Climate Change
Draft Scoping Plan

Measure Documentation
Supplement

Pursuant to AB 32
The California Global Warming Solutions Act of 2006

Prepared by
the California Air Resources Board
for the State of California

The purpose of this supplement is to document the assumptions and calculations Air Resources Board staff (ARB or staff) used as the basis for greenhouse gas (GHG) reduction measures in the Draft Scoping Plan Economic Evaluation. ARB developed the measures contained herein with technical help from other State agencies and the Climate Action Team subgroups. Where appropriate, updated assumptions or corrections to tabulated values in the Draft Scoping Plan and Appendices are noted using a delta symbol (Δ).

General assumptions common to categories of measures or sectors are listed under the major headings below. Unless otherwise noted, cost for a measure is the sum of the annualized capital cost and program maintenance costs. Annualized Capital Cost is defined as the product of the capital expenditure and the capital recovery amortized over a specified period of time at an annual discount rate of 5%. The capital recovery factor (CRF) is calculated using the formula:

$$Capital\_Recovery\_Factor = \frac{i(1+i)^n}{(1+i)^n - 1}$$

Where *i* is the discount rate (5%) and *n* is the life of the capital. A real discount rate of 5% is chosen to match the rate of return on an inflation adjusted 10-year treasury security. The expected life of the capital is estimated for each measure. The amortization period is related to the expected life of the capital or an estimate of the period over which GHG reductions are expected. For example, measures that use a 20-year capital life, the CRF is 0.08024 or approximately $0.08 annually for each dollar of capital expenditure. Each measure described specifies the estimated capital life and associated CRF.

Savings are generally calculated from reduced energy used as a result of efficiency or other measure. For most measures the savings value listed in the tables results from a reduction in fuel or electricity use or the net reduction associated with fuel switching. In the Draft Scoping Plan Appendices the "Net Annualized Cost" is calculated by subtracting the savings from the annualized cost. A negative cost value indicates the measure is expected to have net savings.

The values and assumptions documented here are preliminary and subject to change during the regulatory process.

Preliminarily Recommended Measures and Other Measures Under Evaluation

Transportation

General Assumptions

For transportation measures that reduce fuel combustion, staff used 8.94 $kgCO_2E$/gallon (0.00894 $MMTCO_2E$/million gallons) of gasoline and 10.4 $kgCO_2E$/gallon (0.0104 $MMTCO_2E$/million gallons) of diesel in 2020. These GHG emission factors were also employed in developing the emissions inventory. The cost for fuel in 2020 is projected at $3.673 for gasoline and for $3.685 for diesel[1].

Measure T-1—Pavley I and II (Adopted Regulation)

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Pavley (AB 1493)	31.7	1,372	11,371	-9,999
Pavley II – Light-Duty Vehicle GHG Standards		594	1,642	-1,048

Overview

This measure reduces GHG emissions from passenger vehicles, based on a fleetwide average, through technological efficiency improvements to vehicles or other actions. The Pavley standards (Pavley I) regulate passenger vehicle GHG emissions starting with the 2009 model year and continuing through 2016. The second phase of the Pavley regulations (Pavley II) is expected to affect model year vehicles from 2016 through 2020.

Assumptions for GHG Reduction

The Pavley standards are estimated to achieve a reduction of approximately 27.7 $MMTCO_2E$ in 2020[2] resulting from a reduction of approximately 3.1 billion gallons of gasoline consumed statewide in 2020.

$$3098 Million\_gallons\_gasoline \times 0.00894 \frac{MMTCO_2E}{gallon\_gasoline} = 27.7 MMTCO_2E$$

[1] Fuel costs are California specific from the California Energy Commission Transportation Energy Forecasts for the 2007 Integrated Energy Policy Report; http://www.energy.ca.gov/2007publications/CEC-600-2007-009/CEC-600-2007-009-SF.PDF page B-5. Costs are 2007$

[2] A detailed analysis of the Pavley standards is found at: http://www.arb.ca.gov/regact/grnhsgas/grnhsgas.htm.

The second phase of Pavley targets an additional 4 $MMTCO_2E$ starting with 2016 model year vehicles.

$$447 Million\_gallons\_gasoline \times 0.00894 \frac{MMTCO_2E}{gallon\_gasoline} = 4 MMTCO_2E$$

Assumptions for Costs and Savings

The average cost for control for passenger cars and small trucks/SUVs is estimated at $1050 for 2016 model year vehicles based on staff analysis[2]. The second phase of the Pavley regulations is expected to be approximately twice the average cost of a 2016 vehicle by 2020, or $2100. Fleetwide aggregate costs per vehicle ranging from $33-1910 (2009-2020 model years) for an estimated 1.3 million vehicles per year is annualized over 16-19 years resulting in $1,236M (in 2004$). Multiplying by a Consumer Price Index of 1.11 results in $1,372M in 2007$. For Pavley II the costs/vehicle are estimated at twice the average 2016 value for Pavley I. This results in $594M in cost for 1.3M vehicles annually.

Savings is calculated based on reduced fuel consumption multiplied by $3.673/gallon of gasoline as described above. Savings are based on 27.7$MMTCO_2E$ and 4 $MMTCO_2E$ for Pavley I and II, respectively.

$$3098 Million\_gallons\_gasoline \times \frac{\$3.673}{gallon\_gasoline} = \$11,371M$$

$$447 Million\_gallons\_gasoline \times \frac{\$3.673}{gallon\_gasoline} = \$1,642M$$

Measure T-2—Low Carbon Fuel Standard

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Low Carbon Fuel Standard	16.5	11,000	11,000	0

Overview

This measure reduces GHG emissions by requiring a low carbon intensity of transportation fuels sold in California by at least 10% by the year 2020. The low carbon fuel standard regulation is under development and the reduction pathways are being analyzed.

Assumptions for GHG Reduction

The total projected transportation inventory for fuels affected by the LCFS regulation is approximately 220 $MMTCO_2E$. Assuming that vehicle efficiency (Pavley I and II), land use, and goods movement efficiency measures reduce fuel use, the new projected inventory is approximately 165 $MMTCO_2E$ with these reductions subtracted. A 10% carbon intensity reduction is therefore 16.5 $MMTCO_2E$ (i.e. 0.1 x 165 = 16.5 $MMTCO_2E$).

Assumptions for Costs and Savings

Staff assumes the costs of producing ethanol and biodiesel are highly competitive with the current and projected high prices of gasoline and diesel. Staff assumes that implementation of the LCFS will result in displacing 20% of traditional petroleum derived products and replacing them with alternative fuels. This is approximately three billion gallons per year less of traditional gasoline and diesel that the consumers would buy (savings) and equates to $11 billion dollars in lost sales of petroleum products. Secondarily, staff assumed that alternative fuels could be produced at prices at or below the pretax wholesale cost of petroleum fuels on an energy equivalent basis. Consumers would not necessarily get this benefit as the market price commanded by the alternative fuels would simply be the price of petroleum based products. Recovery of capital expenditure to produce alternative fuels would be recovered from the purchase of $11 billion worth of alternative fuels that replace the petroleum fuels that were displaced (costs). Therefore, staff estimates that there will be no net difference in the costs of producing fuels to meet the LCFS compared with the cost of producing traditional petroleum gasoline and diesel.

Measure T-3—Other Vehicle Efficiency Measures

Includes Tire Pressure Program, Tire Tread Standard, Low-Friction Engine Oils, and Solar-Reflective Automotive Paint and Window Glazing. These measures are assumed to apply primarily to light-duty gasoline passenger vehicles. Vehicle population estimates that staff assumes to be affected by each measure are listed separately below. These measures are expected to primarily affect the light-duty vehicle fleet, however each measure assumes a specific targeted portion of this fleet based on staff engineering judgment.

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Tire Pressure Program	0.82	95	337	-242$^{\Delta}$
Tire Tread Standard	0.3	0.6	123	-123
Low Friction Engine Oils	2.8	520	1,149	-629$^{\Delta}$
Solar Reflective Automotive Paints and Window Glazing	0.89	360	365	-5

Tire Pressure Program

Overview

This measure would increase vehicle efficiency by assuring properly inflated automobile tires to reduce rolling resistance. Increasing fuel efficiency reduces GHG emission by consuming less fuel.

Assumptions for GHG Reduction

1) The U.S. EPA estimates 58 percent[3] of all light-duty vehicles have underinflated tires, of which:
   a. Twenty-three percent have severely underinflated tires (6 pounds per square inch [psi] or more) that average 8.5 psi below the vehicle manufacturer's recommended specification.
   b. Twenty-eight percent have moderately underinflated tires (between 1 and 6 psi) that average 3.5 psi underinflation.
2) Fuel efficiency is reduced by 1 percent for every 3 psi of underinflation (average of all 4 tires).

Staff assumes that starting in the first year following the Program's regulatory and outreach components all vehicles with severely or moderately underinflated tires will have their tires properly inflated. Vehicles with underinflation of 1 psi or less are excluded from calculation assuming that this modest measurement variation arises from ambient temperature fluctuation or error in pressure gauges. Staff estimates that 51% of percent of passenger vehicles will have moderately underinflated tires through 2020 averaging 3.5 psi underinflation (i.e. 1.15% efficiency loss). The 2020 light-duty passenger vehicle fuel use for vehicles affected by the Tire Pressure Program measure is estimated to be 15.7 billion gallons of gasoline in 2020 based on EMFAC2007 model output.

$$15.7BG\_gasoline \times 0.0115(1.15\%\_efficiency) \times 0.51(51\%\_vehicles) = 92MG\_gasoline$$

$$92MG\_gasoline \times 0.00894\frac{MMTCO_2E}{gallon} = 0.82MMTCO_2E$$

Assumptions for Costs and Savings

Staff estimates costs associated with air compressors, air tools, tire gauges, equipment maintenance and Tire Guide/Yearbook. Cost assumptions for each affected facility are:

1) Air compressors are an average cost of $450 with a life expectancy of five years. Staff estimates that test-only smog check facilities will have to purchase an average of 1.5 compressors in 2010, 2015 and 2020.
2) Annual compressor maintenance at an average of $37.50.
3) Air tools and hoses are $50 every two years ($25/year).
4) High quality tire pressure gauge is $25 with a 2-year life expectancy ($12.50/year).
5) Tire Guide/Yearbook is approximately $50 with a 3 year replacement need ($16.67/year)
6) The number of test-only smog check facilities is 1,985 and automotive repair facilities is 33,692 (including smog check facilities).[4]
7) Staff expects that one or two compressors and associated equipment will be purchased per test only facility.
8) The estimated time to check and inflate tires is expected to be 3 minutes per vehicle at an average labor rate of $82.50, which equals an average of $4.13/vehicle

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[3] U.S. Environmental Protection Agency, Office of Transportation and Air Quality Fuel Economy Labeling of Motor Vehicle Revisions to Improve Calculation of Fuel Economy Estimates, EPA420-R-06017, December 2006.

