Energy & Environmental Solutions

Energy Analysis for Window Films Applications in New and Existing Homes and Offices©

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Purpose of This Study/ Scope

The purpose of this study is to demonstrate the cost-effectiveness of energy control window film in homes and offices, in order to make a case for inclusion in energy and green codes, programs, and incentives in the state of California and expand opportunities for window film in the California market.

Energy Analysis

Description of New and Existing Baselines

The home modeled in the study is a 2,123 ft^2, two-story, single family detached unit, with a glazing percentage of 20% of the conditioned floor area. This house is representative of the new construction housing in California. In the new home model, the energy features of the building was specified as meeting Title 24 Building Energy Efficiency Standards, Part 6 (Title 24) for 2008, the requirements for buildings built at the time of this report. The baseline glass type, however, was not code-compliant glass (0.40 U-factor, 0.40 SHGC), but clear, dual pane glass (0.71 U-factor, 0.63 SHGC). NFRC data for window film is benchmarked against clear glass, and the impact of window film is determined by NFRC ratings, which are recognized by the California Energy Commission (CEC) for code compliance. All residential analysis was done using MICROPAS, which is the most frequently used residential compliance software certified for Title 24.

The existing home baseline was the same model as the new homes, but modified to reflect decreased efficiencies, insulation levels and other features according to TABLE R3-50: Vintage Table Values in appendix B of the of the 2008 Residential Compliance Manual. The energy features of the existing building represented those features used for a house built in the 1990s.

The office building modeled in the study is the Energy Plus Commercial Building Benchmark Model developed by the U.S. Department of Energy (DOE), titled large office building. A version of Energy Plus, modified to comply with the 2008 version of Title 24, rather than with ASHRAE 90.1 Standards, was obtained from the California Energy Commission (CEC) to model the new office building in this study. The office building is 12 stories, and 498,588 ft^2 in conditioned floor area.

The existing large office building is based off of the same model, with energy features modified to comply with the Standards for 1990.

Both residential and office simulations were run in each of the four cardinal directions and the energy usage was averaged over the four orientations.

Description of Variables

The homes were simulated in four key climate zones of the sixteen climate zones recognized in California for the purposes of code requirements. The climate zones were chosen in order to get a range of conditions and represent areas with greater building numbers. These were the mild climate of the Northern California Bay Area (CZ4), the coastal climate zone of San Diego (CZ7), the inland climate zone of Riverside (CZ10) and the Central Valley climate zone of Sacramento (CZ12). These climate zones are representative of the areas where most homes are built in the state. Climate Zones 10 and 12 represent locations with high cooling loads where window film should have a substantial impact on energy use.

The office buildings were simulated in a different set of climate zones, based off of volume of existing and new commercial construction. The representative cities for these climate zones are Oakland (CZ3), San Diego (CZ7), Pasadena (CZ9), and Fresno (CZ13).

Using data from manufacturers and the National Fenestration Rating Council (NFRC) Certified Products Directory, the window films on the market were characterized into three groups, “good”, “better” and “best” options, and a rounded median value chosen for solar heat gain coefficient (SHGC) and U-factor. The values used are detailed in Table 1, shown below. For the office building model, the visible transmittance is also modeled for the purposes of evaluating daylighting design, which is not modeled in the residential software. The films were also evaluated with and without an impact on U-factor to account for the variations in different manufacturers’ products, as some do not achieve significant U-factor differences, yet still achieve significant savings through limiting solar heat gain. The good, better, and best categories in the large office model represent these basic technology films which limit primarily solar heat gain. The better(u) and best(u) categories represent spectrally selective and low-e technology films, respectively.

Table 1: Properties of Windows Studied for the Residential Model

	without	good	better	best
SHGC				
Single	0.71	0.45	0.35	0.20
Double	0.63	0.50	0.45	0.25
U-factor				
Single	1.09	1.09	0.90	0.70
Double	0.71	0.71	0.65	0.55
Cost/ft^2		$4.00	$7.00	$9.00

Table 2: Properties of Windows Studied for the Large Office Model

	without	good	better	Best	better(u)	best(u)
SHGC						
Single	0.71	0.45	0.35	0.20	0.35	0.20
Double	0.63	0.50	0.45	0.25	0.45	0.25
U-factor						
Single	1.09	1.09	1.09	1.09	0.90	0.70
Double	0.71	0.71	0.71	0.71	0.65	0.55
VT						
Single	0.74	0.5	0.30	0.18	0.30	0.18
Double	0.67	0.5	0.30	0.18	0.30	0.18
Cost/ft^2		$4.00	$4.00	$4.00	$5.50	$7.00

Simulation Software

The simulation software used for the residential models is MICROPAS v8.1, which is the CEC certified software for demonstrating compliance with Title 24. The simulation runs an annual, hourly calculation for each of the 8,760 hours throughout the year, accounting for interactions between the heating and cooling systems, lighting and envelope features including the fenestration. This performance software is typically used to give builders the flexibility to trade off energy measures with those that would be required if one follows the prescriptive package of Title 24 approach to compliance. The performance method is the least expensive path to compliance and used by the vast majority of builders to obtain compliance with Title 24. Table 1 above represents the variables use in the residential simulation. Note it does not include the visible transmittance, because MICROPAS does not use this variable, nor does it have the capability to model daylighting controls. Daylighting controls are not common in residential spaces, and any dimming or shutting off of lights in homes is performed by occupants who determine if there is adequate light in the space.

The simulation software used for the commercial model is Energy Plus v6.0, which is the newest generation of modeling software from the Department of Energy. This simulation was also run as an 8760 hour annual simulation, and Energy Plus also takes into account building system interactions with each other and with building envelope features, but has additional capabilities to model many non-residential features not available in MICROPAS. The simulations were run with daylighting controls active, since window film can lower the visible light transmittance which interacts with that feature of energy conscious design in large office buildings.

Results

The results in this study are presented differently for the residential and commercial office buildings. For residential applications, the most important information is how the measure compares to other energy efficiency measures that might be taken when considering a new home or a home retrofit. The energy unit used in Title 24 compliance software is a measurement used by the CEC known as Time Dependent Valuation of energy or TDV. The MICROPAS software automatically calculates energy savings in TDV, which is the compliance standard measure for energy use. Energy used during peak usage hours is

weighted more heavily than energy used at night (off peak). TDV energy emphasizes the impact of energy features that reduce peak load (primarily air conditioning load). This is beneficial for window film savings, since the energy saved is typically space cooling energy which occurs during the peak period.

For commercial applications, the return on investment (ROI) is the deciding factor in implementing an energy measure. The results presented here are the return on investment for the application of the window film alone. Utility incentives or other rebate programs represent additional financial incentives to make the investment in energy efficiency and will be discussed in a separate section of this report.

Results in New Homes

The window film in the new home application has a simple payback of 10 to 43 years depending on climate zone. Figure 1 through

Figure 4 show window film in relation to other energy efficiency measures considered for new homes. Only the application of the window film to double pane glass is included in the results for new homes, since new homes would not be code compliant with single pane glass. The energy efficiency features used in new construction are:

- 0.92 AFUE furnace – higher efficiency heating equipment
- 0.30/0.30 glazing – windows with 0.30 U-factor and 0.30 SHGC (code requires 0.40/0.40)
- 13, 14, or 15 SEER – choose more efficent AC equipment
- Buried ducts – ducts buried in ceiling insulation to reduce energy losses
- Concrete roof/ cool concrete roof/ clay roof/ cool clay roof/ cool asphalt roof – roof with higher reflectance value than standard asphalt roof letting less heat into space
- Efficent AC motor
- One coat stucco – wrap house in R-4 foam and add thin coat stucco
- Low air infiltration – seal leaks in envelope
- Quality Insulation – proceses and testing to ensure insulation is installed to be most effective
- R6.0 HVAC ducts – increased insulation on air ducts
- R7 slab edge insulation –insulating edge of slab
- R15/21 walls – increased insulation level in walls
- Radiant barrier – reflective material on underside of roof deck; reduce heat gain
- Right Sizing AC – analysing loads and choosing apropriate equipment for best efficiency
- Tankless water heater – water heated as needed, reduces heat loss from standing hot water
- Tight ducts – test ducts to ensure low leakage rates

In the hotter Central Valley and Riverside climate zones, installing window film on clear double pane glass saves less than 1 TDV per $100 spent on window film. In the milder Bay Area and coastal climate zones, it is less than .5 TDV per $100 spent on window film.

