Meeting AB 32 – Cost-Effective Green House Gas Reductions in the Residential Sector

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Abstract:
In September of 2006, California Governor Arnold Schwarzenegger signed the California Global Warming Solutions Act (AB 32) into law which sets California Green House Gas (GHG) emission standards for the next 50 years. The California Air Resources Board (CARB) is required to develop regulations and market mechanisms that will ultimately reduce California's greenhouse gas emissions. By 2020, AB 32 requires the State's emissions of GHGs to be at the same level as they were in 1990. By 2050, AB 32 and Executive Order S-3-05 require emission levels to be reduced 80% below the levels in 1990. These standards apply to all California sectors including road transportation, industrial processes, commercial, livestock/agriculture and residential. Each sector has a responsibility to help reduce their emissions. This paper will focus on the residential sector, which causes 14.2% of total GHG emissions for the state.

There are approximately 13,270,000 dwelling units in California. Residential new construction typically adds 150,000 new units to the stock each year, which represents just 0.12% (about one-tenth of 1 percent) of the carbon emissions in California. New residential dwelling units built to the 2005 Title 24 energy code are already 25% below the 1990 GHG emissions target levels set by AB 32. Given production levels and the energy efficiency of new homes, the only way to reduce GHG emissions in the entire residential marketplace to required levels is to develop programs to retrofit existing homes to lower the GHG emissions caused by them.

Seventy percent of the GHG emissions related to single-family envelope energy consumption can be attributed to homes built before California had an energy code (1983). The statewide carbon impacts of retrofitting these homes with upgraded energy features were explored. Spending $10,000 retrofitting a 1960s home could save 8.5 tons of carbon, a cost of $588 to $1,176 per ton depending on tax credits and incentives. Increasing the energy efficiency of a new home 35% (from the 2005 T-24 Standards) would cost about $5,000 and would reduce emissions by 1.1 tons at a cost of $4,545 per ton. Retrofitting existing homes with energy-efficient features is four to eight times more carbon- and cost-efficient than adding further energy-efficiency requirements to new housing.

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California Global Warming Solutions Act (AB 32)

In September 2006, California Governor Arnold Schwarzenegger signed the California Global Warming Solutions Act (AB 32) into law, which requires California to reduce its green house gas (GHG) emissions to 1990 levels. The California Air Resources Board (CARB) is required to develop regulations and market mechanisms that will ultimately reduce California's greenhouse gas emissions. By 2050, AB 32 and Executive Order S-3-05 require emission levels to be reduced 80% below the levels in 1990.

California GHG Timeline

Year	Milestone
2009	Completion and adoption of AB 32 Scoping Plan
2010	CARB Early Action Measures take effect
2012	GHG rules and market mechanisms take effect
2020	State GHG emissions reduced to 1990 level
2050	State GHG missions reduced 80% below 1990 level

These regulations will apply to all California industry sectors[1], including road transportation, industrial processes, commercial, livestock/agriculture and residential. Each sector has a responsibility to help reduce their GHG emissions.

According to CARB and the California Energy Commission (CEC), the top three California GHG emitters by sector are transportation, industrial and residential with 40.4%, 25.4% and 14.2% of total emissions, respectively, when electrical emissions are added to the appropriate industry sector. California's residential GHG emissions include emissions from residential gas consumption (water heating and space conditioning) and emissions resulting from the electricity generated for residential use.[2]

GHG to CO_2e Conversion

For the purpose of this study, two principal GHGs, carbon dioxide (CO_2) and nitrous oxides (N_2O), were quantified. Both of these GHG gases were estimated on an annual basis and then multiplied by their global warming potential (GWP) value to get the associated carbon equivalent (CO_2e) value. CO_2e is the reference gas used for GHG analysis. Table 1 provides the 1996 Intergovernmental Panel on Climate Change (IPCC) values[3] for global warming potential.