[4] California Department of Consumer Affairs, Bureau of Automotive Repair, Vehicle Information Database

9) In 2010 California is estimated to have 22,130,110 registered vehicles that are subject to reductions associated with implementation of this measure.
10) Eighty-two percent of drivers have their vehicle oil changed by professionals.[5]
11) Staff expects that the per-vehicle labor costs will be passed onto the consumer.

- For 2010, 2015, and 2020 = $4,015,650:
  Smog test-only: compressor, hoses and tools $(\$450 + 50) \times 1.5 \times 1{,}985 = \$1{,}488{,}750$
  All facilities: pressure gauge and Tire Guide $(\$25 + \$50) \times 33{,}692 = \$2{,}526{,}900$
- For years 2011-2014 and 2016-2019 = $1,168,889
  Annual cost of smog test-only compressor maintenance, hoses, and air tools:
  $(\$37.50 + \$25) \times 1.5 \times 1{,}985 = \$186{,}094$
  Annual cost for Tire pressure gauges and the Tire Guide/Yearbook:
  $(\$12.50 + \$16.67) \times 33{,}692 = \$982{,}796$
- Labor cost for pressure check, tire inflation (for 2010):

  $(\$4.13 \times 22{,}130{,}110 \times 0.82(82\%) = \$74{,}945{,}831$

The total labor cost increases to $87.4 million in 2020 based on expected vehicle population.

To calculate the 2020 annualized cost, staff uses the above assumptions and the capital recovery factor for either 2 or 5 year amortization period (depending on capital expenditure). The result is a net annualized cost of $95.3M:

Calculation	Cost ($Millions)
Capital cost for years 2010,2015, 2020 ($4M/year)	$12.00
Capital cost for years 2010,2015, 2020, using 5 year CRF (0.231)	$2.77
Capital cost for 2011-2014 and 2016-2019 periods (sum of $1.2M/year for these periods)	$9.60
Capital cost 2011-2014, 2016-2019, using 2 year CRF (0.537)	$5.16
Total capital cost for 2020 (sum of annualized costs: $2.77M+$5.16M)	$7.93
2020 operating cost	$87.40
Annualized cost for 2020	$95.33
Net annualized cost (cost-savings)	-$242

The savings is estimated from the fuel reduction and the 2020 projected fuel cost.

$$92MG\_gasoline \times \$3.673/gallon = \$337M$$

Tire Tread Standard

Overview

This measure would increase vehicle efficiency by creating an energy efficiency standard for automobile tires to reduce rolling resistance. A reduction in GHG emissions results from

[5] California Integrated Waste Management Board, Used Oil Source Reduction Study: *Busting the 3000 mile myth*, March 2007.

reduced fuel use. Staff estimates that reducing the rolling resistance of tires by 10% results in a 2% increase in fuel efficiency.

Assumptions for GHG Reduction

The tire tread program will provide information to consumers about the availability of tires which are identified as low rolling resistance. Staff uses the following assumptions in calculating the GHG reduction from this measure:

- In 2020, there will be approximately 25 million passenger vehicles in the fleet affected by this measure.
- Approximately 5.5 million vehicles are new and therefore not in the market to purchase new tires.
- New vehicles have low rolling resistance tires as original equipment from the vehicle manufacturer.
- Passenger vehicles affected by this measure drive an average of approximately 12,000 miles per year.
- The fleet average mileage for passenger vehicles affected by this measure is approximately 21 miles per gallon.
- Approximately 15% of tire purchases will be low rolling resistance (i.e. 15% market penetration)
- A 10% reduction in rolling resistance results in a 2% vehicle efficiency increase.

$$19{,}500{,}000 vehicles \times 15\% = 2{,}925{,}000 vehicles \times 12{,}000 miles = 35{,}100{,}000{,}000 VMT$$
$$35{,}100{,}000{,}000 VMT \div 21 MPG = 1{,}671{,}428{,}571 gallons \times 2\% = 33{,}500{,}000 gallons$$
$$33{,}500{,}000 gallons \div 0.00894 MMTCO_2E / MG = 0.3 MMTCO_2E$$

Assumptions for Costs and Savings

Staff estimates that the there is little, if any, cost differential between tires of varying rolling resistance and therefore assumes no additional cost for choosing low rolling resistance tires. The annual program cost is estimated at $625,000 based on staff experience with programs of similar size and scope. Savings is the result of reduced fuel use.

$$33.5 MG\_gasoline \times \$3.673 / gallon = \$123M$$

Low Friction Engine Oils

Overview

This measure would increase vehicle efficiency by mandating the use of engine oils that meet certain low friction specifications. The American Petroleum Institute has established “energy conserving designation” for certain oils. These specifications would be used as a starting point for the mandated oils under this measure.

Assumptions for GHG Reduction

Staff estimates a 2% efficiency increase based on results from research studies.[6] Staff estimates the efficiency will be achieved in about 85% of vehicles comprising the light-duty fleet. The 2020 GHG emissions inventory from light-duty vehicles is 160.8MMTCO_2E for all fuels.

$$0.02(2\%)\times 0.85(85\%)\times 160.8MMTCO_2E = 2.8MMTCO_2E$$

Assumptions for Costs and Savings

Staff estimates approximately $20 per vehicle additional operating and maintenance costs for 26 million vehicles affected by this measure in 2020. Existing oils meeting the low friction criteria are approximately $1/quart more than conventional oil. The $20 incremental cost is based on use of 5 quarts of engine oil at $1 per quart additional for each of 4 oil changes per year. Savings is the result of reduced fuel use of 313 million gallons of gas at $3.673/gallon.

$$\$20\times 26million\_vehicles = \$520M$$
$$\$3.673/gallon\times 313MG = \$1{,}149M$$

Solar Reflective Automotive Paint and Window Glazing

Overview

This measure would increase vehicle efficiency by reducing the engine load for cooling the passenger compartment with air conditioning. The use of solar reflective automotive paints and window glazing reduces heating of the automobile passenger compartment from the sun resulting in reduced air conditioning use. The result is both less frequent air conditioning use by drivers and smaller air conditioners specified by manufacturers for new vehicles.

Assumptions for GHG Reduction

Staff estimates approximately 170 million gallons of gasoline could be saved annually with full implementation of this measure based on results from a National Renewable Energy Laboratory research study and associated modeling results.[7] This translates into 1.5 MMTCO_2E. This measure is expected to affect 2012 and newer vehicles that are expected to comprise 43% of the 2020 fleet and account for 59% of VMT according to EMFAC2007[8]. The result is a reduction of 0.89 MMTCO_2E in 2020.

$$0.59(59\%)\times 1.5MMTCO_2E - 0.89MMTCO_2E$$

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[6] The Southwest Research Institute (SwRI) conducted a research program that evaluated the effect of engine oil on the fuel economy of gasoline and light-duty diesel engine passenger cars called the Mercedez-Benz M111 Fuel Economy Test—DCED L-54-T-96(http://www.swri.org)

[7] National Renewable Energy Laboratory research study "Reduction in Vehicle Temperatures and Fuel Use from Cabin Ventilation, Solar-Reflective Paint, and a New Solar-Reflective Glazing" (Rugh, J.P *et al*. 2007-01-1194). http://www.nrel.gov/vehiclesandfuels/ancillary_loads/pdfs/40986.pdf

[8] The EMissions FACtors (EMFAC) Model is used by ARB to calculate emission rates and population of motor vehicles. Information is available at: http://www.arb.ca.gov/msei/onroad/latest_version.htm

Assumptions for Costs and Savings

Staff estimates that the additional cost per vehicle is approximately $250 for complying with this regulation. This includes $10-50/vehicle additional cost for solar reflective paint and $150-225/vehicle additional cost for window glazing. The annualized cost assumes a 14-year CRF (0.101) resulting in approximately $26 per vehicle. It is expected that 14 million vehicles will be affected by this measure resulting in total annualized capital cost of approximately $360M.

Savings is the result of reduced fuel use. Reduced fuel of about 99 million gallons results in a $365M savings annually

Measure T-4—Ship Electrification at Ports (Adopted Regulation)

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Ship Electrification at Ports—Shore Power (Discrete Early Action)	0.2	0	0	0

Overview

This regulation requires ships meeting certain criteria to turn off (cold iron) auxiliary engines at port (hotelling) and acquire power from shore electrification or use another equally effective means of reducing emissions. This measure is motivated primarily by air toxics pollutant reductions but achieves a GHG benefit primarily by shifting electrical generation from high-emitting onboard engines to sources providing electricity to the grid, such as combined-cycle gas turbines.

Assumptions for GHG Reduction

Staff calculated the GHG emission reduction as a ratio of the per megawatt-hour emissions from onboard ship auxiliary power to the shore power emission multiplied by the MWh of electricity supplied to the ship. Staff used 690g/KWh (6.9×10^{-7} $MMTCO_2E/MWh$) for auxiliary ship engines. A total estimated 715GWh (715,000MWh) of electricity is used by hotelled ships.[9]

$$6.9 \times 10^{-7}\, MMTCO_2E / MWh \times 715{,}000 MWh = 0.493 MMTCO_2E$$

$$4.37 \times 10^{-7}\, MMTCO_2E / MWh (2020\_Line\_Value) \times 715{,}000 MWh = 0.312 MMTCO_2E$$

$$0.493 MMTCO_2E - 0.312 MMTCO_2E = 0.18 MMTCO_2E$$

[9] The Initial Statement of Reasons (ISOR) for the Shore Power rule (adopted December 2007) is found at http://www.arb.ca.gov/regact/2007/shorepwr07/tsd.pdf. The ISOR details criteria pollutant and GHG emissions and electricity supplied to hotelled ships.

Assumptions for Costs and Savings

The cost and savings associated with this measure are assigned to the diesel risk reduction program and therefore no net cost has been included in the Draft Scoping Plan.

Measure T-5—Goods Movement Efficiency Measures

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Goods Movement Systemwide Efficiency Measures	3.5	TBD	TBD	0

Overview

This measure targets systemwide efficiency improvements in goods movement to achieve GHG reductions from reduced diesel combustion. Staff is developing strategies to achieve the 3.5 $MMTCO_2E$ target. The 3.5 $MMTCO_2E$ target represents about a 22% reduction from the 2020 projected goods movement inventory.

Assumptions for GHG Reduction

A target of 3.5 $MMTCO_2E$ is established in the Draft Scoping Plan. For the purposes of this analysis, staff estimates the targeted reduction will result from reduced diesel combustion from efficiency (90%) and electrification of equipment currently fueled by diesel (10%). However, because this measure is expected to provide flexibility to the industry in determining the emission reduction approaches that work best for them, the proportion of emission reductions from efficiency improvements and electrification may be different than estimated here. The reduction target is the net of GHG reductions from reduced diesel use plus the increases emission from electrification.