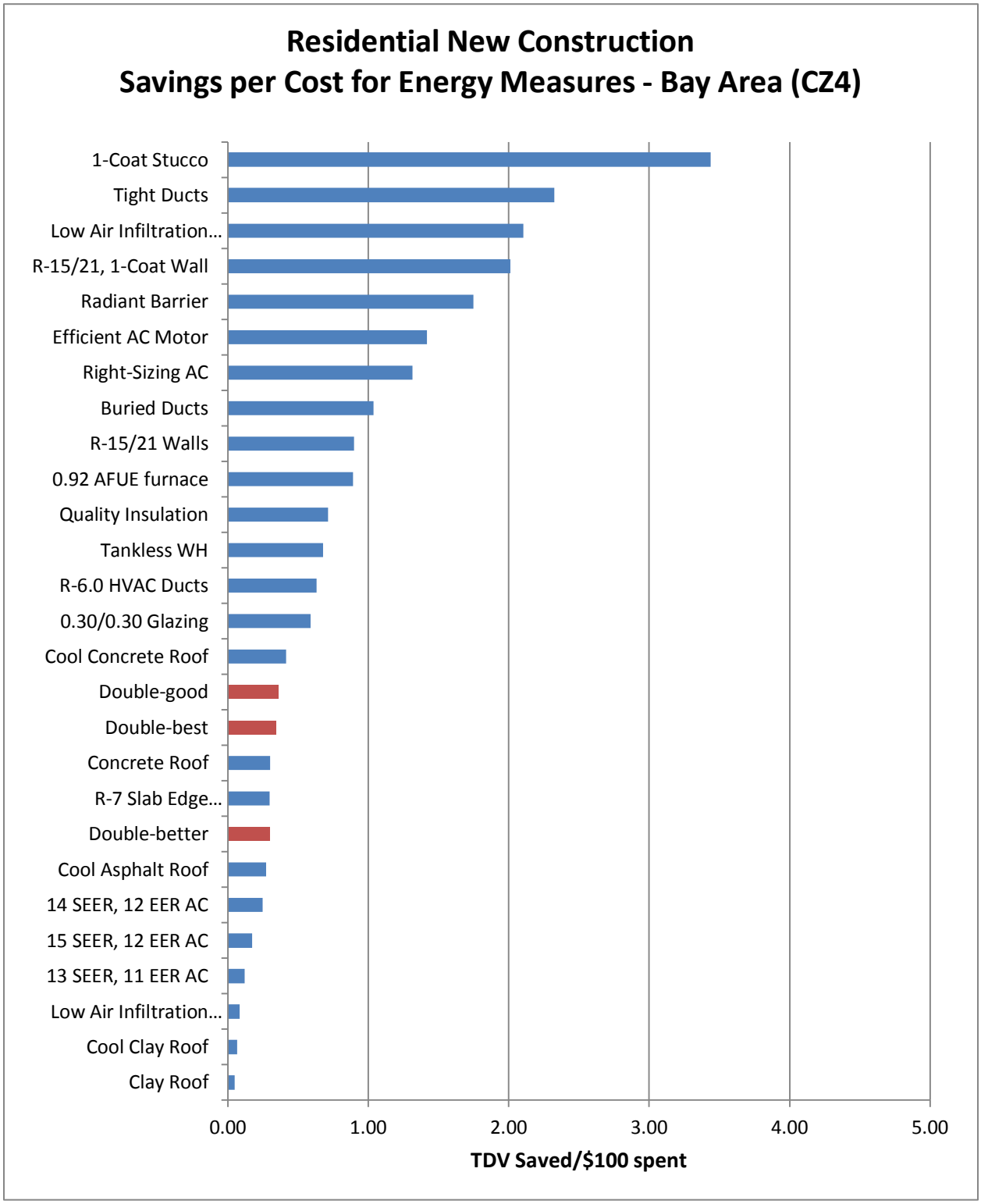


Figure 1: Residential New Construction: Savings per Cost for Energy Measures - Bay Area (CZ4)

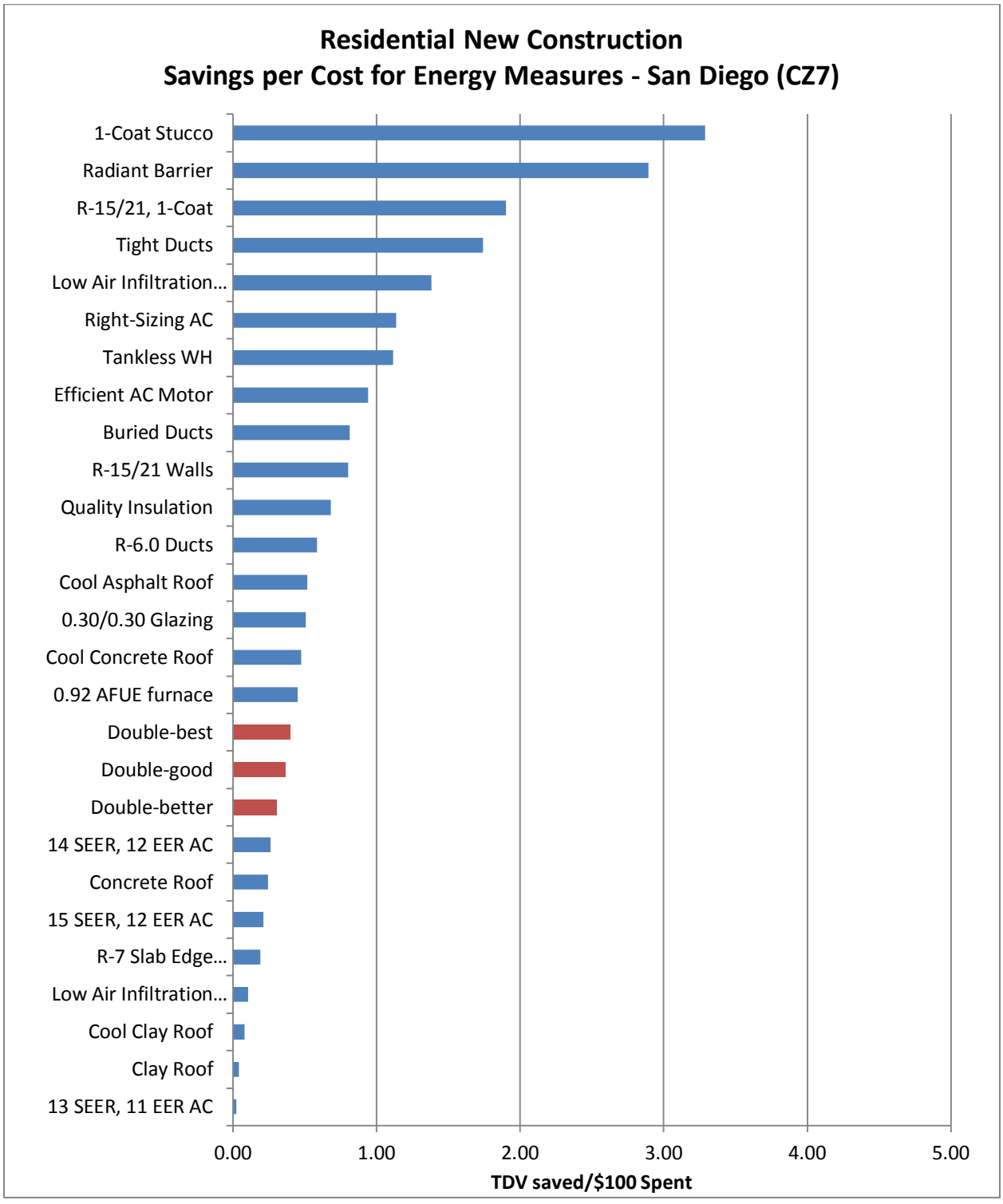


Figure 2: Residential New Construction: Savings per Cost for Energy Measures - San Diego (CZ7)