Table 1: 1996 IPCC 100 Year Global Warming Potentials

Greenhouse Gas	GWP
CO_2	1
N_2O	310
Value of CO_2e = Value of GHG x GWP	

[1] Rogers, Jamesine, et al. "Staff Report – California 1990 Greenhouse Gas Emissions Level and 2020 Emissions Limit." California Air Resources Board. November 16, 2007.
[2] Electrical emissions incorporated via QFER, California Energy Commission, September 2006 http://www.energy.ca.gov/electricity/consumption_by_sector.html
[3] http://www.ipcc.ch/ipccreports/index.htm

Study Summary: 1990 vs. 2006 Homes

Compared to homes built in 1990, whole-house energy use in new homes built to 2005 energy standards (referenced in this study as 2006 homes) has decreased by 25 percent despite the fact that the square footage of typical new homes have increased during the same timeframe from 2,160 to 2,488[3]. This energy reduction is attributed to the stringent California energy code (Title 24) in conjunction with increasingly stringent national appliance standards.

2020 CA GHG Goal

Annual carbon emissions from a new home built to 1990's code was 10.9 metric tons of CO_2e per house. The annual carbon emissions from a new home built in 2006 to code was 8.2 metric tons of CO_2e per house. Thus, new residential construction under the 2005 Title 24 energy code has met and beat the 2020 goal by 25 percent.

New Construction has Minimal Impact on GHG Reduction Goal

There are approximately 13,270,000 residential dwelling units in California. In 2007, 112,000 new residential units were constructed. Assuming that all residential units emit the same amount of GHG, the emissions from residential new construction amount to just 0.12% (approximately one tenth of one percent) of annual GHG emissions in 2007 for California. In fact, the percentage of GHG emissions from new construction is actually smaller than that because new homes emit far less GHG than existing homes. To effectively reduce residential sector GHG emissions, existing homes must be made more energy-efficient.

Retrofit Analysis

The amount of carbon-equivalent emissions attributable to single-family detached homes, by build date and climate zone, in California was determined. Knowing this baseline, we can determine the emissions impact of retrofitting existing homes with upgraded energy features. The retrofit study evaluated single-family detached home energy use and carbon emissions related to the building envelope, not process and plug loads within the house, which include appliances, lighting and miscellaneous electrical loads.

Understanding energy use, and therefore carbon footprint, required five steps in this analysis:

1. Dwelling units – how many exist, when and where were they built;
2. House size – how dwelling unit size has changed since the 1950s;
3. Energy features – what energy features have been used in homes since the 1950s;
4. Energy budgets – annual energy usage through the building envelope; and,
5. Conversion of GHG to CO_2e

Dwelling Units

Since 1967, the Construction Industry Research Board[4] (CIRB) has tracked permit information from all California cities and counties. Adding climate zone location to the permit data allows the age, location and number of single-family detached dwelling units in California from 1967 to 2006 to be determined. Reverse extrapolation was used to estimate annual permits by climate zone prior to 1967. The extrapolated data was compared and scaled to existing U.S. Census

[4] http://www.cirbdata.com/reports/index.html

Bureau[5] data. The extrapolated data estimated total California housing within 3 percent of the Census Bureau data.

This study focused on single-family detached dwelling units. Chart 1 outlines the number of single-family homes built per year reporting by CIRB. Table 2 provides a summary of housing units built per decade.