Additional assumptions used are as follows:

- All fuel used by engines under measure is diesel fuel
- Diesel fuel density of 7 lbs. per gallon
- Diesel GHG emissions of 10.4 kg CO_2E per gallon diesel fuel

<u>For conversion from diesel engine to grid power</u>

- Grid power emission factor of 437 g CO_2E/kWh
- Average diesel engine brake specific fuel consumption value (BSFC) of 250 grams diesel/kWh for the diesel engines covered. Available BSFC data for a sampling of marine, locomotive, and TRU engines ranged from about 200 to 250 g diesel/kWh. Upper end of range (250 g/kWh) used to account for transient operation with lower fuel consumption (higher BSFC).
- CO_2 emission factor of 790 g/kWh for all engines covered under the measure (estimated using 250 g fuel /kWh BSFC and 10.4 kg CO_2E/gallon)

Calculations:

A. Reduction in fuel consumption that will result in 90% of the total 3.5 MMT CO2 emission reduction:

3.5 $MMTCO_2E$ x 90% = 3.15 $MMTCO_2E$ reduction
3.15 $MMTCO_2E$ x (1x 10^{12} g CO_2)/MMT x kg CO_2/1000 g CO_2 x gall diesel/10.4 kg CO_2 = 303 million gallons diesel reduced

B. Increase in grid power (and decrease in diesel consumption) associated with conversion from diesel engine power to grid power that will result in 10% of the 3.5 MMT CO2 emission reduction:

3.5 $MMTCO_2E$ x 10% of reduction = 0.35 $MMTCO_2E$ reduction

0.35 $MMTCO_2E$ reduction = [E kWh x 790 g CO_2/kWh from diesel engines] – [E kWh 437 g CO2E/kWh from power plants]

Note: The 0.35 $MMTCO_2E$ emission reduction is represented in this equation as the difference in CO_2 emissions between diesel engines and the grid when supplying the unknown value for energy E. This assumes that when converting from diesel engines to grid power, the same amount of energy will be provided. Solving for E provides the increase in grid power.

0.35 $MMTCO_2E$ = [353 g CO_2/kWh] x E
E= 0.35 $MMTCO_2E$/353 x 10^{-12} MMT/kWh
E= 991 million kWh = 0.991 million MWh~1 million MWh increase

Diesel fuel reduced = 991 mill kWh x 250 g diesel/kWh x lb/454 g x gall/7 lbs = 78 million gallons reduced

C. Total decrease in diesel fuel consumption (galls) and increase in grid power used (MWh):

Overall decrease in diesel fuel consumed: ~380 million gallons
Increase in grid power: ~ 1 million MWh

Assumptions for Costs and Savings

Staff is developing the strategies to achieve reductions from goods movement systemwide energy efficiency. The preliminary assumption is that costs and savings will be approximately equivalent.

Measure T-6—Heavy Duty Vehicle GHG Emission Reduction from Aerodynamic Efficiency

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Heavy-Duty Vehicle GHG Emission Reduction from Aerodynamic Efficiency	1.4*	1,136	496*	640*

*This measure would result in 13.6 $MMTCO_2E$ outside of California that is not accounted for in this plan. The net annualized cost of this measure incorporates the total cost of the equipment associated with nationwide benefits. The savings, however, only account for the fuel savings that occurs within California associated with the estimated 1.4 $MMTCO_2E$ statewide GHG reduction.

Overview

This measure would increase heavy-duty vehicle (long-haul trucks) aerodynamic efficiency by requiring installation of best available technology and/or ARB approved technology to reduce aerodynamic drag and rolling resistance.

Assumptions for GHG Reduction

Staff estimates the 2020 GHG reduction is approximately 15 $MMTCO_2E$ nationwide of which 1.4 $MMTCO_2E$ (9%) is estimated to occur within California. This reduction is derived from an estimated fuel efficiency improvement of 7% with approximately 1.5% and 5.5% increased efficiency resulting from improvements to the tractor and trailers, respectively. A baseline fuel efficiency of 6 miles per gallon (MPG) is estimated to calculate the benefit from efficiency improvements resulting in an improved mileage of 6.4 MPG (6 MPG X 7% = 6.4 MPG). The 2020 California VMT for heavy-heavy duty diesel trucks (from EMFAC2007) is 17,411,000,000 miles annually of which 2/3 is estimated to derive from trucks affected by this measure (i.e. 11,607,000,000 miles).

$$\frac{11{,}607{,}000{,}000\,miles}{6\,miles/gallon} = 1{,}934{,}500{,}000\,gallons \times 7\% = 135{,}415{,}000\,gallons$$

$$\frac{135{,}415{,}000\,gallons}{0.0104\,MMTCO_2E\,/\,million\_gallon} = 1.4\,MMTCO_2E$$

Assumptions for Costs and Savings

The incremental costs include for tractors included purchase of tires ($100/tire incremental), and for trailers includes side skirts ($1700), front gap fairing ($800), tires ($100/tire incremental) and installation ($800). An industry average 2.5 trailers per tractor is used to estimate the total cost. The sum of truck retrofit ($1000) plus trailer retrofit ($4100 x 2.5 = $10,250) is $11,250. Staff rounded this to $12,000 for calculation of total cost.

Cost and Savings Calculation	
Per vehicle capital cost (estimated at $12,000/truck-trailer)	$12,000/truck
Number of trucks in CA	1,097,000 total trucks
Estimate 2/3 of trucks include retrofit	731,333 trucks retrofitted
2020 cost	$8,776,000,000.00
Estimate 10 year life (10 year CRF at 5% = 0.1295)	Multiply 2020 cost by 0.1295
Capital cost 2020	$1,136,532,149.90
Capital cost 2020	$1,136M
Net annualized cost (cost-savings)	*$640M

*The net annualized cost includes total cost but only the savings benefit from reduced fuel use within California as explained above.

Savings is the result of reduced fuel combustion. The estimated 135 million gallons of diesel reduced is multiplied by $3.685/gallon to result in a California only savings of $496M. The nationwide savings is substantially greater such that the total savings exceeds the cost nationwide. Staff is working to quantify the nationwide benefits as part of the regulation development process.

Measure T-7—Medium- and Heavy-Duty Vehicle Hybridization

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Medium- and Heavy-Duty Vehicle Hybridization	0.5	93	177	-85

Overview

This measure would regulate or incentivize GHG reductions from medium- and heavy-duty vehicles used in vocational applications such as parcel delivery trucks, garbage trucks, utility trucks and transit buses. Hybrid electric technology offers the potential to significantly reduce GHG emissions and improve vehicle efficiency from these vehicles.

Assumptions for GHG Reduction

Staff estimates the potential 2020 GHG emission reduction from the use of hybrid technology on heavy-duty trucks is 0.5 $MMTCO_2E$. This estimate assumes that all new class 3 to 5 (10,001 to 19,500 pounds GVWR) trucks sold in California beginning in 2015 use hybrid technology. Model year 2015-2020 class 3 to 5 trucks are estimated to represent 20 percent of the same class fleet and 30 percent of the same class VMT in 2020 according to EMFAC2007.

From EMFAC2007	CY 2020 (MY 2015-2020)	CY 2020 (ALL MYs)	Assumptions
Vehicles (10,001 to 19,500 lbs)	53,421	273,739	• Fuel economy improvement: 26% • Base truck fuel economy: ~7 mpg
Daily Vehicle Miles (10,001 to 19,500 lbs)	3,694,200	12,166,000	
GHGs Reduced in 2020	0.5 MMTCO$_2$E	1.7 MMTCO$_2$E	

$$\frac{3{,}694{,}200\,miles/day}{7\,miles/gallon} = 527{,}742\,gallons/day \times 347\,days/year \times 26\% = 47{,}610{,}383\,gallons$$ [10]

$$\frac{47{,}610{,}383\,gallons}{0.0104\,MMTCO_2E/million\_gallon} = 0.5\,MMTCO_2E$$

Assumptions for Costs and Savings

	Base Diesel Truck	Parcel Hybrid Truck	Assumptions
Cost ($)	$40,000	$70,000	Cost of the base truck is from a truck dealership. Incremental cost is from a hybrid builder: $30,000 (75% above cost of base truck) for pre-production parcel trucks. ($10,000, or 25% above cost of base truck for production volume of 10,000 trucks or more)
Life of the vehicle (years)	10	10	Source: Parcel delivery truck fleet operator
Maintenance Cost	Unknown	Unknown	Being pre-production vehicles, the parcel fleet operator has not realized maintenance savings because of problems in software, transmission, parking brake, etc.
Assumed maintenance costs: ($/mile)	$0.16	$0.20	Hybrid truck maintenance cost is assumed to be about 4% lower than base truck for conventional maintenance, but 10% greater when a one-time battery replacement cost of $5000 to $8000 at 22,000 miles/year is included.

[10] The VMT output for EMFAC2007 is in units of miles/day for weekday mileage. Annual miles are calculated using a factor of 347 to account for reduced weekend and holiday mileage.

Cost and Savings Calculation	
Number of vehicles 2015-2020	53,421
Per vehicle capital cost	$10,000
Capital cost 2015-2020	$534,210,000
10-year CRF at 5% discount rate 0.1295	0.1295
Capital cost 2020 CRF X capital cost	$69,180,195
Operating cost	$0.20/mile
Annual miles	22,000
Operating cost per vehicle	$440/year
Operating cost 2020	23505240
Operating cost 2020	23.51
Total cost 2020	$92.69M
Total fuel reduced	48 million gallons diesel
2020 diesel cost	$3.685
Savings from reduced fuel use	$177M
Net annualized cost (cost-savings)	-$85M

Measure T-8—Heavy-Duty Engine Efficiency

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Heavy-Duty Engine Efficiency	0.6	26	213	-187

Overview

This measure would require the adoption of a regulation and/or incentive program to take advantage of both emerging and current technology to increase the efficiency of heavy-duty engines.

Assumptions for GHG Reduction

The GHG benefits are calculated assuming:

- Heavy Heavy-Duty Diesels (HHDD): benefit from all engine efficiency improvement strategies (18%)
- Medium Heavy-Duty Diesels (MHDD): benefit from half of the engine efficiency improvement strategies (9%)
- Both MHDD and HHDD GHG benefits:
    - The scenario assumes that engine efficiency improvements are implemented beginning in CY 2016.
    - Therefore, in 2020, the affected model years are 2016 to 2020.
- Implementation of the Truck and Bus Rule will affect the turn over of the heavy-duty fleet.
    - The Truck and Bus Rule requires 70% of the fleet to be turned over by 2015 and 90% by 2020. Therefore, in 2020, the total number of affected vehicles, i.e., MYs 2016 to 2020, is equal to 20% of the total population in 2020

From EMFAC2007	Medium Heavy Duty Diesel	Heavy-Heavy Duty Diesel
2020 CA Registered Vehicle Population	235,398	178,262
2020 Total Daily VMT	12,395,000	27,933,000
2020 affected vehicle percentage of same class total	20%	20%
Fuel Economy (mpg)		
Baseline Fuel Economy	7.2	6.0
Modified Baseline Fuel Efficiency with SmartWay[11]	7.9	6.2
New Fuel Efficiency for a vehicle with engine efficiency improvement (9% for MHDD and 18% for HHDD)	8.6	7.3
GHG Benefits		
Fuel Saved (million gallons/day)	0.03	0.14
GHG Reduction	0.1 $MMTCO_2E$	0.5 $MMTCO_2E$
Total GHG Reduction	0.6 $MMTCO_2E$	
Fuel Reduction (2020)	58 million gallons diesel	

Assumptions for Costs and Savings

Staff estimates the annualized cost of this measure is $26M.