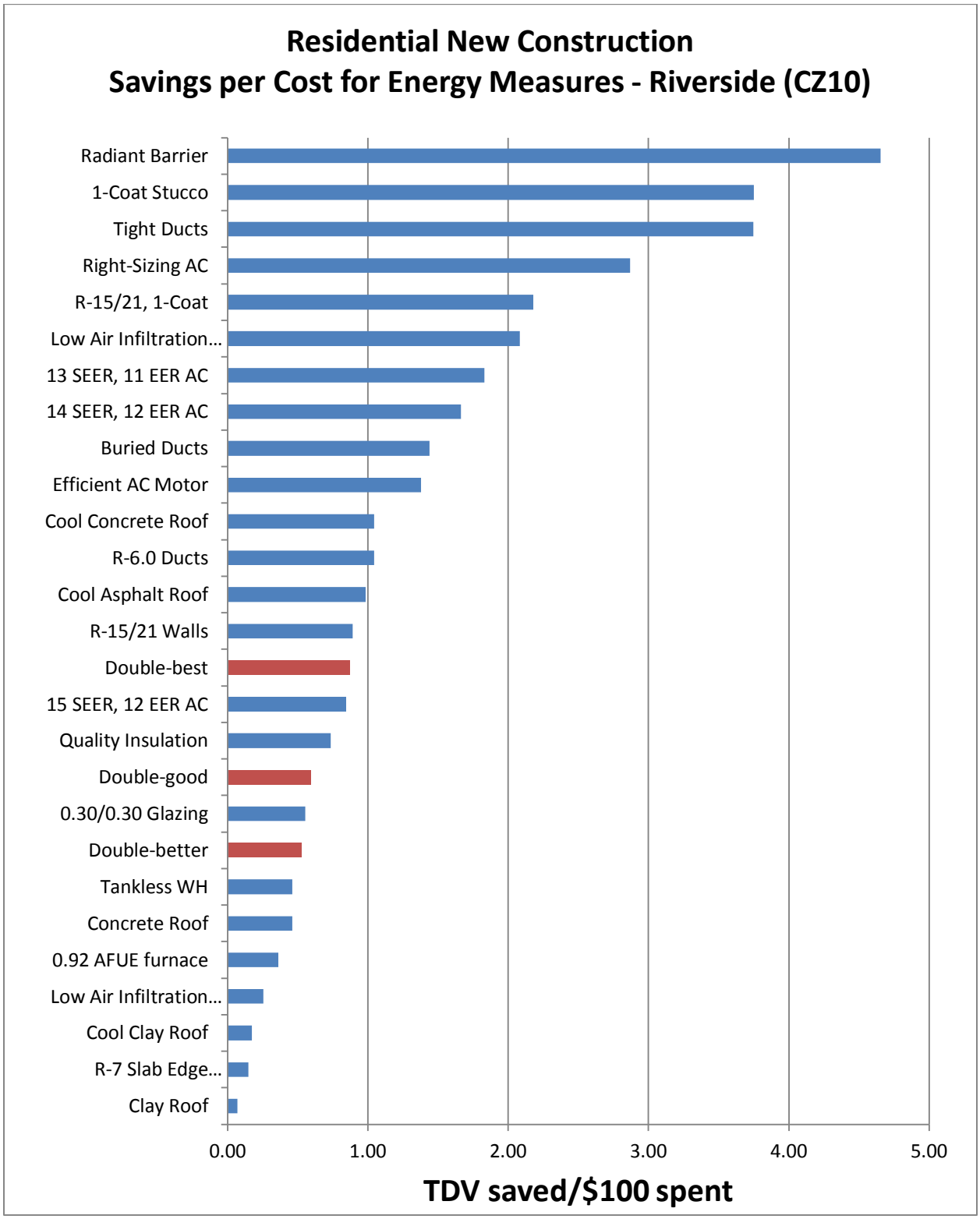


Figure 3: Residential New Construction: Savings per Cost for Energy Measures - Riverside (CZ10)

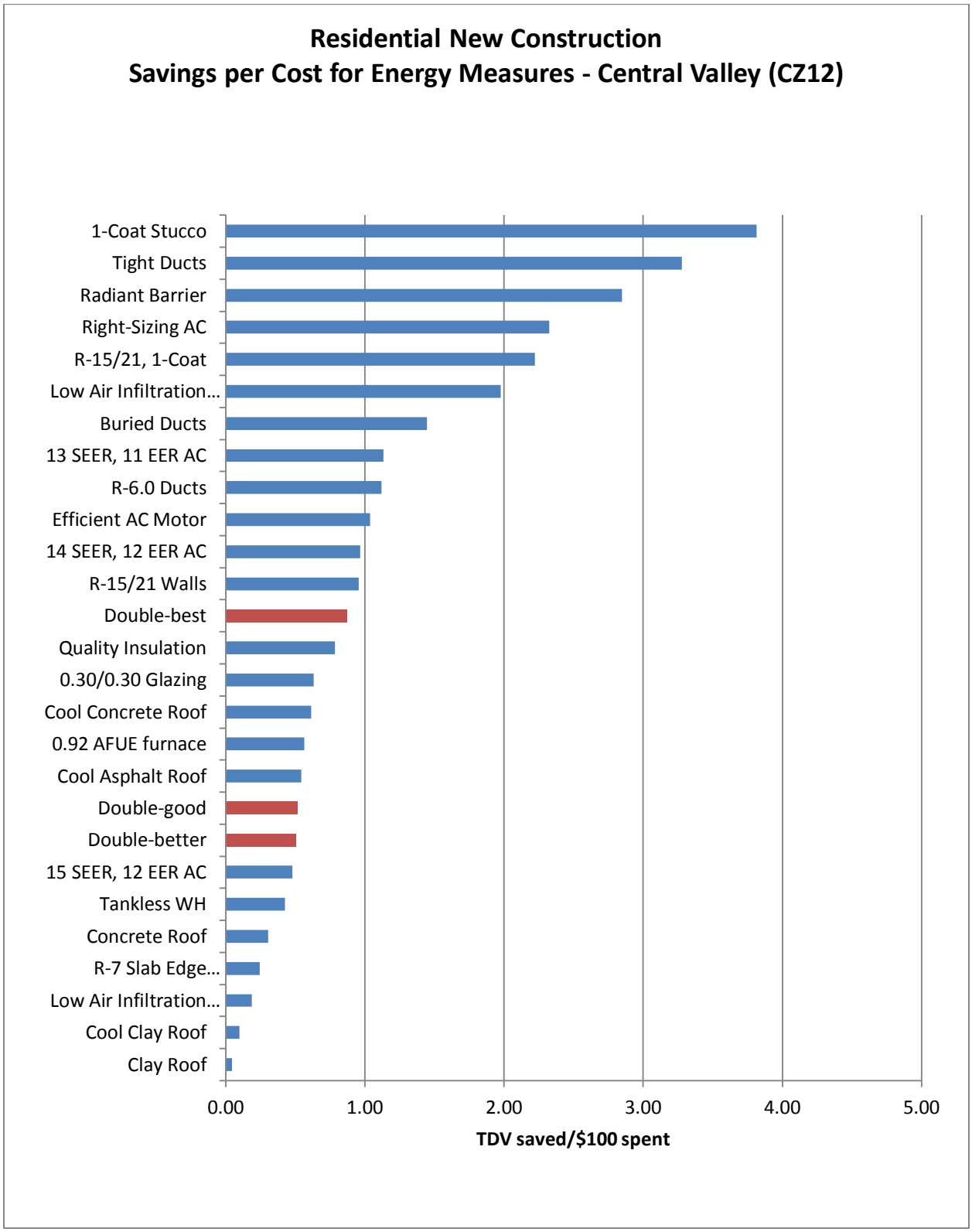


Figure 4: Residential New Construction: Savings per Cost for Energy Measures - Central Valley (CZ12)

The 2008 Standard for new homes assumes windows with a solar heat gain coefficient of no more than 0.4 which already surpasses the performance of the first level of product in this study when applied to clear glass. For the analysis of the new homes, double pane glazing was assumed to be the only option, as new homes are not built with single pane glazing. In the graphs, the relative impact of installing 0.30/0.30 glazing (that is, new windows that have a 0.3 U-factor and a 0.3 SHGC) is more cost effective than adding the film to low performance windows, therefore, window film is not competitive in the new homes market in Californa.

