity Scenario #6	1.29	455.1	33.7

6.7 Faster growth rate in TMA

In this sensitivity analysis, CalMTA increases the TMA growth-rate assumptions for both non-MUSH and MUSH markets relative to the primary forecast values. The growth rates used in this analysis are shown in Table 26. The faster-growth case tests a scenario in which MTI activities catalyze adoption more quickly than assumed in the primary forecast, such as through strong early uptake in MUSH markets or rapid integration into ESCO project portfolios. Together, the slower- and faster-growth cases bracket the primary forecast and show that cost effectiveness remains positive across a plausible range of adoption-timing assumptions. Results for this analysis are shown in Table 27.

Table 26. Growth rates used in sensitivity scenario #7

Growth rate (r)	BMA	TMA non-MUSH	TMA MUSH
Primary Forecast	0.07	0.18	0.22
Sensitivity Scenario #7	0.07	0.21	0.25

Table 27. Sensitivity scenario #7 results

Model Run	TRC ratio	TSB ($M)	Net incremental adoption (M sq ft)
Primary Forecast	1.31	508.8	37.6
Sensitivity Scenario #7	1.31	551.6	40.7

Attachment 1: Documentation of unit energy savings and avoided cost calculations for commercial replacement and attachment window solutions (CRAWS)

This document provides a reference of the scenarios and methodology used to develop unit energy savings shapes and avoided cost calculations that serve as inputs to the cost effectiveness and total system benefit models for the CRAWS MTI.

Product information

The product in this MTI is CSWs, retrofit products comprised of one or more panes of glass, polymer, or acrylic that are mounted in a fixed or operable frame that is attached to either the interior or exterior of existing windows without replacing the primary glass or frame. CSWs may include low-e coatings,[38] insulating gases, thermal films, and/or VIG units in their construction. CSWs may be permanently installed or removable. Because CSWs are installed over the existing window and because light-weight options are available, installation can be substantially easier, faster, and less expensive than full window replacement.

The lower product costs and significantly lower installation costs of CSWs compared to primary commercial fenestration are an attractive solution for any building that needs to address envelope performance without the need to undergo a deep retrofit.

Baseline equipment

In this MTI, we are considering the installation of CSWs to be a scenario of building weatherization. In this scenario, the baseline is existing equipment rather than alternative new equipment. For the baseline scenario, the equipment is the existing windows, which are typically either single-pane or double-pane clear windows. This program is targeting existing buildings with clear glass windows (i.e., buildings without low-e or reflective coatings on their windows) because this is the type of existing condition where CSW can offer the largest energy savings and best payback. **Table 28** summarizes the basic performance characteristics for the baseline existing windows. The performance values of existing windows were taken from the eTRM

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[38] Low-E refers to low-emissivity coatings which are used to reduce the solar heat gain of glass. Clear glass has no low-e coating and a higher solar heat gain coefficient.

measure for CSWs and represent the existing commercial building stock in California.[39] The U-factor and SHGC of the baseline windows are comparable with single-pane and double-pane clear glass with older framing (i.e., lower insulation). CSWs have demonstrated the ability to substantially reduce air infiltration in many cases,[40] which contributes to energy savings. However, by following the draft CSW measure framework in the eTRM, the benefits of reduced air infiltration were not accounted for in the energy models.

Table 28. Baseline window characteristics for existing buildings

Climate Zone	U-factor (Btu/hr-ft²-°F)	Solar Heat Gain Coefficient (SHGC)
CZ01	1.03	0.707
CZ02	1.03	0.707
CZ03	1.03	0.737
CZ04	1.03	0.718
CZ05	1.03	0.753
CZ06	1.03	0.725
CZ07	1.03	0.726
CZ08	1.03	0.724
CZ09	1.03	0.723
CZ10	1.03	0.573
CZ11	1.03	0.643
CZ12	1.03	0.643
CZ13	1.03	0.635
CZ14	1.03	0.607
CZ15	1.03	0.571
CZ16	1.03	0.627

Proposed equipment

The proposed equipment is CSWs, representing typical products that might be used in existing California commercial buildings. CalMTA chose a U-factor to represent typical CSWs based upon

[39] California eTRM draft measure SWBE012-01-draft, High Efficiency Window, Commercial, Accessed February 10, 2026.