Savings is the result of reduced fuel combustion for an estimated 58 million gallons of diesel in 2020.

$$\$3.685 / gallon \times 58MG = \$213M$$

Measure T-9—Local Government Actions and Regional GHG Targets

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
VMT Reduction-Local Government Actions and Targets	2	200	821	-621

Overview

This measure would reduce vehicle miles traveled (VMT) by approximately 2% through land use planning. Staff estimated a 2% reduction based on review of modeling literature.

Assumptions for GHG Reduction

A 2% reduction in VMT results in a 2% reduction in GHG emissions based on the affected portion of the emissions inventory. Passenger vehicles are projected to emit

[11] For HHDDs, the modified baseline fuel efficiency (FE) is the weighted average FE and considers 50% of HHDDs to use SmartWay technology (10% improvement) and assumes 75% of the VMT to be at speeds near 60 mph. For MHDDs, the modified baseline weighted average FE considers 25% of the MHDDs to use hybrid technology (40% improvement) and 75% use current technology.

160.7 $MMTCO_2E$ in 2020 which derives primarily (99.8%) from gasoline combustion. Measures in the Draft Scoping Plan that reduce GHG emissions from reduced fuel consumption and the LCFS[12] affecting passenger vehicles include Pavley I and II (measure T-1 reduces GHG emissions by 31.7 $MMTCO_2E$), vehicle efficiency measures (T-3 reduces GHG emissions by 4.8 $MMTCO_2E$). Subtracting the T-1, T-2 (passenger vehicle only portion), and T-3 reductions from the projected inventory results in approximately 115 $MMTCO_2E$ net GHG emission for passenger vehicles. A two percent reduction (or 2.3 $MMTCO_2E$) is rounded to 2 $MMTCO_2E$.

$$160.7 MMTCO_2E - 31.7 MMTCO_2E - 10 MMTCO_2E - 4.8 MMTCO_2E = 114.2 MMTCO_2E$$
$$114.2 MMTCO_2E \times 0.02 (2\%) = 2.3 MMTCO_2E$$

Note that the order in which the reductions are calculated changes the resulting expected GHG reduction for this measure. For example, if a 2% reduction in VMT were calculated from the business-as-usual projection of 160.7 $MMTCO_2E$, more than 3 $MMTCO_2E$ would result (i.e. 0.02 [2%] x 160.7 $MMTCO_2E$ = 3.2 $MMTCO_2E$).

Assumptions for Costs and Savings

Staff conservatively estimates \$100/ton of carbon reduced for costs and savings are based upon reduced fuel consumption.

$$2 MMTCO_2E \times \frac{gallon\_gasoline}{0.00894 MMTCO_2E} = 223 million\_gallons\_gasoline$$

$$223 million\_gallons\_gasoline \times \frac{\$3.673}{gallon} = \$821 million$$

Measure T-10—High Speed Rail

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
High-Speed Rail	1	0	0	0

Overview

This measure supports implementation of plans to construct and operate a High Speed Rail (HSR) between Northern and Southern California. Development of HSR presents a significant opportunity to reduce GHG emissions by offering more GHG efficient travel options and alternatives to business as usual.

[12] Staff estimates the LCFS will reduce passenger vehicle GHG emissions by approximately 10 $MMTCO_2E$ in 2020. The passenger vehicle only GHG emissions reduction of 10 $MMTCO_2E$ is approximately 2/3 of total LCFS GHG emissions reduction of 16.5 $MMTCO_2E$ in 2020.

Assumptions for GHG Reduction

Staff analysis of estimated net CO_2 emission reductions are based on the HSR operating a Phase 1 system between San Francisco and Anaheim for 2020. Cambridge Energetics forecasts 61.5 million annual passengers (MAP) ridership for this system in 2030. For planning purposes, staff assumes that in 2020 ridership is 40% of this amount, or 24.6 MAP and that operating the HST will require 50% of the energy that it will use in 2030.

Staff assumes the ridership will include 17% from air passengers, 76% from motor vehicle passengers, and 7% from conventional rail and induced trips.[13]

- Air passenger displacement from HSR ridership: Air passengers would number about 4.2 MAP with an associated reduction of 0.33 $MMTCO_2E$ based on 350 air miles per passenger trip and 0.5 pounds CO_2 per air passenger mile.
- Motor vehicle passenger displacement from HSR ridership: Motor vehicle passengers would number about 18.7 MAP resulting in CO_2 emission reduction of 1.28 $MMTCO_2E$ based on 225 miles per average motor vehicle trip, 1.5 average occupants per vehicle trip, 22 miles per gallon, and 8.94kgCO_2E/gallon of gasoline.
- Riders from other modes would total 1.7 MAP and would displace about 0.04 $MMTCO_2E$, assuming trips in these modes use about 1/3rd the energy per passenger - mile compared to motor vehicle trips.
- The total emissions reduction is the sum of benefits equaling1.65 $MMTCO_2E$ per year (0.33 + 1.28 + 0.04).
- A preliminary estimate of total electric energy to operate the HST in Phase 1 in 2030 is 2.3 million megawatt-hours per year. Staff estimates the electricity required in 2020 would be about 50% of this amount, or 1.15 million MWh.
- Using the 2020 emission factor of 4.37×10^{-7} $MMTCO_2E$/MWh, the energy to operate the HST would be about 0.5 $MMTCO_2E$. Thus, the net benefit for the Phase 1 HST would be about 1.15 $MMTCO_2E$ (1.65 – 0.50).
- Net reduction for HSR is rounded to 1 $MMTCO_2E$.

Assumptions for Costs and Savings

Costs of the measure are the result of existing state policy direction and therefore are not attributed to the AB 32 GHG emissions reduction program.

Transportation Measures Under Evaluation

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Feebates for New Vehicles	4	594	1,642	-1,048$^{\Delta}$

Overview

This measure under evaluation would establish a Feebate regulation to reduce passenger vehicle GHG emissions. A Feebate regulation would combine a rebate program for low

[13] http://www.cahighspeedrail.ca.gov/images/chsr/20080128135423_R9a_Report.pdf

emitting vehicles with a fee program for high emitting vehicles. The regulation would include a fee or rebate of $15-20/gram CO2/mile in relation to a yet undetermined standard.

Assumptions for GHG Reduction

ARB estimates that a fee and rebate schedule of $15-20/gram CO2/mile would result in a fleet mix in 2020 that is about 3% more efficient than what would result from Pavley regulations alone. The GHG reduction is estimated through the fuel savings, using 14.46 billion as the value for gallons of gasoline consumed in 2020 after factoring in the Pavley regulations.

GHG Reduction Calculation	
BAU gasoline use	17,975 million gallons
Gasoline use reduced by Pavley regulations	3,546 million gallons
Estimated gasoline consumption after Pavley regulations	14,430 million gallons
Additional light-duty fleet efficiency from Feebate regulation	3%
Estimated fuel savings from Feebate regulation	447 million gallons
Emission factor for 2020 gasoline combustion	0.00894 $MMTCO_2E$/MG
GHG reduction from Feebate regulation (EF x fuel use)	4 $MMTCO_2E$

Assumptions for Costs and Savings

Under ARB's current vision the fee and rebate schedules would be engineered to be revenue neutral after accounting for administrative expenses. That is, there are no net costs associated with program administration. The annualized cost of $594 million is calculated based on the same assumption as Pavley 2, above. Savings is calculated based on reduced fuel consumption of 447 million gallons of fuel, multiplied by $3.673/gallon of gasoline.

$$447\,Million\_gallons\_gasoline \times \frac{\$3.673}{gallon\_gasoline} = \$1{,}642M$$

Electricity and Natural Gas

General Assumptions

Measures in the Draft Scoping Plan to reduce electricity and natural gas use are developed based on reducing an amount of energy use and calculating the reduction of GHG emission using an emission factor.

For electricity, measures are assumed to replace in-state natural gas electricity generation. This emission factor is 4.37×10^{-7} $MMTCO_2E$/MWh (963 $lbsCO_2E$/MWh).

For natural gas combustion, the emission factor is 5.3156×10^{-8} $MMTCO_2E$/MMBTU for Commercial and Residential combustion and 5.3072×10^{-8} $MMTCO_2E$/MMBTU for Industrial and Electric Power use. All conversion constants are 2020 values.

The calculation of cost and savings rely on $7.94/MMBTU ($0.80/therm) for natural gas, $113.12/MWh for solar electricity generation and an average cost of $86.09/MWh for other electricity generation. When appropriate, ARB assumed a 7.8% line loss associated with in-state electricity transmission. The benefits from reduced line loss are pointed out in the specific measures below.

Note that in the development of measures for the Draft Scoping Plan, a natural gas combustion emission factor of 5.2082×10^{-8} $MMTCO_2$/MMBTU was used. This emission factor results in a modest difference in the calculated reduction because it only accounts for CO_2 and not total equivalent GHG reductions (i.e. not CO_2E).

Measure E-1 and CR-1—Energy Efficiency and Conservation

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Electricity Energy Efficiency (32,000GWh)	15.2	3,294	4,904	-1,610$^{\Delta}$
Natural Gas Energy Efficiency (800 million therms)	4.3$^{\Delta}$	910	1,355	-445$^{\Delta}$
Measures Under Evaluation				
Additional Electricity Efficiency (up to additional 8000GWh)	Up to 4	1,235	1,226	9$^{\Delta}$
Additional Natural Gas Efficiency (up to additional 200 million therms)	Up to 1	358	355	3$^{\Delta}$

Overview

This measure would reduce GHG emissions by increasing statewide energy efficiency for electricity and natural gas beyond current demand projections.