Results in Existing Homes:

In Figure 6 through Figure 8, the orange bars represent the effect of film on single pane existing glass, and the red bars represent the effect of film on existing double pane glass. The blue bars as before are the other common energy efficiency measures used during retrofits. Typically, there are fewer energy efficient features considered for retrofitting a home compared to the energy features considered for new construction.

The energy efficiency features that window film was compared to for existing homes are:

- R-38 ceiling insulation – adding insulation to the attic
- 0.80 AFUE furnace – replacing furnace with more efficient new unit
- 13 SEER, 11 EER AC – replacing AC equipment with more efficient new unit
- Air Sealing – sealing gaps in building envelope (walls, doors, around windows, etc.)

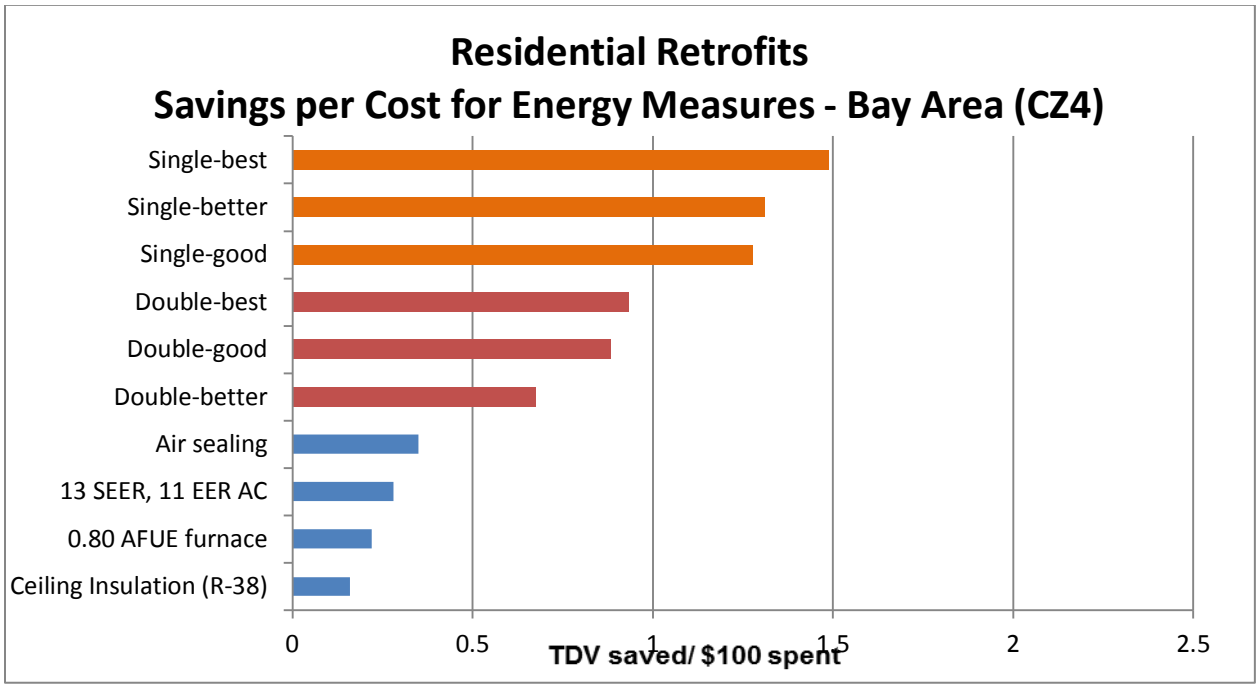


Figure 5: Residential Retrofits: Savings per Cost for Energy Measures - Bay Area (CZ4)

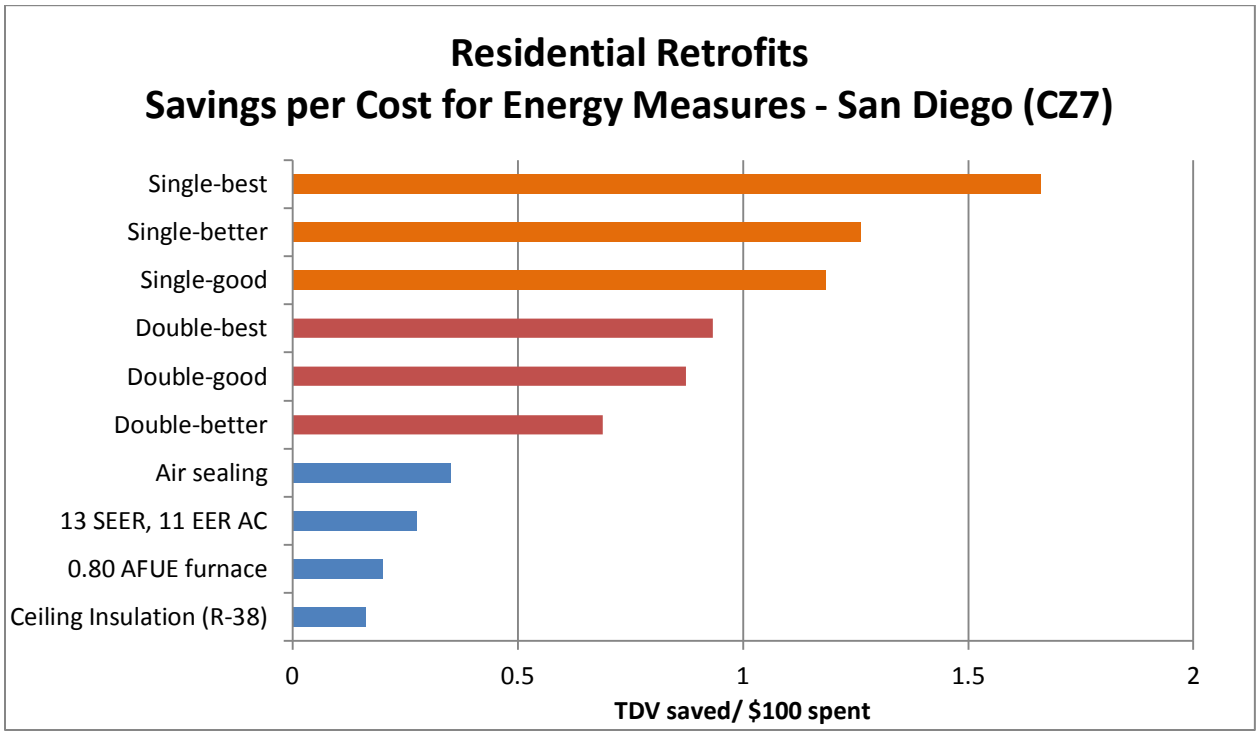


Figure 6: Residential Retrofits: Savings per Cost for Energy Measures - San Diego (CZ7)