Chart 1: Annual California Single-Family Permits

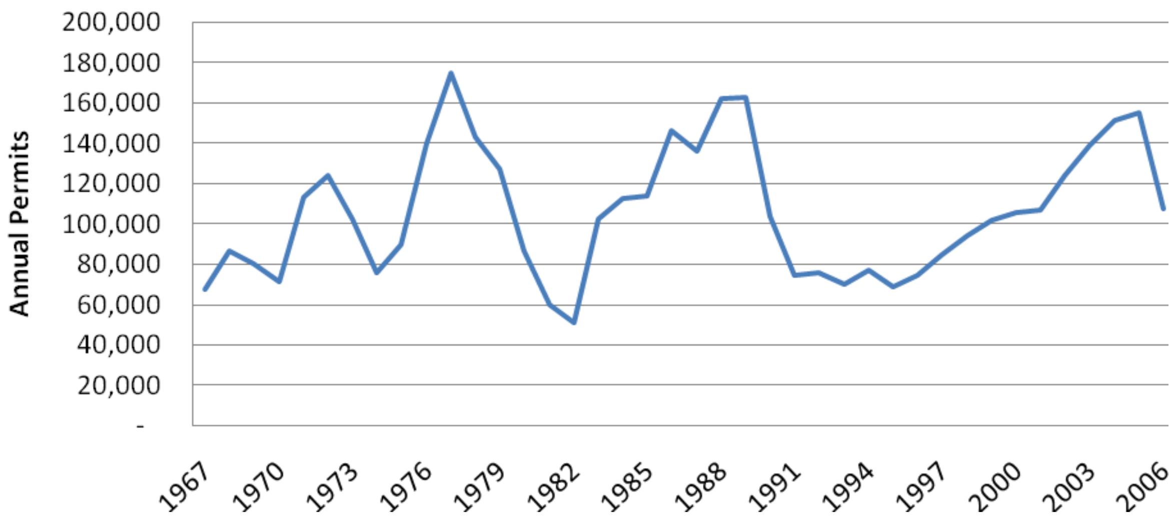


Table 2: Single-Family Units Built by Decade

Decade	Single Family Units Built
pre 1960s	2,392,460
1960s	1,143,459
1970s	1,162,924
1980s	1,135,153
1990s	826,346
2000s	889,181

House Size

To create models for all single-family homes in California, an accurate estimate of the size of a home was needed. Numerous house size data exist for California; however, none were historically consistent. House size was determined using 1974 through 2007 U.S. Census Bureau data for the Western Region,[6] which includes California, Oregon and Washington. This data historically reports single-family new construction home sizes by year and region. These sizes are not state-specific; however, they are similar to average sizes seen in ConSol's energy code compliance department over the past two decades. Again, reverse extrapolation was used to

[5] http://www.infoplease.com/us/census/data/california/housing.html

[6] U.S. Census Bureau. "New Privately Owned Housing Units Completed in the West, by Intent and Design". 7 August 2007 http://www.census.gov/const/compsweintenta.pdf

determine house size prior to 1974. A summary of average house size by decade is provided in Table 3.

Table 3: Average House Size by Decade

Decade	Average House Size (square feet)
1950s	1402
1960s	1495
1970s	1654
1980s	1819
1990s	2116
2000s	2367

Energy Features

Historic energy features were derived from the California Energy Commission's (CEC) 2005 Residential Compliance Manual.[7] Energy features used in this study are listed in Table 4. As an example, the CEC estimates homes built in 1980 have R-19 ceiling insulation, R-13 wall insulation, single pane windows, 78% AFUE furnaces and 8.9 SEER air conditioners.

Table 4: Historic Energy Features for Single-Family Detached Units

Energy Feature	1950s	1960s	1970s	1980s	1990s
Roof	R-0	R-11	R-11	R-19	R-19
Wall	R-0	R-0	R-0	R-13	R-13
Floor Over Garage	R-0	R-0	R-0	R-13	R-13
Floor Cantilever	R-0	R-0	R-0	R-13	R-13
Door	0.5	0.5	0.5	0.5	0.5
Ducts	no ducts	no ducts	R-2.1	R-2.1	R-4.2
Window U-Value	1.28	1.28	1.28	1.28	0.79
Window SHGC	0.83	0.83	0.83	0.83	0.73
Gas Furnace	0.57	0.6	0.75	0.78	0.78
AC SEER	7.0	7.5	8.0	8.9	9.7
Water heating	0.525	0.525	0.525	0.525	0.525
Setback Thermostat	No	no	No	yes	yes

Homes built before 1950 were assumed to have 1950s features. For simplification, homes built after 1999 were assumed compliant with the 2005 Title-24 Standards. This study did not take into account energy-efficiency improvements that homeowners have made to their homes.