[40] Henderson, H.I., A.C. Walburger, J.B. Cummings, C. Withers, L. Gu, J. Zhang, M. Bomberg, M. Salonvaara, T. Brennan, M. Clarkin. 2007. 'Mitigating the Impacts of Uncontrolled Air Flow on Indoor Environmental Quality and Energy Demand in Non-Residential Buildings.' Final Report DOE Project No. DE-FC-36-02GO12012. April. http://www.fsec.ucf.edu/en/publications/pdf/FSEC-CR-1744-07.pdf

the available products from the Attachments Energy Rating Council (AERC) database.[41] From the 28 products analyzed, we excluded the worst quartile of performing products (U > 0.49 Btu/hr-ft^2-°F). Of the remaining 20 products with a range of U-factors from 0.16 to 0.48, we used the average of 0.35 Btu/hr-ft^2-°F. For SHGC, the most popular type of low-e coatings for warmer climates have a SHGC of approximately 0.25.[42] **Table 29** summarizes the performance characteristics for the proposed CSW products.

Table 29. Proposed attachment and replacement window characteristics

Characteristic	Commercial Secondary Windows
Number of panes of glass	2
Low-e coating	Yes
U-factor (Btu/hr-ft^2-°F)[43]	0.35
SHGC	0.25

Energy modeling software

DOE's open-source building energy modeling software, EnergyPlus, is used in this analysis (version 24.2). EnergyPlus simulates whole-building energy consumption on sub-hourly timesteps and can output the energy consumption of the whole building on an hourly basis, which is used here to generate savings shapes. Each savings shape is an hourly (8760) profile of electricity consumption (in kWh) and gas consumption (in therms) that represents the difference between the baseline and proposed window specifications for different energy models. The final hourly savings shapes include contributions from multiple building types and climate zones, as discussed in subsequent sections.

Building models

Building energy modeling is performed with DEER commercial prototype building models to represent the target existing building stock in California. A total of 18 different prototype buildings were used, taken directly from the source Modelkit framework from the CSW eTRM measure. The characteristics of the prototype buildings are shown in **Table 30**.

[41] https://aercenergyrating.org/product-search/ Accessed August 2025.
[42] Many CSW products are listed in the AERC database and in spec sheets with a standard SHGC ~0.35; however, in speaking with manufacturers, offering the same product with the lower SHGC (~0.25) simply requires ordering different low-e glass from the float glass manufacturer. The lower SHGC low-e coating is a widely available product used frequently in standard commercial glazing products.
[43] Total fenestration U-factor including glass and framing,

Table 30. Description of buildings used for energy modeling

Building Code	Full name	Floor Area (ft^2)	Window Area (ft^2)
Asm	Assembly	68,007	2,102
ECC	Education – community college	284,193	11,564
EPr	Education – primary school	40,745	1,690
ERC	Education – relocatable classroom	2,884	64
ESe	Education – secondary school	74,402	4,518
EUn	Education - university	857,786	34,140
Hsp	Health/medical - hospital	494,056	5,083
Htl	Lodging – hotel	137,117	6,745
Mtl	Lodging – motel	29,986	4,776
Nrs	Health/medical – nursing home	110,999	6,340
OfL	Office - large	349,920	21,384
OfS	Office - small	20,005	2,286
RFF	Restaurant – fast food	3,996	581
RSD	Restaurant – sit down	11,205	510
Rt3	Retail – multistory large	240,000	998
RtL	Retail – single-story large	130,502	868
RtS	Retail – small	16,003	604
SCn	Storage - conditioned	499,990	1,358

Building HVAC

Each prototype model has a unique HVAC system that was left unmodified for this analysis. In all cases, most of the heating energy was from natural gas. CalMTA used the default efficiency settings from the DEER ModelKit framework for the CSW measure in the eTRM.[44] The basic HVAC properties are listed for each building in **Table 31**, and the detailed HVAC descriptions are listed in Table 33.

[44] California eTRM draft measure SWBE012-01-draft, High Efficiency Window, Commercial, Accessed February 10, 2026.