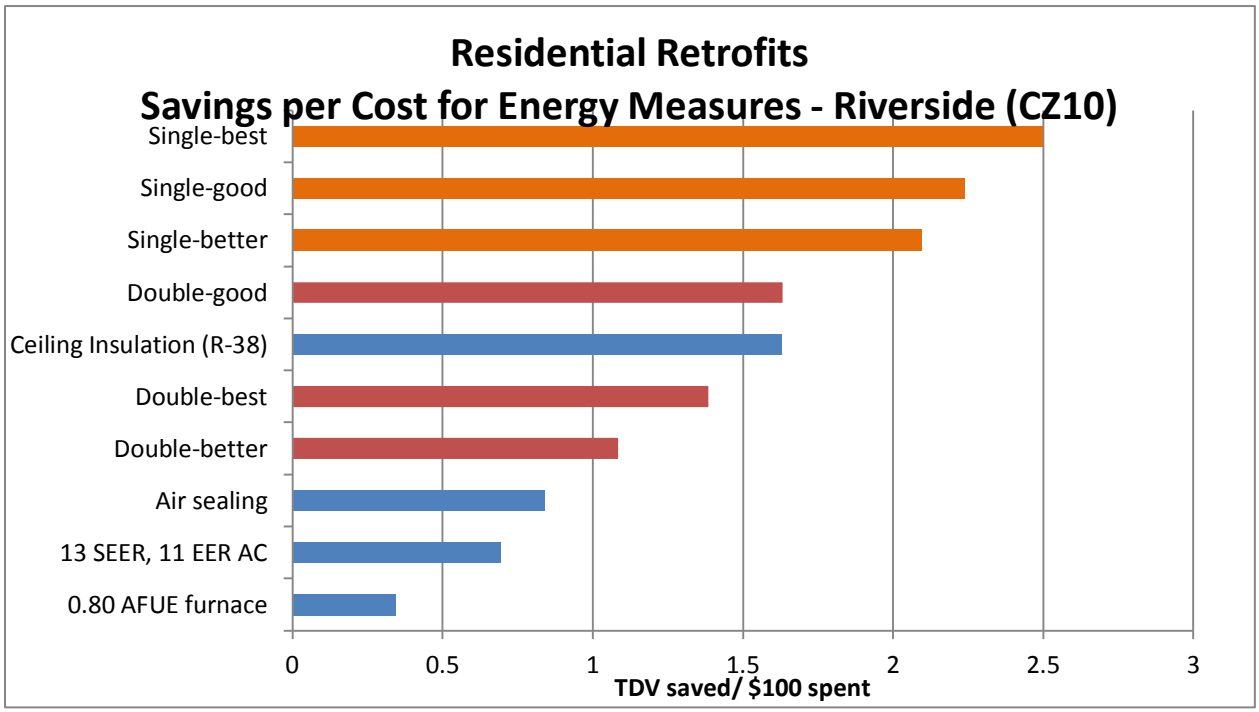


Figure 7: Residential Retrofits: Savings per Cost for Energy Measures - Riverside (CZ10)

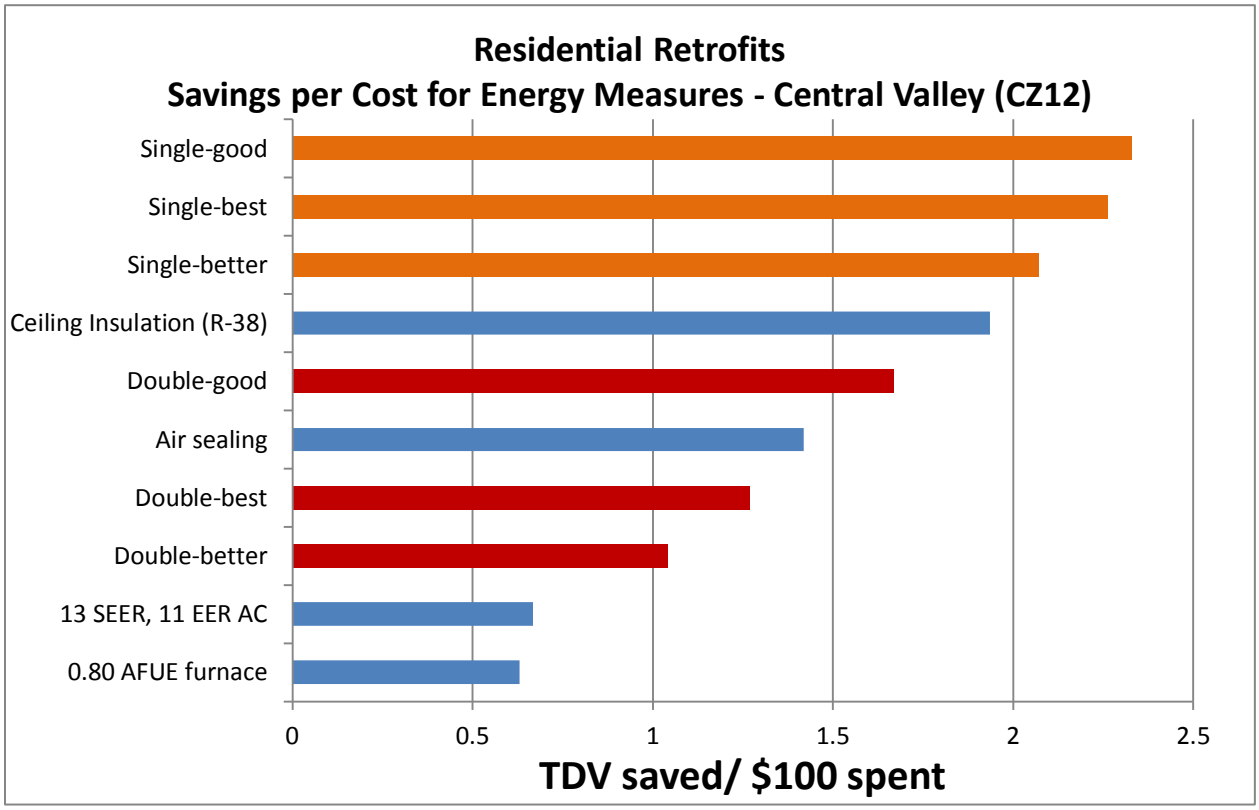


Figure 8: Residential Retrofits: Savings per Cost for Energy Measures - Central Valley (CZ12)

In the warmer climate zones of Riverside and the Central Valley, installing window films can save between 1 and 2 TDV per $100 spent when applied to double pane glass, and over 2 TDV per $100 spent when applied to single pane glass. In fact, in homes with single pane glass, there is little that one could do to improve energy performance more cost effectively.

Results in New Offices:

In new construction, ROIs for offices are around 1-3% annually, due to the fact that code compliant windows are already using high performance glazing (0.47U/0.31SHGC). Window films are not an attractive energy efficiency option for new office buildings.

Results in Existing Offices:

In existing offices, window film represents a significant opportunity for cost effective energy savings. Figure 9 shows the typical electricity breakdown in the large office building by end use. The cooling electricity is isolated from this data in Figure 10, to demonstrate the effect that window film has on space cooling, which is the majority of the savings (along with reduced fan energy which is the other end use involved in cooling the building). Return on investment ranges from 6% to 68% annually depending on climate zone and product as detailed in Table 3 through Table 10