Assumptions for GHG Reduction

For measure E-1, a target of 32,000 GWh reduced demand is assumed. The benefit from reduced line loss (2,707 GWh) is also included.

$$32{,}000GWh + 2707GWh = 34{,}707GWh$$

$$34{,}707{,}000MWh \times 4.37 \times 10^{-7} MMT / MWh = 15.2MMTCO_2E$$

For measure CR-1 a target of 800 million therms reduced consumption is assumed.

$$800{,}000{,}000therms \times {}^{1MMBTU}\!/\!_{10therm} = 80{,}000{,}000MMBTU$$

$$80{,}000{,}000MMBTU \times 5.3156 \times 10^{-8} MMTCO_2E / MMBTU = 4.3MMTCO_2E$$

Likewise, for additional efficiency of 8,000GWh reduced electrical demand and 200 million therms reduced natural gas consumption staff calculates 3.8 $MMTCO_2E$ and 1.1 $MMTCO_2E$, respectively.

$$8{,}000GWh + 677GWh = 8{,}677GWh$$

$$8{,}677{,}000MWh * 4.37 \times 10^{-7} MMT / MWh = 3.8MMTCO_2E$$

$$200{,}000{,}000therms \times {}^{1MMBTU}\!/\!_{10therm} = 20{,}000{,}000MMBTU$$

$$20{,}000{,}000MMBTU \times 5.3156 \times 10^{-8} MMTCO_2E / MMBTU = 1.1MMTCO_2E$$

Assumptions for Costs and Savings

Staff estimated the cost and savings from energy efficiency using the Climate Action Team Updated Macroeconomic Analyses Final Report.[14] Costs of $217 per ton and savings of $323 per ton of CO2E reduced as derived from the CAT report are used to calculate the net annualized cost for both electricity and natural gas efficiency.

[14] The Climate Action Team Updated Macroeconomic Analysis of Climate Strategies for combined electricity and natural gas energy efficiency is found in Exhibit 11 on page 24 of: http://www.climatechange.ca.gov/events/2007-09-14_workshop/final_report/2007-10-15_MACROECONOMIC_ANALYSIS.PDF. Note that the cost and savings are in 2006$ from the CAT report.

Measure	GHG Reduction	Cost (at $217/MTCO$_2$E) $Millions	Savings (at $323/MTCO$_2$E) $Millions
E-1	15.2	3,294	4,904
CR-1	4.3	910	1,355
Additional Efficiency*			
Measure	**GHG Reduction**	**Cost (at $325/MTCO$_2$E) $Millions**	**Savings (at $323/MTCO$_2$E) $Millions**
+8000GWh	3.8	1,235	1,226
+200M therms	1.1	358	355

*Costs for additional efficiency are assumed at 50% greater than the cost for the recommended measure. Savings for additional efficiency are assumed to be equivalent to the recommended measure.

The net cost and savings per MTCO$_2$E are derived from the average cost and savings in the CAT Macroeconomics report for building and appliance standards and IOU efficiency programs. Staff estimates the cost for additional efficiency under evaluation is 50% greater than the cost for the preliminarily recommended efficiency measures (i.e. $217/MT x 1.5 = $325/MT).

Energy Efficiency Cost and Savings from the CAT-Macroeconomics Update Final Report

Reduction Strategy	GHG Reduction MMTCO$_2$E	Cost (2006$)	Savings (2006$)	Cost per MTCO$_2$E	Savings per MTCO$_2$E
Building Standards	2.14	$255M	$658M	$119.16	$307.48
Appliance Standards	4.48	$509M	$1,489M	$113.62	$332.37
IOU Energy Efficiency Programs	3.66	$987M	$1,186M	$269.67	$324.04
Additional IOU Energy Efficiency programs	5.60	$1,690M	$1,790M	$301.79	$319.64
Total	15.88	$3,441M	$5,123M	**$216.69**	**$322.61**

Measure CR-2—Solar Water Heating

GHG Reduction Measure	Potential 2020 Reductions MMTCO$_2$E	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Solar Water Heating (AB 1470 goal)	0.1	0	0	0^{Δ}
Measures Under Evaluation				
Expanded Solar Water Heating	Up to 1	452	160	292

Overview

This measure would reduce natural gas use for commercial and residential water heating by installing 200,000 solar water heaters by 2020 per AB 1470 (Huffman). A reduction in GHG emissions of 0.1 $MMTCO_2E$ is calculated. Solar heating is an alternative, zero emission, energy source to heat residential water that works with traditional water heating to replace a portion of the natural gas that would normally be burned. The recommended measure would replace an estimated 26 million therms of residential natural gas use each year. ARB is also considering expansion of the measure to reach 1.75 million total installed units by 2020, which would replace approximately 200 million therms of natural gas.

Assumptions for GHG Reduction

Each solar water heater is assumed to reduce annual natural gas use by 130 therms[15]. In early years of the program, Staff estimates that 5,000 heaters will be installed annually, increasing up to 10,000, 15,000, 25,000 and finally 50,000 installations each year to meet the total 200,000 installed solar water heaters goal.

$$130 \, therms / heater \times 200{,}000 \, heaters = 26{,}000{,}000 \, therms$$

$$26{,}000{,}000 \, therms \times {}^{1MMBTU}\!/_{10 \, therm} = 2{,}600{,}000 \, MMBTU$$

$$2{,}600{,}000 \, MMBTU \times 5.3156 \times 10^{-8} \, MMTCO_2E / MMBTU = 0.14 \, MMTCO_2E$$

For the expanded solar water heating measure under consideration, Staff calculated a GHG reduction based on a total of 1.75 million installed units (i.e. an additional 1,550,000 units).

$$130 \, therms / heater \times 1{,}550{,}000 \, heaters = 201{,}500{,}000 \, therms$$

$$201{,}500{,}000 \, therms \times {}^{1MMBTU}\!/_{10 \, therm} = 20{,}150{,}000 \, MMBTU$$

$$20{,}150{,}000 \, MMBTU \times 5.3156 \times 10^{-8} \, MMTCO_2E / MMBTU = 1.1 \, MMTCO_2E$$

Assumptions for Costs and Savings

Costs of the recommended solar water heating measure are the result of existing state policies (AB 1470) and therefore are not attributed to the AB 32 GHG emissions reduction program.

For the expanded solar water heating measure under evaluation, costs are assumed to be $6,500/system for existing homes and $3,000/system for new. Staff assumed a split of 57% new installs and 43% existing building retrofits for cost calculation. Further, Staff estimates a 2% reduction in technology cost annually occurs. Savings of $160 million is the result of reduced natural gas consumption of over 200 million therms at $0.80/therm in 2020.

[15] Personal communication, California Center for Sustainable Energy from implementing the CPUC's pilot project.

1.75 Million total units installed (additional 1.55 million to CR-2)			
Year	**Cumulative # SWH Installations (net of CR-2)**	**Annual Capital Cost* (net of CR-2)**	**Therms saved/yr (net of CR-2)**
2010	0	$0 M	M
2011	19,000	$55 M	2 M
2012	68,000	$177 M	9 M
2013	149,000	$293 M	19 M
2014	260,000	$405 M	34 M
2015	404,000	$513 M	52 M
2016	584,000	$676 M	76 M
2017	797,000	$804 M	104 M
2018	1,037,000	$899 M	135 M
2019	1,287,000	$903 M	167 M
2020	1,550,000	$911 M	202 M
Total	**1,550,000**	**$5,636 M**	**202 M**

*Assume ~20% of cost is covered through incentives & the rest is borne by consumers

Cost and Savings Calculation	
Cumulative capital cost	$5,636M
Estimated Lifetime	20 years
CRF (20 year amortization and 5% discount rate)	0.080242587
Annualized capital cost in 2020 (CRF x total capital cost)	$452M
Natural gas savings	201.5M therms
Value of natural gas saved in 2020 (@ $0.80/therm)	$160M
Net annualized cost (cost-savings)	$292M

Measure E-2—Combined Heat and Power Distributed Electrical Generation

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Combined Heat and Power	6.7^{Δ}	362	1,673	-1,311

Overview

This measure would encourage the use of efficient combined heat and power co-generation, targeting an increase in installed generation capacity of 4000MW by 2020.

Assumptions for GHG Reduction

For purposes of calculating GHG reductions, Staff estimated the electric generation potential from CHP (of the amount of electricity offset from the grid, based on an assumed 85% capacity factor), the total amount of fuel consumed onsite, and the amount of waste heat generated for useful thermal purposes (which was then used to calculate the amount of fuel not consumed to produce that amount of thermal energy). Staff estimated that 80% of the cogeneration units would be less than 5MW (i.e. small and medium CHP) and 20% greater than 5MW (i.e. large CHP)[16].

The following table details the assumptions for installations, total electricity generation, amount of natural gas used to make both electricity and heat, the amount of reduced natural gas used in the displaced original heat load, and the net fuel consumption. The total electricity saved includes the benefits of avoided line loss.

	Annual Installations (MW)		**Total Electricity Saved (GWh)**	**Annual MMTherms For Electricity & Heat**		**Annual MMTherms Displaced heating load**		**Net Fuel Consumption (MMTherms)**
Year	**<5MW**	**>5MW**		**<5MW**	**>5MW**	**<5MW**	**>5MW**	
2009	267	67	2,692	219	48	129	22	116
2010	267	67	5,384	437	97	258	44	232
2011	267	67	8,076	656	145	387	65	349
2012	267	67	10,768	875	194	516	87	465
2013	267	67	13,460	1,094	242	645	109	581
2014	267	67	16,152	1,312	291	774	131	697
2015	267	67	18,844	1,531	339	904	153	814
2016	267	67	21,536	1,750	388	1,033	175	930
2017	267	67	24,228	1,968	436	1,162	196	1,046
2018	267	67	26,920	2,187	484	1,291	218	1,162
2019	267	67	29,612	2,406	533	1,420	240	1,279
2020	267	67	32,304	2,624	581	1,549	262	1,395
***Total**	**3,200**	**800**	**32,304**	**2,624**	**581**	**1,549**	**262**	**1,395**
	4,000 MW total			**3,206**		**1,811**		

The net GHG reduction is calculated as the difference between the GHG emissions from the grid displaced electricity (32,304GWh including the avoided line loss) and the GHG emissions from natural gas combusted to produce both heat and power onsite.

<u>Net Natural gas GHG emission increase:</u>

$$139{,}500{,}000 MMBTU \times 5.3072 \times 10^{-8} MMTCO_2E / MMBTU = 7.41 MMTCO_2E$$

<u>Grid supplied electricity GHG emission decrease:</u>

$$32{,}300{,}000 MWh * 4.37 \times 10^{-7} MMT / MWh = 14.1 MMTCO_2E$$

<u>Net GHG Reduction:</u>

$$14.1 MMTCO_2E - 7.4 MMTCO_2E = 6.7 MMTCO_2E$$

[16] California Energy Commission, Draft Consultant Report, <u>Assessment of California CHP Market and Policy Options for Increased Penetration</u>. Prepared by the Electric Power Research Institute. April 2005.

Assumptions for Costs and Savings

The installed costs for CHP were estimated by averaging costs for several <5MW turbines ($1,300/kW for small CHP) and calculating the cost of one 40MW turbine ($1,750/kW for large CHP).