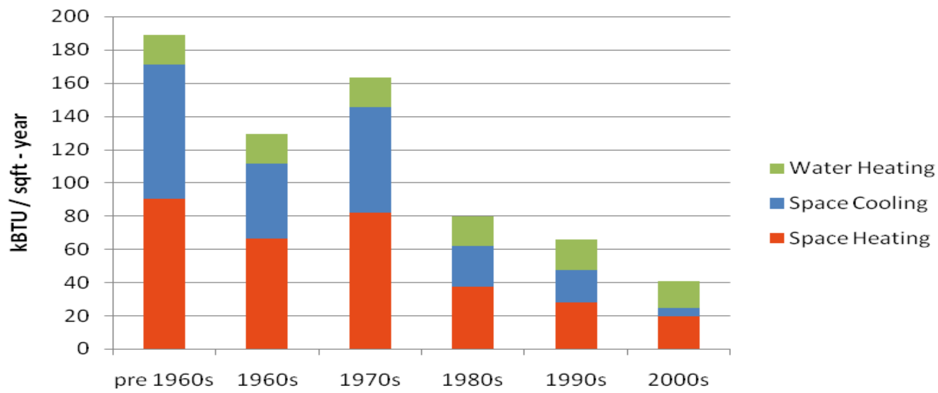
Energy Budgets

Four prototype homes, ranging from 945 to 2,123 square feet, were evaluated in this study. MICROPAS 7.3, a Title 24 energy software program certified by the California Energy Commission, was used to generate energy use. This program is a hourly simulation tool. From the energy features listed in Table 4, annual envelope energy budgets for space heating, space cooling and water heating were generated for all 16 CEC climate zones[8] for each prototype

[7] http://www.energy.ca.gov/title24/2005standards/residential_manual.html
[8] http://www.energy.ca.gov/maps/climate_zone_map.html

home. Chart 2 outlines sample energy budgets from homes built in the Sacramento area, Climate Zone 12.

Chart 2: Single-Family Home Envelope Energy Consumption



The budgets were averaged from the four prototypes giving approximate annual envelope energy use per square foot for any single-family detached home in California, built in any decade. Multiplying energy budgets by the number of units and the average unit size for each decade produced annual envelope energy consumption in kilo-BTUs (kBTU) by decade for single-family homes in California. The annual kBTUs were converted to therms for gas use and kilowatt hours (kWh) for electric use. Therms and kWh were translated to tons of carbon dioxide (CO_2) and nitrous oxides (N_2O) via methods outlined by the California Climate Action Registry[9] (CCAR). CCAR provides leadership on climate change by developing and promoting credible, accurate, and consistent GHG reporting standards and tools for organizations to measure, monitor, third-party verify and reduce their GHG emissions consistently across industry sectors and geographical borders.