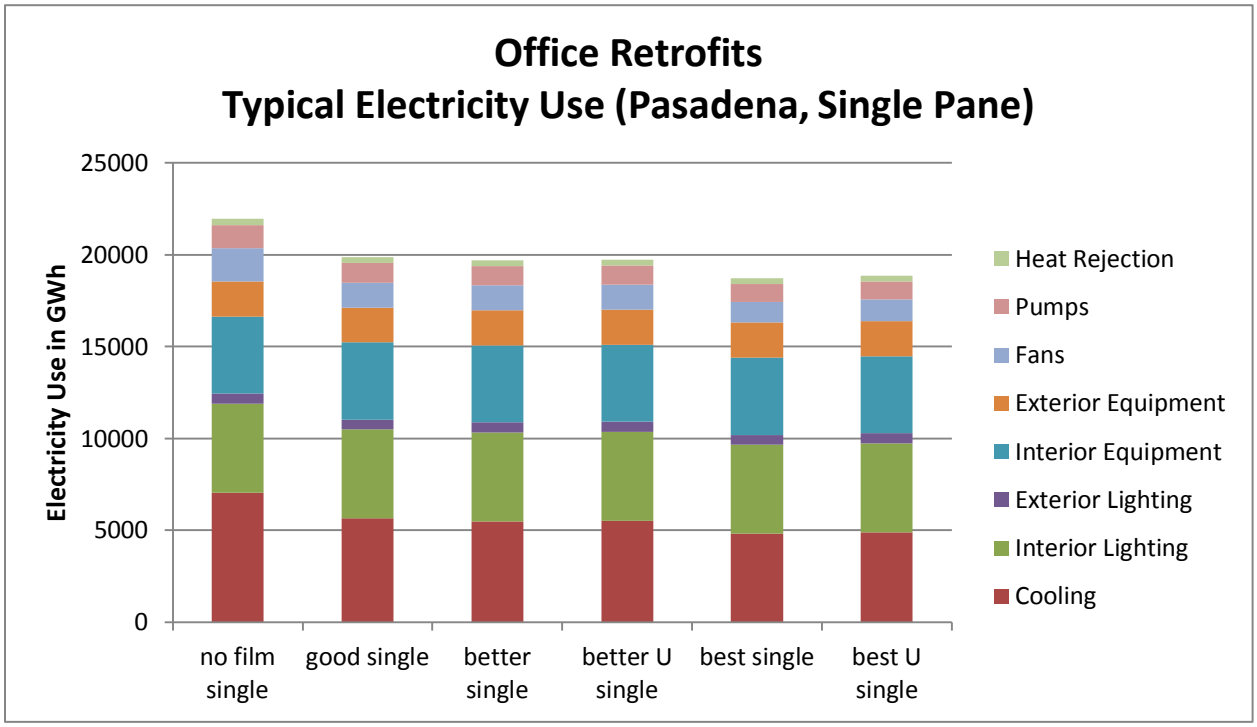


Figure 9: Office Retrofits: Typical Electricity Use (Pasadena, Single Pane)

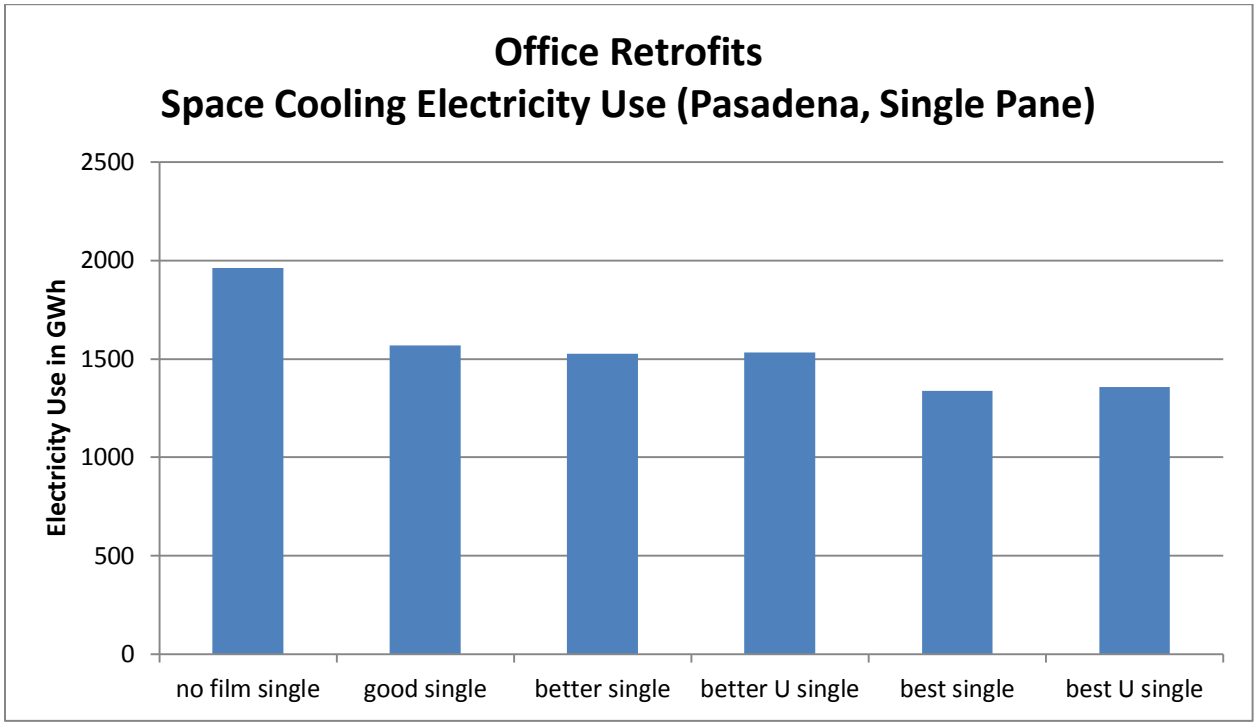


Figure 10: Office Retrofits: Cooling Electricity Use (Pasadena, Single Pane)

Existing Offices in Oakland

Table 3: Oakland (CZ3) ROI for Existing Offices with Single Pane Glass

SINGLE PANE	good	better	better U	best	best U
Total Electricity	4542	4284	4295	4134	4157
Total Gas	1,092	1,051	1,026	882	848
Energy Cost	$ 682,418	$ 643,611	$ 645,230	$ 621,042	$ 624,430
Annual Savings	$ 12,704	$ 51,510	$ 49,891	$ 74,080	$ 70,691
Cost of Film	$ 199,614	$ 199,614	$ 274,469	$ 199,614.07	$ 349,325
Annual ROI	6%	26%	18%	37%	20%
Simple Payback	15.7	3.9	5.5	2.7	4.9

Table 4: Oakland (CZ3) ROI for Existing Offices with Double Pane Glass

DOUBLE PANE	good	better	better U	best	best U
Total Electricity	4383	4330	4335	4209	4222
Total Gas	1,056	1,051	1,034	892	848
Energy Cost	$ 658,555	$ 650,621	$ 651,273	$ 632,186	$ 634,212
Annual Savings	$ 23,863	$ 31,797	$ 31,145	$ 50,232	$ 48,207
Cost of Film	$ 199,614	$ 199,614.07	$ 274,469	$ 199,614.07	$ 349,324
Annual ROI	12%	16%	11%	25%	14%
Simple Payback	8.4	6.3	8.8	4.0	7.2

In mild Oakland-like climates the ROI ranges from 6%-37%. Single pane existing windows provide an opportunity for up to a 37% ROI, while adding film to double pane windows will pay back at about 20% annually.

Existing Offices in San Diego

Table 5: San Diego (CZ7) ROI for Existing Offices with Single Pane Glass

SINGLE PANE	good	better	better U	best	best U
Total Electricity	5436	5408	5162	5131	5162
Total Gas	522	493	432	447	432
Energy Cost	$ 815,987	$ 811,755	$ 774,722	$ 770,121	$ 774,722
Annual Savings	$ 82,709	$ 88,791	$ 86,941	$ 128,575	$ 123,974
Cost of Film	$ 199,614	$ 199,614	$ 274,469	$ 199,614	$ 349,325
Annual ROI	41%	44%	32%	64%	35%
Simple Payback	2.4	2.2	3.2	1.6	2.8

Table 6: San Diego (CZ7) ROI for Existing Offices with Double Pane Glass

DOUBLE PANE	Good	better	better U	best	best U
Total Electricity	5561	5468	5472	5248	5266
Total Gas	512	497	493	447	439
Energy Cost	$ 834,732	$ 820,666	$ 821,345	$ 787,690	$ 790,266
Annual Savings	$ 40,941	$ 55,006	$ 54,327	$ 87,983	$ 85,406
Cost of Film	$ 199,614	$ 199,614	$ 274,469	$ 199,614	$ 349,325
Annual ROI	21%	28%	20%	44%	24%
Simple Payback	4.9	3.6	5.1	2.3	4.1

In coastal, San Diego -like climates the ROI ranges from 16%-64%. Single pane existing windows provide an opportunity for 32%-64% ROI, while adding film to double pane windows will pay back at 20%-44% annually.