	Annual Installations (MW)		Annual Installed Costs (millions $)**	
Year	**<5 MW**	**>5 MW**	**<5 MW @ $1,300/kW**	**>5 MW @ $1,750/kW**
2009	267	67	347	117
2010	267	67	347	117
2011	267	67	347	117
2012	267	67	347	117
2013	267	67	347	117
2014	267	67	347	117
2015	267	67	347	117
2016	267	67	347	117
2017	267	67	347	117
2018	267	67	347	117
2019	267	67	347	117
2020	267	67	347	117
*Total	3,200	800	4,164	1,404
	4,000		5,568	

Cost Calculation	
Capital cost	$5568M
30-year CRF at 5% discount	0.06505
Annualized capital cost in 2020 based on 30 year life	$361M
Savings Calculation	
Electricity savings 2020	32,304GWh
Value of electricity savings 2020 (@ $86.09/MWh)	$2,781M
Natural gas consumed for CHP 2020	1,395 million therms
Cost of natural gas consumed for CHP 2020 (@ $0.80/therm)	$1,108M
Net energy savings	$1,673
Net annualized cost (cost-savings)	-$1,311

Measure E-3—33% Renewables Portfolio Standard

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
33% Renewables Portfolio Standard	21.3$^{\Delta}$	3,671	1,889	1,782$^{\Delta}$

Overview

This measure would increase electricity production from eligible renewable power sources to 33% by 2020. A reduction in GHG emissions results from replacing natural gas fired electricity production with zero GHG emitting renewable sources of power.

Assumptions for GHG Reduction

The Renewables Portfolio Standard measure would require 33% of RPS eligible retail electricity sales to be generated from eligible renewable sources. Measures that reduce retails sales of electricity, i.e. efficiency, co-generation, and other distributed generation, are subtracted from the projected demand in 2020 to calculate the amount of generation (in GWh) to meet the 33% renewables standard. The CEC electricity forecast for 2020 projects 308,070 GWh of RPS eligible retails sales. The preliminary recommendation in the Draft Scoping Plan assumes 32,000 GWh of energy efficiency gains, approximately 30,000 GWh of combined heat and power generation, and approximately 4500 GWh of solar distributed generation. There are additional benefits from reduced line loss associated with these measures, which is assumed to be 7.8% statewide.

$$308{,}070GWh(RS) - 34{,}707GWh(EE) - 32{,}304GWh(CHP) - 4{,}845GWh(Solar) = 236{,}214GWh$$
$$236{,}214GWh \times 0.33(33\%RPS) = 77{,}951GWh$$
$$77{,}951GWh - 29{,}286GWh(Current\_RPS) = 48{,}665GWh(RPS\_Target)$$
$$48{,}665{,}000MWh * 4.37 \times 10^{-7} MMT / MWh = 21.25MMTCO_2E$$

Where *RS* is 2020 projected retail sales, *EE* is energy efficiency and conservation plus reduced line loss benefits, *CHP* is generation from the combined heat and power measure, and *Solar* is the generation and reduced line loss benefits from the million solar roofs program. Using 4.37×10^{-4} $MMTCO_2E$/GWh gives an emissions reduction of 21.3 $MMTCO_2E$.

The emissions reduction associated with going from 20% to 33% RPS is necessary for the cost and savings calculation below. Using the approach from above Staff calculates a net GHG emissions reduction for 20-33% RPS of 13.4 $MMTCO_2E$.

$$236{,}214GWh \times 0.2(20\%RPS) = 47{,}243GWh$$
$$47{,}243GWh - 29{,}286GWh(Current\_RPS) = 17{,}957GWh$$
$$17{,}957{,}000MWh * 4.37 \times 10^{-7} MMT / MWh = 7.84MMTCO_2E$$
$$21.25MMTCO_2E - 7.84MMTCO_2E = 13.4MMTCO_2E$$

Assumptions for Costs and Savings

Cost and savings assumptions are derived from Energy and Environmental Economics, Inc.'s (E3) modeling of renewables.[17] Staff estimated costs at \$274/ $MTCO_2E$ and savings at \$141/ $MTCO_2E$ based on the E3 modeling work with a net cost of \$133/$MTCO_2E$ for a net GHG reduction going from 20-33% RPS of 13.4 $MMTCO_2E$. Costs for the GHG reduction associated with the existing 20% RPS are the result of existing State policies and therefore are not attributed to the AB 32 GHG emissions reduction program.

$$13.4\,MMTCO_2E \times \$274/MT = \$3{,}671M$$
$$13.4\,MMTCO_2E \times \$141/MT = \$1{,}889M$$

Measure E-4—Million Solar Roofs

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost (\$Millions)	Savings (\$Millions)	Net Annualized Cost (\$Millions) [Cost-Savings]
Million Solar Roofs	2.1	0	0	0
Measures Under Evaluation				
Expanded Million Solar Roofs	1.4^{Δ}	\$1,348	339	1,009

Overview

This measure follows the direction of Governor Schwarzenegger's Million Solar Roofs program to install 3000MW of photovoltaic electrical generation in residential and commercial applications by 2017. A measure under evaluation to expand this program by an additional 2000MW (for 5000MW total) by 2020 is included.

Assumptions for GHG Reduction

Staff used a capacity factor for photovoltaic solar power of 17% in calculating the displaced grid electricity from this measure. The benefit from reduced line loss (a constant 7.8%) is also included.

$$3000MW \times 8760hours/year \times 17\% = 4{,}467{,}600MWh/year + 377{,}953MWh(avoided\_line\_loss)$$
$$2000MW \times 8760hours/year \times 17\% = 2{,}978{,}400MWh/year + 251{,}969MWh(avoided\_line\_loss)$$
$$4{,}845{,}553MWh \times 4.37 \times 10^{-7}\,MMT/MWh = 2.1MMTCO_2E$$
$$3{,}230{,}369MWh \times 4.37 \times 10^{-7}\,MMT/MWh = 1.4MMTCO_2E$$

Assumptions for Costs and Savings

Costs of the E-4 measure are the result of existing state policies and therefore are not attributed to the AB 32 GHG emissions reduction program. For the expanded Million Solar Roofs measure under evaluation Staff assumes an installed cost of \$8.40/watt for an additional 2000MW by 2020.

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[17] Energy and Environmental Economics, Inc. (E3), http://www.ethree.com/GHG/E3_CPUC_GHGResults_13May08%20(2).pdf

Cost and Savings Calculation	
2000MW @ $8.40/watt	$16,800M
Estimated Lifetime	20 years
CRF (20 year amortization and 5% discount rate)	0.080242587
Annualized capital cost in 2020 (CRF x total capital cost)	$1,348M
Electricity produced at 17% capacity factor (savings) 2020	3,000,000MWh
Value of electricity produced in 2020 (@ $113/MWh)	$339M savings
Net annualized cost (cost-savings)	$1009M

Other Energy Measures Under Evaluation

Coal Emission Reduction Standard

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Coal Emission Reduction Standard	Up to 8	850	0	850

Overview

This measure under evaluation would reduce GHG emissions by replacing coal-produced electricity with less carbon-intensive alternatives. To calculate GHG emissions reduction benefits, Staff assumed 40% of the existing 32,000 GWh of annual coal-produced electricity would be replaced by combined cycle gas turbine (CCGT) power by 2020. A 40% reduction results in 12,800GWh less coal generation in 2020.

Assumptions for GHG Reduction

Staff used 9.88×10^{-4} $MMTCO_2E/GWh$ for coal generation and 3.22×10^{-4} $MMTCO_2E/GWh$ for CCGT generation for a net reduction of 6.66x10-4 $MMTCO_2E/GWh$ (i.e. 9.88-3.22=6.66).

$$6.66 \times 10^{-4} MMTCO_2E / GWh \times 12{,}800 GWh = 8.5 MMTCO_2E$$

Assumptions for Costs and Savings

Staff estimated that compliance with this measure under evaluation would cost $\$100/MTCO_2E$ for a total cost of $850M. This total cost results in a net cost difference between coal and CCGT supplied electricity of $0.066/KWh for an 8.5 $MMTCO_2E$ reduction. No savings is assumed.

Industry

Measure I-1: Energy Efficiency and Co-Benefits Audit for Large Industrial Sources

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Energy-Efficiency and Co-Benefits Audit for Large Industrial Sources	TBD	TBD	TBD	TBD

Overview

This recommended measure would require an energy efficiency audit for large stationary GHG emissions sources to identify potential reductions that are cost-effective for GHG, criteria and toxics.

Assumptions for GHG Reduction

TBD

Assumptions for Costs and Savings

TBD

Industrial Measures Under Evaluation

Carbon Intensity Standard for Cement Manufacturers

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Carbon Intensity Standard for California Cement Manufacturers	1.1-2.5	19.4	22.8	-3

Overview

This measure under evaluation sets a standard of 0.8 metric tons of CO_2/metric ton of cement as the average carbon intensity factors (CIF) for cement used in California. This standard would apply to imported cement as well as cement manufactured in California. The CIF is defined as metric tons CO_2 emitted per metric ton of cement produced. CIF improvements at the cement production level are expected to be met through alternative fuels or energy efficiency measures. There is very little addition of supplementary cementious materials (SCMs) that occur at the manufacturing plants today. Therefore, the focus would be to ensure that lower carbon cement is produced by maximizing the use of alternative fuels and energy efficiency.

Assumptions for GHG Reduction

Alternative Fuels

The alternative fuel scenario is calculated based on the ARB inventory. The baseline year is 2004 for the cement production and GHG emissions from manufacturers. Staff assumed a 2% annual increase in cement production and imports are 40% of cement consumed in California. The 2004 statewide baseline numbers are as follows:

- Fuel combustion = 4.06 $MMTCO_2E$
- Calcination = 5.77 $MMTCO_2E$
- Electricity = 0.70 $MMTCO_2E$ (based on California Energy Commission emission factor and the Portland Cement Association external electricity output for 2005)
- Total CO2 emissions for California cement plants = 10.53 $MMTCO_2E$
- Clinker Production = 11.23 MMT (, 2004)
- Cement Production = 11.92 MMT (USGS, 2004)

Based on ARB's analysis of potential alternative fuel options, we believe a 5 percent reduction in greenhouse gas emissions is feasible and cost-effective.

The estimated statewide CIF based on instate cement production is 0.895 metric tons CO_2 per metric ton cement. If the 5% reduction were implemented, the CIF for each one would be 0.855.

Improved Energy Efficiency

The improved energy efficiency is based on fuel and electricity intensity scenarios of 3.0 MBtu per short ton of clinker produced and 109 kWh per ton of cement produced with 2004 and 2005 California cement industry data. Staff estimated an emission reduction of 0.93 $MMTCO_2E$ and a 0.055 $MTCO_2E$/MT of cement reduction in the CIF value. When combining the alternative fuel and improved energy efficiency CIF value, the instate CIF value would decrease to below 0.8 $MTCO_2E$/MT cement.