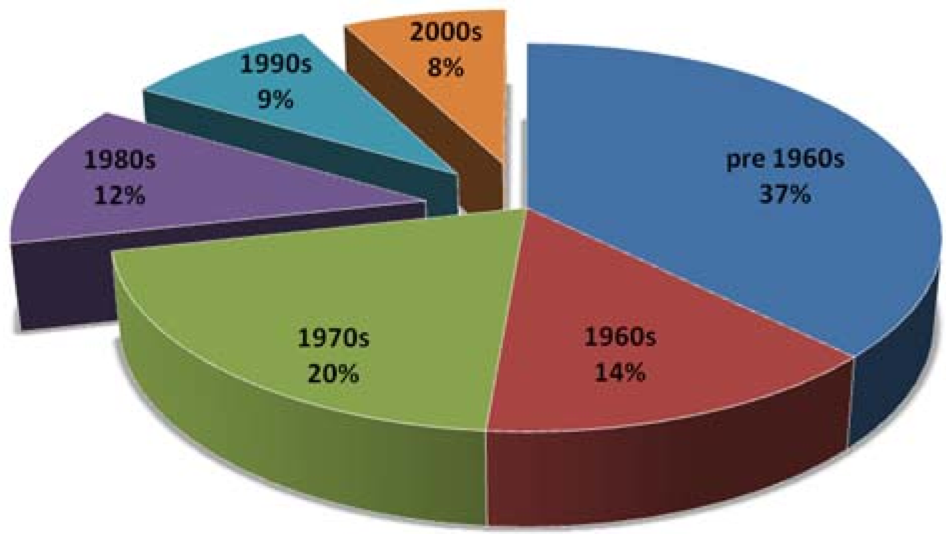
Results

The initial result from this study was the quantification of GHG from all single-family home envelope energy use in California. After scaling the initial results to California Energy Comission electricity and natural gas use numbers, the estimate of GHG from the energy needed for space cooling, space heating and hot water is 21,943,225 metric tons of CO_2e per year.

Over 70 percent of GHG related to single-family envelope energy consumption can be attributed to homes built before 1980; essentially homes built before California's energy codes were adopted. GHG emissions by housing decade are represented in Chart 3.