Existing Offices in Pasadena

Table 7: Pasadena (CZ9) ROI for Existing Offices with Single Pane Glass

SINGLE PANE	Good	better	better U	best	best U
Total Electricity	5519	5469	5482	5195	5233
Total Gas	690	663	644	626	611
Energy Cost	$ 828,479	$ 821,087	$ 823,014	$ 779,931	$ 785,633
Annual Savings	$ 86,630	$ 94,021	$ 92,094	$ 135,178	$ 129,475
Cost of Film	$ 199,614	$ 199,614	$ 274,469	$ 199,614	$ 349,325
Annual ROI	43%	47%	34%	68%	37%
Simple Payback	2.3	2.1	3.0	1.5	2.7

Table 8: Pasadena (CZ9) ROI for Existing Offices with Double Pane Glass

DOUBLE PANE	Good	better	better U	best	best U
Total Electricity	5634	5542	5539	5309	5327
Total Gas	668	648	645	610	645
Energy Cost	$ 845,720	$ 831,902	$ 831,544	$ 797,033	$ 799,750
Annual Savings	$ 43,323	$ 57,141	$ 57,500	$ 92,010	$ 89,293
Cost of Film	$ 199,614	$ 199,614	$ 274,469	$ 199,614	$ 349,325
Annual ROI	22%	29%	21%	46%	26%
Simple Payback	4.6	3.5	4.8	2.2	3.9

In Pasadena -like climates the ROI ranges from 21%-68%. Single pane existing windows provide an opportunity for 34%-68% ROI, while adding film to double pane windows will pay back at 20%-46% annually.

Existing Offices in Fresno

Table 9: Fresno (CZ13) ROI for Existing Offices with Single Pane Glass

SINGLE PANE	good	better	better U	best	best U
Total Electricity	5558	5513	5517	5215	5229
Total Gas	1376	1319	1288	1254	1189
Energy Cost	$ 835,111	$ 828,243	$ 828,874	$ 783,502	$ 785,547
Annual Savings	$ 88,055	$ 94,923	$ 94,292	$ 139,664	$ 137,619
Cost of Film	$ 199,614	$ 199,614	$ 274,469	$ 199,614	$ 349,325
Annual ROI	44%	48%	34%	70%	39%
Simple Payback	2.3	2.1	2.9	1.4	2.5

Table 10: Fresno (CZ13) ROI for Existing Offices with Double Pane Glass

DOUBLE PANE	good	better	better U	best	best U
Total Electricity	5675	5572	5576	5328	5327
Total Gas	1316	1292	1280	1218	1213
Energy Cost	$ 852,578	$ 837,090	$ 837,662	$ 800,387	$ 799,750
Annual Savings	$ 43,220	$ 58,708	$ 58,136	$ 95,411	$ 96,048
Cost of Film	$ 199,614	$ 199,614	$ 274,469	$ 199,614	$ 349,325
Annual ROI	22%	29%	21%	48%	27%
Simple Payback	4.6	3.4	4.7	2.1	3.7

In hot, Fresno -like climates the ROI ranges from 21%-70% annually. Single pane existing windows provide an opportunity for 34%-70% ROI, while adding film to double pane windows will pay back at 21%-48% annually.

In general, standard improved SHGC film gives as good or better return on investment than the more expensive options of spectrally selective or low-e films. The energy saved by these low U-factor options is outweighed in office buildings by the higher cost for these technologies. This is most likely because offices are dominated by cooling loads, rather than the mixture of cooling and heating loads seen in residential buildings. The monetary cost to improve SHGC from one film to the next is negligible, but the loss of visible transmittance can determine the choice of film between these options, balancing energy savings with such concerns as occupant comfort and views. Again the hotter climate zones, in this case Pasadena and Fresno, benefit most from window film. But even the mildest climate zone, Oakland, finds around a 20% annual return on investment with the various window films. In existing offices with single pane windows, anywhere other than the mildest zones, window film is an energy efficiency measure that can pay back in less than 2 years.

Results summary

New homes are not a particularly attractive market for window films in California, since there are many more cost effective ways to reduce energy in new homes, and the windows that go into new homes

already perform well in the areas that window film addresses. There may be an opportunity in the high desert, an area that was not studied due to a low concentration of homes built there, but typically, new homes are not a good market for window film. On the other hand, existing homes are a market in which window films perform very favorably against other typical energy retrofit options, particularly in the hotter climate zones of California.

New office buildings likewise show little opportunity for this technology to thrive. Again the Standards already require that windows have a high degree of performance. Existing office buildings, however, are a very attractive market for window film products. High ROIs can attract building managers to invest in this energy efficiency technology. Only as small percentage of buildings are added to the building stock each year, while existing buildings represent a large market for efficiency measures, consuming more energy due to a less advanced design.

Global Warming Implications

AB 32 Global Warming Solutions Act Background

AB32 requires greenhouse gas emissions to be reduced to 1990 levels by 2020, which constitutes approximately a 30% reduction over business-as-usual projections for 2020.

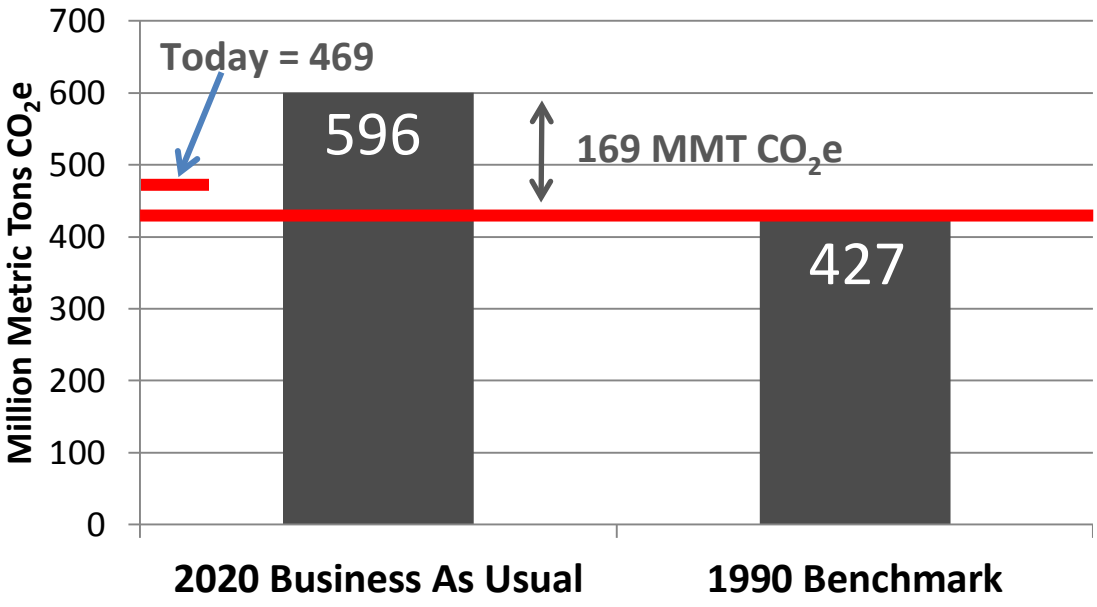
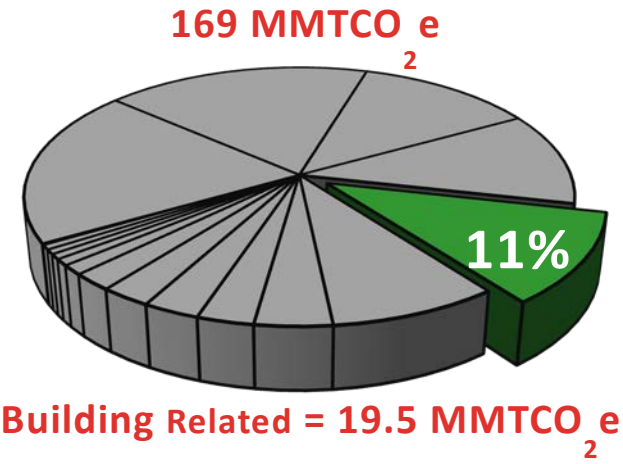


Figure 11 Greenhouse Gas Emission Goals

Within the AB 32 Scoping Plan to reduce the total greenhouse gas emissions for California by 169 Million Metric Tons of CO_2 equivalent ($MMTCO_2e$), the Air Resources Board (ARB) has outlined 16 greenhouse gas reduction strategies, one of which is implementing energy efficiency in California's buildings. The recommendation is that 11% or 19.5 $MMTCO_2e$ of the total savings goal will come from reduction in energy in residential and commercial buildings.