GHG Calculation	
California Cement Produced	11.92 MMT
Current in-state CIF	0.895
CIF with measure under evaluation	0.8

Taking into consideration the 2% growth rate reductions from BAU cement emissions would be:

$$(0.895 - 0.8)\times(11.92MMT)\times(1.02)^{16} = 0.095\times 11.92MMT\times 1.37 = 1.55MMTCO_2E$$

Assumptions for Costs and Savings

The ARB 2004 baseline shows that cement manufacturers are using over 3.60 MBtu/ton clinker. Staff believes, through improved energy efficient equipment and using less fuel, that the cement manufacturers would be able to meet a 3.0 MBtu/ton clinker. This number is stated in literature for 4 to 5-stage preheater/precalciner kilns. ARB estimates this will result in an initial capital investment of $220 million dollars with an annual fuel expenditure savings of $22.75 million.

Cost and Savings				
Year	**Capital Costs ($millions)**	**Cost Savings from Energy Efficiency - Electricity ($millions)**	**Cost Savings from Energy Efficiency – Fuel ($millions)**	**Cost Increase from Alternative Fuels ($millions)**
2012	220	11.66	17.45	11.46
2013		11.89	17.80	11.69
2014		12.13	18.16	11.93
2015		12.37	18.52	12.16
2016		12.62	18.89	12.41
2017		12.87	19.27	12.66
2018		13.13	19.65	12.91
2019		13.39	20.05	13.17
2020		13.66	20.45	13.43

Cost and Savings Calculation
Annualized Capital Expenditure:
$202.4 million*0.0802 = $16.23 million (CA cement manufacturers annualized capital cost)
$16.23 million + $1.35 million (annual operating cost) = $17.58 million (CA cement manufacturer's total annual cost)
$17.58 million*1.10 (10% of $17.58 million is the capital cost for imported cement) = $19.34 million
Annual Fuel Expenditure Savings:
$13.66 million + $20.45 million – $13.43 million = $20.68 million
$20.68 million*1.10 (10% of $20.68 million is the fuel savings for imported cement) = $22.75 million
Net Annual Savings: $3.41 million

Carbon Intensity Standard for Concrete Batch Plants

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Carbon Intensity Standard for Concrete Batch Plants	2.5-3.5	0	0	0

Overview

This measure under evaluation would require concrete batch plants to have a lower carbon intensity factor (CIF) for cementious material than the CIF required at the cement manufacturing facility. The standard would be set at 0.6 metric ton CO_2/metric ton of cementious material used. The standard at the concrete batch plant could be met either by using cement with very low carbon intensity factors, by adding materials such as SCMs to replace cement in the concrete blend, or using a combination of both approaches.

Assumptions for GHG Reduction

Concrete batch plants can double the total amount of CO_2 reductions through blending of cement compared to the cement manufacturers. The scenario for the concrete batch plants is to blend SCMs in Portland cement to equal at least 15% or more of blended cement and meet a 0.66 CIF standard by 2012. In 2015, the cement that is used to manufacture concrete must meet a 25% blend of SCMs and comply with a 0.6 CIF standard.

The CIF standard for cement used by concrete batch plants in 2012 through 2014 would comply with 0.66 MT CO_2/MT cement. By 2015, the CIF for cement would be 0.6 $MTCO_2$/ MT cementious material. The calculation for GHG reductions in 2020 is below.

GHG calculation assumptions:

- California Cement Produced: 11.92 MMT
- CIF Factor Under Manufacturer Regulations: 0.8
- CIF Under Batch Plant Regulations: 0.6

Taking into consideration the 2% growth rate reductions from BAU cement emissions would be:

$$(0.8-0.6)\times(11.92MMT)\times(1.02)^{16} = 0.2\times 11.92MMT\times 1.37 = 3.27MMTCO_2E$$

Assumptions for Costs and Savings

Currently, the cost of a ton of SCMs is approximately the same as the cost of a ton of cement (about $100/ton). Therefore Staff estimates there is no net cost or savings for this measure.

Waste Reduction in Concrete Use

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Waste Reduction in Concrete Use	0.5-1.0	55	83	-28

Overview

This measure under evaluation would set a minimum waste requirement or establish emissions fees on unused returned concrete.

Assumptions for GHG Reduction

ARB estimates that approximately five to eight percent of the concrete that is made in California each year is returned to the plant as waste. Given cement is the main source of GHG emissions in concrete, a reduction opportunity over 1 MMTCO2E exists by 2020.

GHG calculation assumptions:

- Total Cement: 11.92 MMT
- Wasted Cement: (0.08)(11.92)= 0.954 MMT
- Current CIF: 0.895 $MTCO_2$/MT cement
- 2% Annual Growth Rate

$$0.08 \times 11.92 MMT \times 1.02^{16} \times 0.895 = 1.17 MMTCO_2 E$$

Assumptions for Costs and Savings

ARB assumes $100 as an average cost per ton of cement and an added operational cost of $70 per ton of wasted cement to achieve maximum efficiency. This results in a net cost savings of $30/ton of cement and an annual savings of $28 million.

Cost and Savings Calculation	
Wasted Cement	0.954MMT
Net savings per MT ($100-$70=$30)	$30
Annual savings	$28M

Refinery Energy Efficiency Process Improvements

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Refinery Energy Efficiency Process Improvements	2-5	71	461	-390$^{\Delta}$

Overview

This measure under evaluation would reduce GHG emissions from refineries by reducing fossil fuels consumption across a variety of refinery processes including process heaters, boilers, fluid catalytic crackers, hydrogen plants, and flares.

Assumptions for GHG Reduction

Measure	Description	Number of Units Affected	Estimated Capital Cost ($million)	Existing Emissions (MMT CO2E)	Emissions Reduction (MMT CO2E)	Percent Emissions Reduction
1.Improve Efficiency of Boilers and Process Heaters	Improve efficiency of half of total units by 15%	300 of 600	272	14.8	1.0	6.8
2.Install FCC Power Recovery Turbine	Capture mechanical work from FCC regenerator flue gas	3 of 10	21	6.11*	0.47	7.7
3.Improve Catalyst Type at FCC	Reduce carbon buildup on catalyst	4 of 10	11	* included above	0.82	13
4.Modernize Hydrogen Plants	Use pressure swing adsorption technology	Reduce H_2 plant emissions by 20% overall	387	5.8	1.1	19
5.Increase Gas Recovery Capacity at Flares	Install additional compressors in flare systems	Flare systems at 19 refineries	71	0.67	0.33	50
Totals			**762**	**27.4**	**3.7**	**14**[18]

Notes:

1. Improve efficiency of 300 boilers and process heaters from 73 percent to 88 percent (fuel savings)
2. Valero refinery in Houston uses pressure drop of regenerator gas to drive turbine and recover mechanical power to compress regenerator inlet air, saving 22MW of energy otherwise needed for this compression (assume fuel savings)
3. Less carbon buildup on catalyst means less combustion to remove it (fuel savings)
4. Pressure swing adsorption requires 20 percent less energy than amine systems per cubic foot of hydrogen produced (fuel savings)
5. Measure entails providing adequate gas recovery capacity and best operating practices (fuel recovery savings)

[18] Total refinery GHG emissions are estimated at 35.2 MMT CO_2 E. Therefore, overall estimated refinery emissions reductions represent 11 percent of that total.

Assumptions for Costs and Savings

Cost and Savings Calculation	
Capital cost 2020	$762M
Capital life	20 years
20-year CRF (@5% discount rate)	0.08024
Annual cost 2020 (Capital cost x CRF)	$61M
2020 operational costs	$10M
total annual cost 2020	$71M
Natural gas savings	56,900,000 MMBTU
2020 value of fuel savings (@ $7.94/MMBTU)	$452M
Operational savings	$9M
Total savings	$461M
Net annualized cost (cost-savings)	-$390M

Removal of Methane Exemption from Existing Refinery Regulations

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Removal of Methane Exemption from Existing Refinery Regulations	0.01-0.05	5	2.7	2^{Δ}

Overview

This measure under evaluation would remove the methane exemptions from the regulations applicable to equipment and sources employed in California's refineries.

Assumptions for GHG Reduction

ARB relied on the analysis performed by South Coast Air Quality Management District (SCAQMD) for the adoption of their Rule 1173, Control of Volatile Organic Compound Leaks and Releases from Components at Petroleum Facilities and Chemical Plants. ARB staff assumed that exempt hydrocarbons, assumed to be methane, could be reduced by a similar 80 percent if the equipment associated with the processing and piping of the methane-rich streams were subject to the leak detection and repair requirements of the rule. Staff also applied this factor to two refineries located in the San Joaquin Valley Unified Air Pollution Control District. The Bay Area Air Quality Management District rule for leak detection and repair already included methane.

Assumptions for Costs and Savings

ARB staff used the cost estimates provided by the SCAQMD analysis for Rule 1173, updated the labor costs, estimated that an additional five percent of valves, compressors, and connections would be inspected and repaired, and applied these factors to the SCAQMD and SJVAPCD.

Cost and Savings Calculation	
Operational cost in 2020	$5M
2020 Savings	$2.7M
Net annualized cost (cost-savings)	$2M

Oil and Gas Extraction GHG Emission Reduction

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Oil and Gas Extraction GHG Emission Reduction	1-3	107	274	-167[Δ]

Overview

This measure under evaluation would address GHG emissions from the extraction of California's large oil and gas industry, including on and off-shore sources. Extraction-related GHG emissions come primarily from combustion (95%) and secondarily from fugitive sources. These emissions are produced mainly from the combustion of natural gas in generators, boilers, pumps and other related equipment. This measure would include: repowering, retrofitting, replacing or repairing existing equipment; installing new combined heat and power; electrifying equipment; using monitoring equipment to detect leaks; and possibly employing CO_2 injection to enhance oil recovery.

Assumptions for GHG Reduction

Replacement and retrofitting of boilers and steam generators with more efficient ones, as well as replacing internal combustion engine (ICE) pumps with electric motors, achieves an estimated 1.8 $MMTCO_2E$ reduction. The remaining 0.2 $MMTCO_2E$ reduction comes from a limited amount of changing operating practices while taking compressors off-line; installing compressor rod packing systems; replacing high-bleed pneumatics with low-bleed pneumatics; improved leak detection; and installing electronic flare ignition devices. These estimations will be refined as a more robust emission inventory is developed via an industry-wide survey and the control approaches of the measure identified.

Assumptions for Costs and Savings

Cost and Savings Calculation	
Capital cost	$357M
Estimated capital lifetime	20 years
20-year Capital Recovery Factor	0.08024
Annualized Capital cost 2020	$28.6M
Operating cost in 2020	$23.3M
Non-energy cost savings in 2020	$8.8
Electricity use	637,000 MWh
Value of electric use in 2020 (@ $86/MWh)	$55M
Natural gas reduction	33,400,000 MMBTU
Value of Natural Gas Savings (@ $7.94/MMBTU)	$265M
Total 2020 cost	$106.9M
Total 2020 savings	$274M
Net annualized cost (cost-savings)	-$167M

GHG Leak Reduction from Oil and Gas Transmission

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
GHG Leak Reduction from Oil and Gas Transmission	0.5-1.5	19	34.2	-15

Overview

This measure under evaluation addresses emissions from the transmission and distribution of natural gas throughout California. This measure would included: replacing older equipment (flanges, valves and fittings); substituting high bleed with low bleed pneumatic devices; installing vapor recovery devices; using emission monitoring equipment to detect leaks; installing more energy efficient equipment; switching to low carbon fuels to run the equipment; and improving practices for inspection and management.