Table 31. Basic HVAC properties for prototype buildings[45]

Building	HVAC System 1	HVAC System 2	Kitchen System	Data Center System	Heating Plant	Cooling Plant
Asm	Sys5-PVAV	-	-	-	2 Boilers	-
ECC	Sys6-VAV	-	Sys13	Sys11	2 Boilers	Chillers
Epr	Sys7-SZVAV-DCV	Sys7-SZCAV	Sys13	-	-	-
ERC	Sys7-SZCAV	-	-	-	-	-
ESe	Sys5-PVAV-DCV	Sys7-SZVAV	Sys13	Sys11	2 Boilers	-
Eun	Sys6-VAV-DCV	Sys1-SZAC	Sys13	Sys11	2 Boilers	Chillers
Hsp	Sys6-VAV-DCV	Sys6-VAV	Sys13	-	2 Boilers	Chillers
Htl	Sys5-PVAV	Sys1-SZAC	Sys13	-	2 Boilers	-
Mtl	Sys5-PVAV	Sys1-SZAC	-	-	2 Boilers	-
Nrs	Sys5-PVAV-DCV	Sys5-PVAV	Sys13	-	2 Boilers	-
OfL	Sys6-VAV	Sys6-VAV-DCV	-	-	2 Boilers	Chillers
OfS	Sys7-SZCAV	-	-	-	-	-
RFF	Sys7-SZCAV	-	Sys13	-	-	-
RSD	Sys7-SZCAV	Sys5-PVAV-DCV	Sys13	-	-	-
Rt3	Sys5-PVAV-DCV	Sys7-SZCAV	-	-	2 Boilers	-
RtL	Sys7-SZVAV	Sys7-SZCAV	Sys13	-	-	-
RtS	Sys7-SZVAV	Sys7-SZCAV	-	-	-	-
SCn	Sys6-VAV	-	-	-	2 Boilers	Chillers

[45] https://calbem-benchmarking.com/docs/building-energy-models/non-residential/hvac/

Table 33. HVAC detailed descriptions[45]

System Type	Description	Detail
System 1 - SZAC	Residential Air Conditioner	Single-zone system with constant volume fan, no economizer, DX cooling and furnace
System 3 - SZAC	Packaged Single-Zone	Single-zone constant volume DX unit with gas heating
System 5 - PVAV	Packaged VAV Unit	VAV reheat system; packaged variable volume DX unit with gas heating and with hot water reheat terminal unit
System 6 - VAVS	Built-up VAV Unit	Variable volume system with chilled water and hot water coils, water-cooled chiller, tower and central boiler
System 7 - SZVAV	Packaged Single-Zone VAV Unit	Single-zone variable volume DX unit with variable-speed drive and gas heating
System 9 - HEATVENT	Heating and Ventilation Only	Gas heating and ventilation
System 10 - CRAH	Computer Room Air Handler	Built-up variable volume unit with chilled water, no heating
System 11 - CRAC	Computer Room Air Conditioner	Packaged variable volume DX unit with no heating
System 13 - KITCH	Kitchen HVAC System	Dedicated single-zone makeup air unit (MAU) with dedicated exhaust fan.

Case descriptions

There are two different modeling cases that are used to create the proposed and baseline installations in the final scenarios for savings shapes and avoided cost calculations. **Table 32** gives a description of each modeling case.

Table 32. Summary of case characteristics

#	Case name	Case description[46]
1	CSW	CSW windows
2	Ex	Existing windows

Effective useful life

EUL is the estimated median life, in years, that a measure remains in operation. At the time of analysis, the CA eTRM did not have an EUL for commercial windows, but the CPUC is recommending the TRM use an EUL of 30 years which is consistent with several other efficiency programs including the Illinois state TRM[47] and the Northwest Regional Technical Forum[48] which specify an EUL of 30 years for CSWs.

Climate zones

The energy savings of window upgrades is heavily climate dependent. CalMTA analyzed energy consumption and bill impacts across all 16 California climate zones using CZ2022 weather files, which represent 20 years of weather observed from 1998 to 2017, and were adopted for Title 24 Version 2022.[49] The weather files used are shown in **Table 33**.