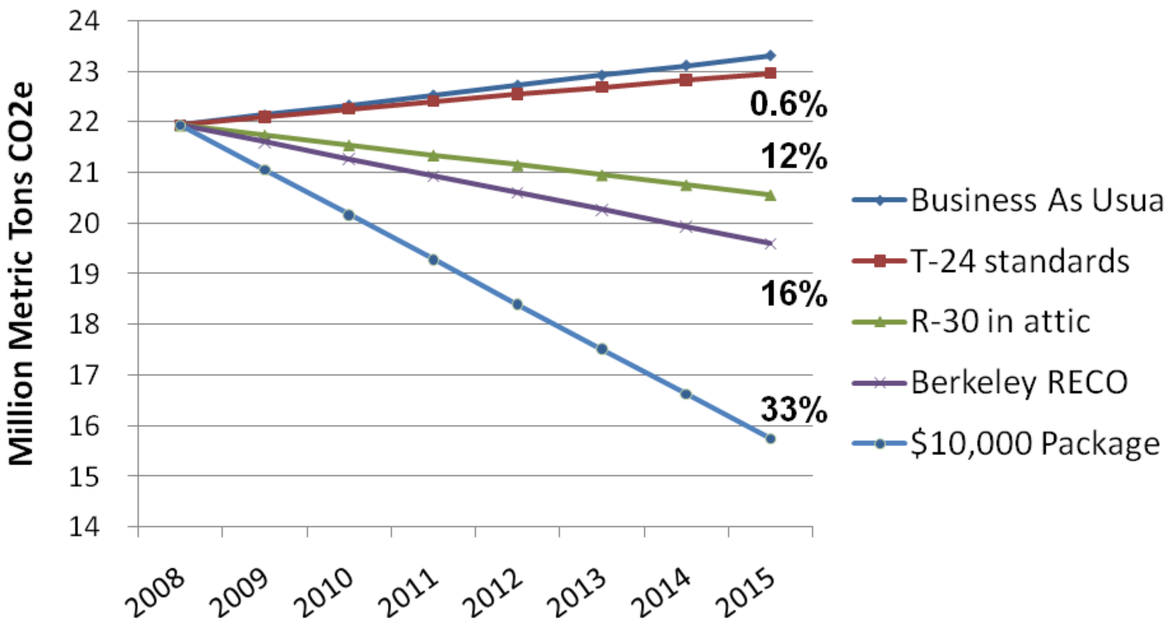
[9] http://www.climateregistry.org/

Chart 3: Single-Family Home Emissions by Vintage



Given that the vast majority of single-family home envelope GHG emissions are attributable to homes built before the 1980s, the statewide carbon impacts of retrofitting these homes with upgraded energy features was explored. Replacing individual existing energy features with upgraded retrofits and running the same energy simulations outlined in "Energy Budgets" provided data on the potential technical reduction in GHG. Chart 4 illustrates the impact of individual and package retrofit energy features on envelope energy emissions in California over a seven-year implementation period. For purposes of this study, this implementation period assumes retrofitting one-seventh of all existing homes in California annually over a period of seven years. If the feature already exists (e.g.; R-30 ceiling insulation) then it would not be replaced.

Chart 4: Retrofit Impact on Single-Family Residential Envelope GHG Over a Seven Year Implementation



The "Business As Usual" line in Chart 4 represents the growth in residential GHG as the single-family market continues to build at the historically averaged rate. The "T-24 Standards" line highlights the impact of increasing stringency on California's energy code at the 2008 and 2011 cycles. The R-30 attic line represents the reduction in carbon emission from the residential sector if all homes that do not have R-30 ceiling insulation had it installed. Features included in the Berkeley Residential Energy Conservation Ordinance (RECO). Berkeley enacted a RECO in 1985 to improve efficiency of existing homes at time of sale)[10] package were R-30 insulation in the attic and R-3 sealed ductwork.

R-30 attic insulation, sealed R-6 ducts, 13 SEER air-conditioning equipment and an 80% efficiency furnace made up the $10,000 package. The $10,000 cost of this package assumes there is substantial buy-down in the market due to the volume purchase. The cost could be substantially less to the consumer or installer if there were effective public goods funds incentives (funds made available by utility companies to help pay for energy efficiency programs) along with federal and state tax credits for energy efficiency improvements. Currently there are public goods funds incentives of up to $2,000 per home for new construction that exceeds 2005 Title 24 requirements by 35% (for example, the New Solar Homes Partnership, Tier II level) and a federal tax credit of $2,000 for energy-efficient new homes that exceed the requirements of the 2004 International Energy Conservation Code by 50%. Effective layering of tax credits and public goods funds could lower the cost of retrofit energy efficiency improvements to the consumer by 50% (e.g., federal tax credit $2,000, state tax credit $1,000 and public goods funding incentive $2,000).

[10] http://www.ci.berkeley.ca.us/ContentDisplay.aspx?id=16030

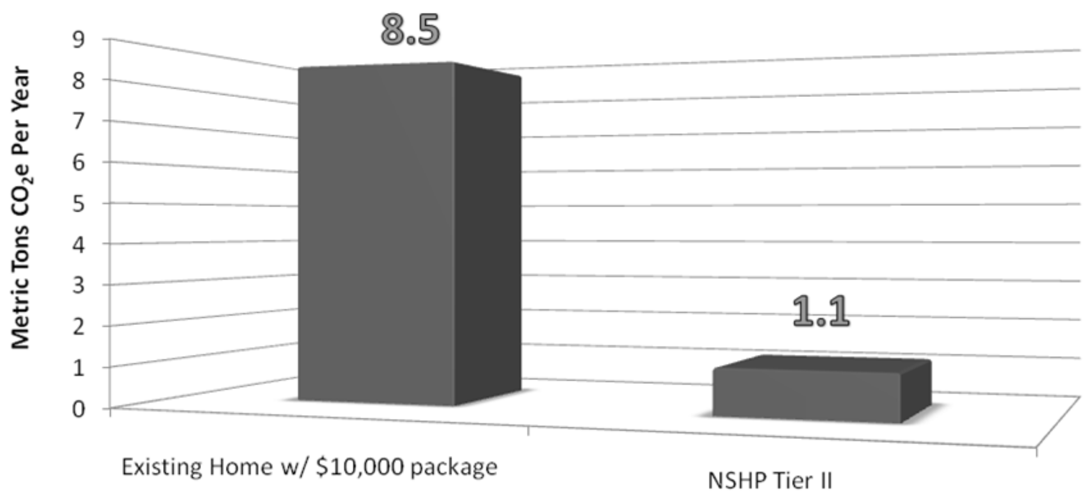
Other energy features were evaluated and their carbon emission reductions are listed in Table 5.