This is equivalent to the emissions from 3.5 million cars or from 1.8 million homes. It is also equivalent to a 14% reduction in energy use in every building in the state. ARB recommendations outline that part of that savings come from more stringent new buildings standards, but that 75% come from retrofits to existing buildings. The Scoping Plan suggests that there will be substantial pressure on voluntary (utility) programs as well as legislative requirements to improve the energy efficiency of existing buildings.

New construction has minimal impact on the GHG reduction goal. There are approximately 13,460,000 residential dwelling units in California. In 2011, 46,000 new residential units were constructed. If all residential units emitted the same amount of GHG, new construction would amount to only 0.34% (approximately one third of one percent) of annual GHG emissions in 2011 for California homes. In fact, new homes emit far less GHG than existing homes, meaning that new homes are an even smaller part of the equation. 2011, like the preceding few years, has been abnormally slow for the home building sector; yet, this trend is not expected to change for at least the next five years. The California Legislative Analyst Office predicts residential new construction will not recover until after 2017[1]. To effectively reduce residential sector GHG emissions, existing homes must be made more energy efficient.

[1] http://www.lao.ca.gov/reports/2011/bud/fiscal_outlook/fiscal_outlook_2011.aspx

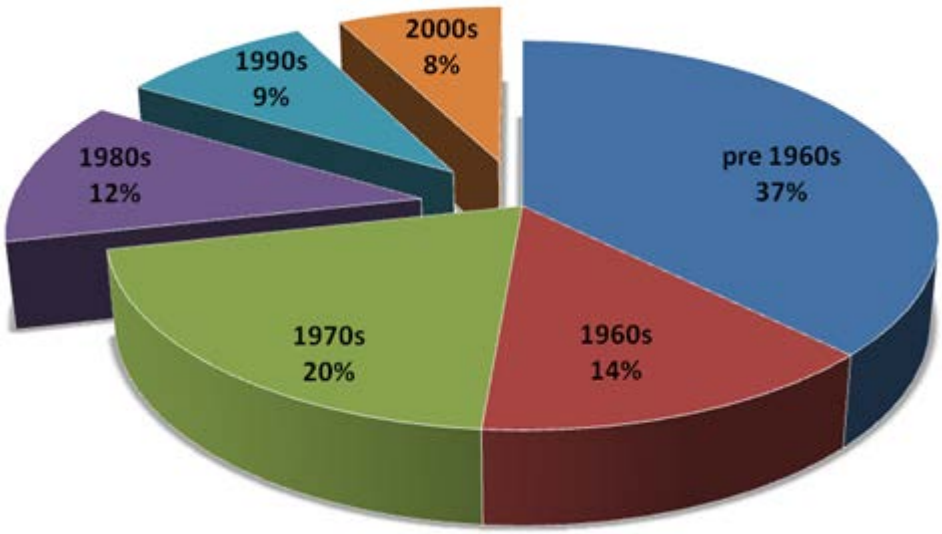


Figure 12: Single Family Home Emissions by Decade Built[2]

Over 70% of GHG related to single-family envelope energy consumption can be attributed to homes built before 1980; homes built before any energy codes were adopted in California (see Figure 12). Since most GHG comes from older homes and increasing energy codes on new homes has such a minimal impact, retrofitting existing homes with cost effective energy upgrades is essential to meeting AB 32 GHG reduction goals. Window films are among the most cost effective energy retrofits for existing residential and commercial buildings. Window films should be recognized as a viable solution to cost effectively reduce GHGs.

Window Film GHG Impact

To demonstrate window film impact on GHG Figure 13 shows a theoretical situation in which all existing homes in the state of California are retrofitted with a given energy efficiency measure over the course of 7 years, by retrofitting one seventh of the existing homes each year. The measures examined are replacing the AC with a 13 SEER unit, adding the "better" window film as analyzed in this study, adding R-30 insulation in the attic, and replacing the furnace with a 92% efficient furnace. These measures are compared against business as usual, updated title 24 standards, and net zero new construction.

[2] From " Meeting AB 32 – Cost Effective Green House Gas Reductions in the Residential Sector" ConSol, August, 2008

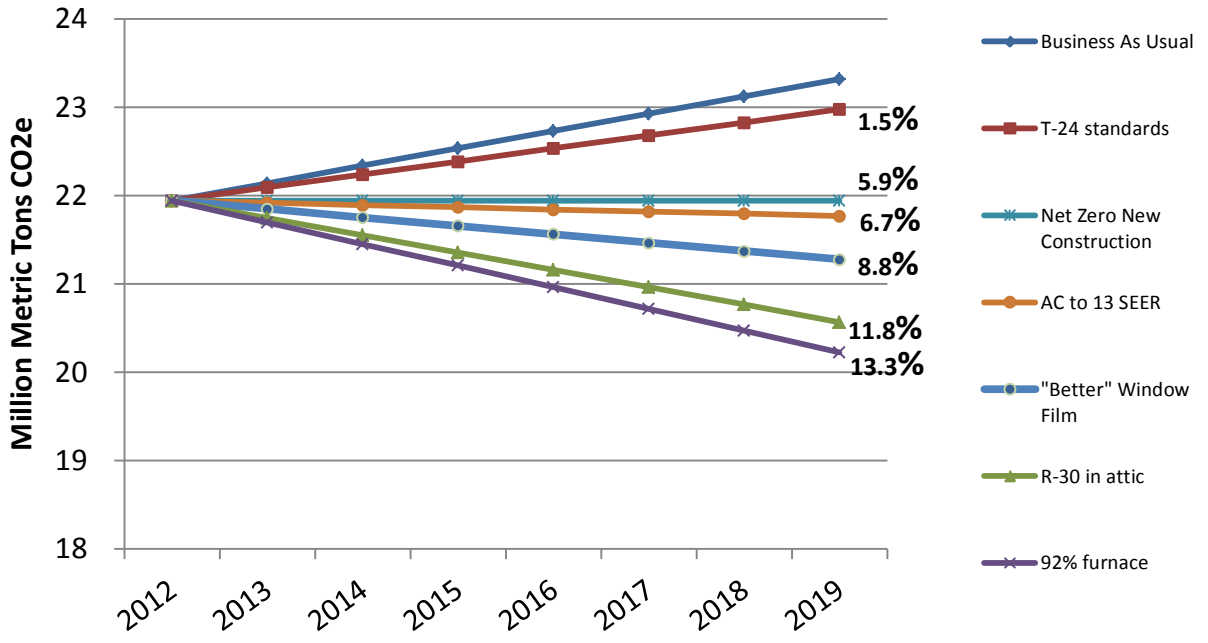


Figure 13: Theoretical Reduction in GHG over Time in California

This comparison is meant to demonstrate two things. First, that targeting only new homes, as in the case of Title 24, has a limited potential for reducing GHG emissions compared to targeting existing homes. And second, that window films have a relatively good potential to impact GHG emissions when compared to other retrofit measures. When cost is taken into account as in the previous sections, it is one of the most effective measures that can be considered.

Conclusions

The best opportunities for saving energy with window films in California are in existing buildings, especially in existing high-rise office buildings. New homes are not an attractive opportunity because of the high energy standards for windows already in place. New non-residential buildings have the same problem. Window films are a more cost effective retrofit opportunity for homes than other measures, however, especially in homes with single pane glass. Existing office buildings are an ideal opportunity for window film retrofits. They contain a large amount of glazing and cooling loads typically dominate. Rates of return on investment are high, even before utility incentives. Window films also demonstrate an effective means of reducing GHG emissions when used in retrofitting existing buildings.