Table 33. Weather files for energy modeling in each climate zone

Climate zone	Weather file	Included in TSB Calculations
1	CA_EUREKA_725940S_CZ2022.epw	Yes
2	CA_NAPA-CO_724955S_CZ2022.epw	Yes
3	CA_OAKLAND-METRO-AP_724930S_CZ2022.epw	Yes
4	CA_SAN-JOSE-IAP_724945S_CZ2022.epw	Yes
5	CA_SANTA-MARIA-PUBLIC-AP_723940S_CZ2022.epw	Yes
6	CA_LOS-ANGELES-IAP_722950S_CZ2022.epw	Yes
7	CA_SAN-DIEGO-LINDBERGH-FLD_722900S_CZ2022.epw	Yes
8	CA_LONG-BEACH-DAUGHERTY-FLD_722970S_CZ2022.epw	Yes
9	CA_LOS-ANGELES-DOWNTOWN-USC_722874S_CZ2022.epw	Yes
10	CA_RIVERSIDE-MUNI_722869S_CZ2022.epw	Yes
11	CA_RED-BLUFF-MUNI-AP_725910S_CZ2022.epw	Yes
12	CA_STOCKTON-METRO-AP_724920S_CZ2022.epw	Yes

[47] 2025 Illinois Statewide Technical Reference Manual for Energy Efficiency, Version 13.0, https://www.ilsag.info/wp-content/uploads/IL-TRM_Effective_010125_v13.0_Vol_2_C_and_I_09202024_FINAL.pdf
[48] The NW-RTF measure ran from 2017 to 2025. https://rtf.nwcouncil.org/measure/commercial-secondary-glazing-systems/
[49] https://www.calmac.org/weather.asp

Climate zone	Weather file	Included in TSB Calculations
13	CA_FRESNO-YOSEMITE-IAP_723890S_CZ2022.epw	Yes
14	CA_DAGGETT-BARSTOW-AP_723815S_CZ2022.epw	Yes
15	CA_EL-CENTRO-NAF_722810S_CZ2022.epw	Yes
16	CA_BISHOP-AP_724800S_CZ2022.epw	Yes

Avoided cost calculations

The CPUC's ACC[50] provides a robust framework for evaluating the benefits of distributed energy resources such as energy efficiency and fuel-switching measures. The ACC estimates system-level costs of providing electric or gas service on an hourly basis in $/kWh and $/therm.[51] The calculator is composed of three parts: an electric ACC, a natural gas ACC, and a refrigerant calculator. The calculator converts gas and electricity use into avoided cost dollars, providing a metric to quantify savings from fuel switching and efficiency measures. The avoided cost factors (in $/kWh and $/therm) are applied to a unit energy savings shape on an hourly basis to calculate the avoided cost benefit per scenario, which is an input for the estimate of the MTI's cost-effectiveness and total system benefit (TSB).

The previous TSB calculations for CRAWS in the CRAWS Advancement Plan used the 2022 version of the ACC workbook. A new version was released in 2024; all calculations in this analysis are based on the 2024 version. There are significant changes in the factors between the 2022 and 2024 ACC workbooks, including the following, as noted in CPUC documentation:[52]

- Energy value is more time-dependent (lower midday and higher overnight and early morning)
- Higher GHG value concentrated in evenings and early mornings

[50] Per the CPUC, "The primary benefits of demand-side resources are the avoided costs related to generation and distribution of energy. The avoided costs of electricity are modeled based on the following components: generation energy, generation capacity, ancillary services, transmission and distribution capacity, and decarbonization policy compliance. The Avoided Cost Calculator was established in 2005 and is updated biennially to improve the accuracy of how the benefits of demand-side resources are calculated."
[51] 2024 Distributed Energy Resources Avoided Cost Calculator Documentation. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/demand-side-management/acc-models-latest-version/2024-acc-documentation-v1b.pdf.
[52] https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/demand-response/cost-effectiveness/2024-draft-acc-workshop---final.pdf.

- Lower annual generation capacity value spread out over more hours
- Gas avoided costs are slightly higher, with the largest increases in winter months

CalMTA uses the electric, gas, and refrigerant workbooks. The electric and gas ACC workbook settings used to produce hourly factors are shown in **Table 34**.[53] One climate zone is used for each IOU to develop avoided cost factors as a simplification due to the large amount of data required from the avoided cost workbooks for each new set of factors (the factor data file for a single climate zone contains approximately 9 million entries).