Table 5: GHG Reduction by Retrofit Feature

Energy Feature	Total Reduction
T-24 standards	1.5%
SHGC to 0.40 (film)	0.6%
0.62 WH	3.9%
R-6 tested ducts	5.6%
Net Zero New Construction	5.9%
R-8 tested ducts	6.0%
AC to 13 SEER	6.7%
80% furnace	8.4%
0.40/0.40 windows	10.3%
R-30 in attic	11.8%
R-38 in attic	12.6%
92% furnace	13.3%
Berkeley RECO	15.9%
$10,000 package	32.5%

Not only would mounting an aggressive existing home retrofit program result in much greater reductions in GHG than imposing additional standards for new construction, it would be much more cost effective as well. New housing is substantially more energy-efficient and the lower energy use generates significantly lower carbon emissions. Adding a new furnace, air conditioner, tight duct system and R-30 ceiling insulation to a typical existing home in California built in the 1960s would result in a reduction of 8.5 tons of carbon per year (Chart 6). The cost to make these improvements would be between $5,000 and $10,000, depending on tax credits and incentives, a cost of between $588 and $1,176 per ton removed. In contrast, making a 2005 T-24 house 35% more energy-efficient results in a reduction of carbon emissions of just 1.1 tons at an estimated cost of $5,000, which translates to $4,545 per ton. In reducing carbon emissions from the residential sector, it is four to eight times more cost effective to improve the energy efficiency of existing homes.

Chart 5: Existing Home Versus New Home Carbon Reduction Potential



The 2008 CPUC California Long Term Energy Efficiency Strategic Plan[11], the goals the investor owned utilities have proposed to meet California's long term energy goals, recommends new construction to become net zero housing by 2020. The costs to achieve net zero housing has been estimated to be $30 per square foot above a 2005 T-24 home[12,13]. This would add approximately $75,000 to the construction costs of a new home. To make all new dwelling units in California net zero would cost approximately $15 billion per year (200,000 dwelling units per year times $30 per square foot times 2,500 square foot home). Assuming net zero carbon emissions from new homes over a seven year period, the program would reduce carbon emissions by just 5.9 percent from Business As Usual. If one spent far less money per home (new furnace, new air conditioner, tight ducts and R-30 ceiling insulation; the $10,000 package) in the retrofit market, the carbon reduction would total 33%. It is more cost-effective – and far more productive – to reduce carbon emissions by improving the energy efficiency of existing housing than focusing on new construction.