Table 34. Avoided cost workbook settings

Cost test	**Total Resource Cost (TRC)**	**Societal Cost Test (SCT)**
ACC workbook version	2024 v1b	2024 v1b
Discount rate	7.30%	5.06%
Social cost of carbon	-	Base and high
Start year	2024	2024
End year	2054	2054
IOU climate zones		
PG&E	12	12
SCE	10	10
SDG&E	7	7
Electric components to include		
Cap & trade	TRUE	TRUE
GHG adder	TRUE	TRUE
GHG rebalancing	TRUE	TRUE
Energy	TRUE	TRUE
Generation capacity	TRUE	TRUE
Transmission capacity	TRUE	TRUE
Distribution capacity	TRUE	TRUE
Ancillary services	TRUE	TRUE
Losses	TRUE	TRUE
Methane leakage	TRUE	TRUE
Air quality adder	TRUE	TRUE
Final air quality adder	FALSE	TRUE
Gas main inputs		

[53] The final air quality adders for both electric and gas are FALSE for TRC and TRUE for SCT, as these are hard-coded settings in the workbook that adjust based on the chosen cost test.

Cost test	Total Resource Cost (TRC)	Societal Cost Test (SCT)
Class	Commercial	Commercial
End use	Small Boiler	Small Boiler
Emission control	Low NOx	Low NOx
Gas components to include		
Market	TRUE	TRUE
Transmission & distribution (T&D)	TRUE	TRUE
Environment	TRUE	TRUE
Upstream methane leakage	TRUE	TRUE
Behind-the-meter methane leakage	TRUE	TRUE
Air quality adder	TRUE	TRUE
Final air quality adder[54]	FALSE	TRUE

6.8 Weighting factors

The final single ACC scenarios included energy modeling results from 16 climate zones, 18 building types, and two installation cases, for 576 unique load shapes. Final unit energy savings (UES) hourly profiles are weighted using the relative contribution of each building type, climate zone, and modeling case. The unit for energy savings is one square foot of window area. A single UES is derived as follows:

$$UES_n = \sum_{i=1}^{18}\sum_{j=1}^{16} w_{bldg,i} \cdot w_{cz,j} \left[\sum_{k=1}^{1} w_{base,k} \cdot BLS_{base,k} - \sum_{m=1}^{1} w_{prop,m} \cdot BLS_{prop,m}\right]$$

Where:

UES_n represents the savings shape for the nth scenario (in either kWh or therms),

w_{bldg} is the weighting of building type,

w_{cz} is the weighting of the climate zone,

$w_{base,k}$ is the weighting of case k for the baseline equipment,

$BLS_{base,k}$ is the hourly building load for the base equipment in case k (in either kWh or therms),

$w_{prop,m}$ is the weighting of case m for the proposed equipment, and

[54] The final air quality adder is controlled by the cost test and is automatically FALSE for TRC and TRUE for SCT.

$BLS_{prop,m}$ is the hourly building load for the proposed equipment in case m (in either kWh or therms).

The building weighting factors are derived from the Building Weights CPUC Support Table in the eTRM.[55] These weights represent the total floor area by climate zone for existing buildings. This MTI uses a normalization of window area; the floor area weights were converted to window area weights using the ratio of window area to floor area for each prototype shown in Table 30. The weights for buildings without cooling are shown in Table 35.

[55] https://www.caetrm.com/cpuc/table/buildingweights/

Table 35. Building weighting factors for cooling cases

Building	CZ01	CZ02	CZ03	CZ04	CZ05	CZ06	CZ07	CZ08	CZ09	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
Asm	0.03	0.32	1.59	0.87	0.13	2.64	0.62	3.89	2.60	2.48	0.24	0.93	0.85	0.48	0.79	0.33
ECC	0.07	0.20	0.98	0.25	0.19	1.23	0.48	2.03	1.12	0.73	0.25	0.35	0.50	0.21	0.17	0.38
EPr	0.03	0.22	0.83	0.43	0.06	1.12	0.35	1.95	1.43	1.43	0.19	0.67	0.76	0.32	0.11	0.18
ERC	0.02	0.12	0.44	0.23	0.03	0.60	0.19	1.04	0.76	0.77	0.10	0.36	0.41	0.17	0.06	0.10
ESe	0.04	0.32	1.21	0.62	0.09	1.64	0.51	2.85	2.09	2.10	0.28	0.98	1.12	0.47	0.16	0.26
EUD	0.11	0.30	1.47	0.37	0.28	1.84	0.72	3.03	1.67	1.09	0.37	0.52	0.74	0.31	0.25	0.57
EUn	0.07	0.19	0.96	0.24	0.18	1.21	0.47	1.98	1.10	0.71	0.24	0.34	0.49	0.20	0.16	0.37
Gro	0.04	0.26	0.89	0.40	0.12	1.66	0.65	2.42	1.70	2.01	0.24	0.78	0.80	0.42	0.25	0.20
Hsp	0.01	0.07	0.20	0.09	0.03	0.34	0.13	0.38	0.33	0.21	0.05	0.15	0.16	0.03	0.04	0.03
Htl	0.01	0.05	0.28	0.10	0.04	0.42	0.21	0.29	0.33	0.09	0.03	0.09	0.07	0.04	0.18	0.06
Mtl	0.15	0.71	4.30	1.51	0.68	6.53	3.24	4.52	5.12	1.44	0.40	1.40	1.08	0.56	2.79	0.87
Nrs	0.04	0.37	1.10	0.51	0.19	1.88	0.74	2.13	1.83	1.18	0.26	0.85	0.86	0.19	0.22	0.15
OfL	0.11	1.25	13.18	5.63	0.56	16.54	5.21	21.17	21.19	5.81	0.49	4.21	2.25	1.07	1.28	0.54

Building	CZ01	CZ02	CZ03	CZ04	CZ05	CZ06	CZ07	CZ08	CZ09	CZ10	CZ11	CZ12	CZ13	CZ14	CZ15	CZ16
OfS	0.26	0.64	3.83	3.00	0.29	7.36	5.12	9.17	7.51	7.82	0.95	3.74	4.76	0.96	1.83	0.66
RFF	0.06	0.26	1.19	0.52	0.15	3.28	0.84	3.88	3.23	3.42	0.23	0.80	0.81	0.66	0.62	0.30
RSD	0.02	0.08	0.37	0.16	0.05	1.03	0.26	1.22	1.01	1.07	0.07	0.25	0.25	0.21	0.19	0.09
Rt3	0.01	0.04	0.18	0.08	0.02	0.35	0.10	0.42	0.33	0.36	0.03	0.13	0.12	0.06	0.04	0.01
RtL	0.01	0.06	0.28	0.12	0.03	0.56	0.16	0.66	0.53	0.57	0.05	0.21	0.19	0.09	0.07	0.02
RtS	0.05	0.34	1.59	0.70	0.17	3.18	0.93	3.77	3.00	3.26	0.28	1.18	1.09	0.53	0.41	0.13
SCn	0.00	0.03	0.16	0.06	0.00	0.19	0.07	0.54	0.26	0.57	0.03	0.12	0.10	0.01	0.01	0.01

Avoided cost factors are calculated separately for each IOU because the avoided cost factors differ for each utility. Climate zone weighting factors vary for each utility based upon the energy consumption by IOU and climate zone. The climate zone weighting factors are shown in Table 36.

Table 36. Climate zone apportionment for investor-owned utilities

Climate Zone	PGE	SCE	SDGE	Total
CZ01	100%	0%	0%	100%
CZ02	100%	0%	0%	100%
CZ03	100%	0%	0%	100%
CZ04	100%	0%	0%	100%
CZ05	97.56%	2.44%	0%	100%
CZ06	1.43%	89.29%	9.29%	100%
CZ07	0%	0%	100%	100%
CZ08	0%	96.30%	3.70%	100%
CZ09	0%	100%	0%	100%
CZ10	0%	68.49%	31.51%	100%
CZ11	100%	0%	0%	100%
CZ12	100%	0%	0%	100%
CZ13	86.56%	13.44%	0%	100%
CZ14	1.14%	81.82%	17.05%	100%
CZ15	0%	86.11%	13.89%	100%
CZ16	68.52%	30.86%	0.62%	100%

For CRAWS, there is only a single installation scenario: CSWs installed over existing windows. The single proposed and baseline case is combined to create a single installation scenario for avoided cost calculations and market adoption. The scenario creates a savings shape based on the difference between one baseline and one proposed load shape. The weighting is very simple due to the lack of multiple blended installation cases, resulting in one case each for the baseline and proposed cases (Table 37 and Table 38, respectively).

Table 37. Weights for modeling cases for each ACC - baseline cases

Baseline load shape	S01
Ex	-1

Table 38. Weights for modeling cases for each ACC - proposed cases

Proposed load shape	S01
CSW	1

Refrigerant avoided costs

In this MTI plan, there is no change in refrigerant between any baseline and proposed cases, thus refrigerant avoided costs are not included in the analysis.