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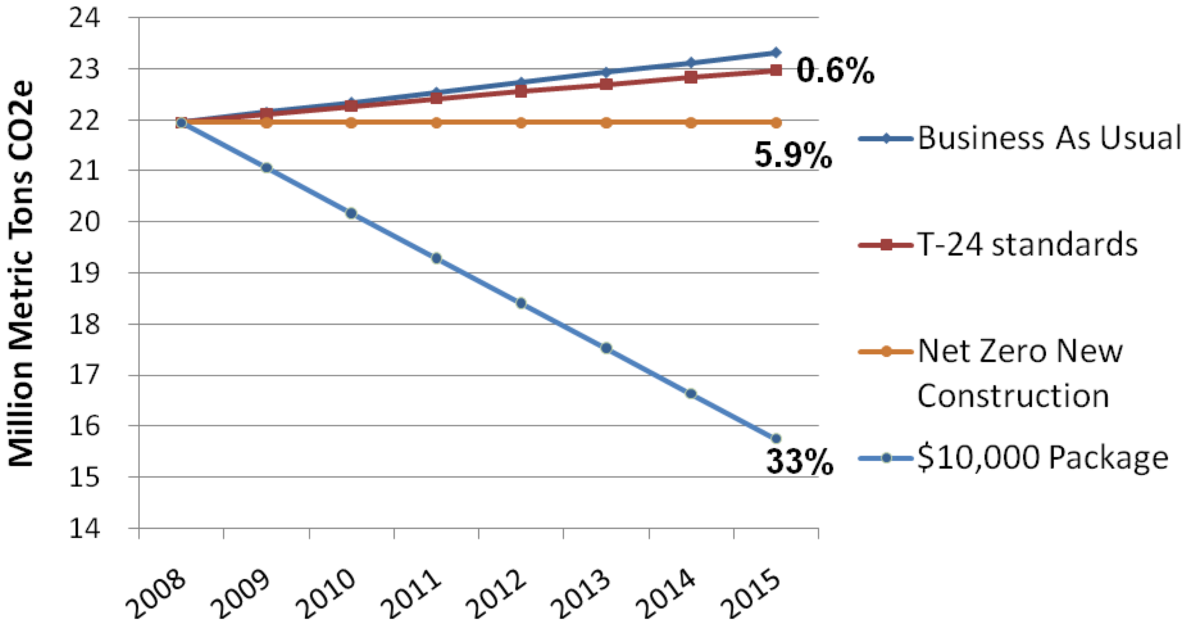
[11] California Public Utilities Commission, July 2008

[12] Hammon, Rob, PhD., ConSol, "Zero Energy Homes: What are they? How do we get there?", November 29, 2007 presentation to CPUC Strategic Planning Group

[13] Anderson, Ren, PhD., NREL, "Energy Targets and Performance Specifications, SMUD House of the Future," September 10, 2007 presentation to SMUD, Sacramento, CA

Chart 6: Retrofit Impact on Single-Family Residential Envelope GHG Over a Seven Year Implementation



Summary

There are approximately 13,270,000 dwelling units in California. Residential new construction adds typically 150,000 new units to the stock each year and represents 0.12% (about one-tenth of 1 percent) of the carbon emissions in California. New residential dwelling units built to the 2005 Title 24 energy code are already 25% below the 1990 GHG emissions target levels set by AB 32. To reduce GHG emissions in the entire residential marketplace to required levels, retrofitting existing homes must be included.

Seventy percent of the GHG emissions related to single-family envelope energy consumption can be attributed to homes built before California had an energy code (1983). The statewide carbon impact of retrofitting these homes with upgraded energy features was explored. Spending $10,000 retrofitting a 1960s home could save 8.5 tons of carbon at a cost of between $588 and $1,176 per ton depending on tax credits and incentives. Increasing the energy efficiency of a new home by 35% (from the 2005 T-24 Standards) would cost about $5,000 and would reduce emissions by 1.1 tons at a cost of $4,545 per ton. Retrofitting existing homes with energy-efficient features is four- to eight times more carbon- and cost-efficient than adding even more energy efficiency requirements to new housing.

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Next Steps to Reducing Residential GHG Emissions

This preliminary study conducted by ConSol is useful in determining where GHG emission reductions should focus, but more-detailed study is needed in the following areas:

- Expanded Retrofit Study
    - Detailed analysis of retrofit energy feature by climate zone
    - Cost benefit by feature in both energy savings and dollar savings
    - Determine packages of cost-effective energy retrofits for each climate zone
    - In-depth study of California specific home sizes (square feet).
        - Census Western States data was used for this study. Home size specific to California would produce more accurate results
    - Incorporate more energy models
- Impacts of the various utility-subsidized residential retrofit programs on GHG savings
- Impact of above-code programs to determine reduction in residential GHG emissions
- Review of additional economic factors