Assumptions for GHG Reduction

Changing operating practices while taking compressors off-line achieves almost all of the estimated 0.9 $MMTCO_2E$ emissions reduction. Replacing just a handful of ICE pumps and compressors with electric motors achieves the remaining 0.1 $MMTCO_2E$ emissions reduction. These estimations will be refined as a more robust emission inventory is developed via an industry-wide survey and the control approaches of the measure identified

Assumptions for Costs and Savings

Cost and Savings Calculation	
Capital cost 2015	$28M
Lifetime	5 years
5-year Capital Recovery Factor	0.2310
Annualized capital cost 2020	$6.6M
Electricity cost	138,000 MWh
Value of electricity cost in 2020 (@$86/MWh)	$12M
Natural gas reduction	4,130,000 MMBTU
Value of natural gas savings (@ $7.94/MMBTU)	$33M
Operating cost 2020	$0.54M
Non-energy cost savings in 2020	$1.2M
Total 2020 cost	$19.0M
Total 2020 savings	$34.2M
Net annualized cost (cost-savings)	-$15

Industrial Boiler Efficiency

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Industrial Boiler Efficiency	0.5-1.5	22.9	150	-127

Overview

This measure under evaluation would require one or more of the following: annual tuning of all boilers, the installation of an oxygen trim system, and/or a non-condensing economizer to maximize boiler efficiency. A source could also replace an existing boiler with a new one that is equipped with these systems.

Assumptions for GHG Reduction

Assumptions:

- Estimated annual emissions based on draft Greenhouse Gas Inventory Forecast Estimates (February 6, 2008) 2020 projected emissions from natural gas: 24.19 $MMTCO_2E$
- Boiler efficiency measure applies to approximately 80% of the universe due to this natural gas usage
- Boiler Efficiency Measure accomplishes a 5% reduction in GHG emissions

$$(0.80)(24.19\ MMTCO_2E)(0.05) = 1.0\ MMTCO_2E \text{ reduction annually}$$

The Boiler Efficiency Measure requires the efficiency improvements summarized in the table below. Costs were estimated by determining the cost of each requirement and the approximate number of boilers that would need each type of the two retrofits or tuning.

Summary of Measure Requirements	
Applicability	Requirement
All permitted boilers	Annual tuning
Boilers rated at or over 10 MMBtu/hr	Retrofit with an oxygen trim system including parallel positioning and VFD
Boilers rated at or over 50 MMBtu/hr	Retrofit with a non-condensing economizer

Assumptions for Costs and Savings

- Total Capital Cost ($90,390,000)
  - The capital cost is derived from the cost of purchasing and installing equipment retrofits required by the measure multiplied by the approximate total number of installations. The total number of installations was estimated using engineering judgment, data from ARB's CEIDARS database, air district databases, and from information supplied by an industry sales representative and representatives of a consulting firm that administers a commercial and industrial boiler efficiency program.
- Annual Tuning requirement
  - Capital cost = $0.
- Retrofit of 10 MMBtu/hr boilers with oxygen trim, parallel positioning, VFD
- Equipment costs for retrofit assuming 600 boilers rated at or over 10 MMBtu/hr with oxygen trim, parallel positioning, and VFD ($96,000 per unit) = $57,600,000
- Note: Assumed 60% (600) of the 1000 boilers in CEIDARS inventory are not already equipped with oxygen trim, parallel positioning, and VFD and need the retrofit.
- Capital costs for retrofit of 105 boilers rated at or over 50 MMBtu/hr with a non-condensing economizer ($200,000 per unit) = $21,000,000
- Assumed 60% (105) of the 175 boilers in the State are not already equipped with a non-condensing economizer and need the retrofit. South Coast database shows there are 70 boilers in the District over 50 MMBtu/hr.
- Assuming South Coast has 40 percent of the inventory in the State, the total number of boilers over 50 MMBtu/hr in California is 70/0.4 = 175 boilers.
- Capital costs: $78,600,000
- Total installation costs (15 percent of capital costs) = $11,790,000
- Total capital and installation costs for boiler retrofits = $90,390,000
- Annual operating cost ($15,610,000)
- Annual maintenance costs for boiler retrofits (assumed to be 10 percent of capital costs) = $7,860,000
- Annual tuning costs for 3100 boilers ($2500 per unit) = $7,750,000
- Note: all the costs for the tuning requirement are considered to be an annual maintenance cost. The 2004 CEIDARS NO_x inventory showed approximately 3100 permitted natural gas boilers.
- Total annual operating costs (annual maintenance costs and annual tuning costs) = $15,610,000
- Lifetime Expenditures 2016 through 2020 ($168,440,000)
- $90,390,000 + (5 years)($15,610,000) = $168,440,000

- Cost Savings ($149,640,000)
- (There will also be an unknown electricity savings from the VFD.)
  - 1 $MMTCO_2E$)(10^6 metric ton/MMT)/(0.05306 metric tons CO_2/MMBtu) = 18,846,588 MMBtu natural gas annual savings
- Annual fuel cost savings ($7.94/MMBtu)(18,846,588 MMBtu) = $149,641,908
- Lifetime Cost Savings 2016 through 2020
- (5 years)($149,641,908) = $748,209,543

Summary Cost and Savings Calculation	
Total capital cost	$90.4M
Operating cost 2020	$16M
Estimated capital life	20 years
20-year CRF	0.08024
Annualized capital cost (capital x CRF)	$7.25M
Total cost in 2020	$22.86M
Natural gas savings	18,846,588 MMBTU
Value of Natural Gas Savings in 2020 (@ $7.94/MMBTU)	$149.7M
Net annualized cost (cost-savings)	-$127M

Stationary Internal Combustion Engine Electrification

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Stationary Internal Combustion Engine Electrification	0.1-0.5$^{\Delta}$	17.9	25	-7.1$^{\Delta}$

Overview

This measure under evaluation would affect owners and operators of engines in industrial and commercial operations rates at over 50 hp and used as primary power sources (“prime” engines). This measure would not affect internal combustion (IC) engines used for emergency power generation. This measure would include the replacement of IC engines with electric motors (electrification).

Assumptions for GHG Reduction

In the Draft Scoping Plan ARB estimated the GHG emission reduction potential as approximately 0.1 to 1.0 $MMTCO_2E$. As ARB continued to evaluate this measure, it became apparent the high end of the range – 1 MMT, was unrealistic. Such a large reduction would require electrifying over two-thirds of the engines in this category by 2020. This level is not achievable due to both logistical difficulties (access to electrical service and/or required duty cycles) and high cost for engines that are not operated a high percentage of the time. To reflect this, ARB believes a more realistic range of potential reductions is 0.1 to 0.5.

Assumptions for Costs and Savings

Cost and Savings Calculation	
Total capital cost	$50.7M
Operating cost 2020	$14M
Estimated capital life	20 years
20-year CRF (@ 5% discount rate)	0.8024
Annualized capital cost (capital x CRF)	$4.1M
Total 2020 cost	$17.9M
Natural Gas Savings	7,670,600 MMBTU
Value of Natural Gas Savings in 2020 (@ $7.94/MMBTU	60.92
Diesel Savings in 2020	11.4 million gallons
Value of Diesel Savings 2020 (@ $3.685/gallon)	$41.9M
Increased electricity use in 2020	904,443 MWh
Cost of increased electricity (@ $86/MWh)	$77.9M
Net savings in fuel	25.04
Net annualized cost (cost-savings)	-$13M

Glass Plant Energy Efficiency—Equipment Efficiency and Use of Recycled Materials

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Glass Manufacturing Energy Efficiency	0.1-0.2	36.9	23.6	13[Δ]

Overview

This measure under evaluation would increase the requirement for recycled glass (cullet) content and would require facilities to use the best technology to reduce GHG emissions or adopt energy efficient operation and maintenance procedures for manufacturing glass.

Assumptions for GHG Reduction

The GHG emissions reduction was based on the industry's increase in cullet use of 10% or more and the use of other potential energy efficiency measures which would result in 5 to 10% energy savings.

Assumptions for Costs and Savings

Cost and Savings Calculation	
Total capital cost	$15M
Estimated capital life	10 years
10-year CRF	0.1295
Annualized capital cost (capital x CRF)	$1.94M
2020 operating cost	$35M
2020 total annualized cost	$36.94M
Natural gas savings	281700 MMBTU
Value of natural gas savings (at $7.94/MMBTU)	$2.24M
Electricity savings	5979 MWh
Value of electricity savings (at $86/MWh)	$0.5M
Operational cost saving as a result of material	$20.8M
Total savings	$23.6M
Net annualized cost (cost-savings)	$13M

Off-Road Equipment

GHG Reduction Measure	Potential 2020 Reductions MMTCO$_2$E	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Off-road Equipment	Up to 0.5	TBD	TBD	TBD

Overview

This measure targets a number of efficiency improvements in offroad equipment including solar-reflective paint and window glazing, reduced idling emissions, equipment electrification, and low friction engine oil. Staff is evaluating the potential GHG reductions and cost and savings from this measure.

Assumptions for GHG Reduction

TBD

Assumptions for Costs and Savings

TBD

Recycling and Waste

Landfill Methane Capture

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Landfill Methane Capture (Discrete Early Action)	1	52[19]	0	52

Overview

This measure would reduce methane emissions from municipal solid waste landfills by requiring owners and operators to install gas collection and control systems at smaller and other uncontrolled landfills. Additionally, all affected landfills will be required to satisfy enhanced methane monitoring requirements to ensure that their gas collection and control system is operating optimally and that fugitive emissions are minimized.

Assumptions for GHG Reduction

Staff estimates 0.8 $MMTCO_2E$ GHG emissions reduction from the approximately 53 landfills having greater than 450,000 tons of waste-in-place that may generate sufficient gas to support the installation of a gas collection and control system with a flare. Staff estimated an additional 0.2 $MMTCO_2E$ GHG emissions reduction from enhanced monitoring requirements to ensure that the landfill's gas collection and control system is operating optimally and that fugitive emissions are minimized. The total estimated reduction is 0.8+0.2 = 1 $MMTCO_2E$.

Assumptions for Costs and Savings

Staff estimated a capital cost of $3,438,000 and annual operating cost of $706,397 for the aforementioned 53 facilities. The lifetime of the gas collection and control systems is estimated at 15 years. The total estimated cost is approximately $1M per facility in 2020. Total industry costs, included those for landfills with existing gas collection and control systems, will be estimated in the staff report for the landfill methane control measure. The costs and emission reduction estimates presented here are preliminary estimates.

[19] In reviewing costs for the Landfill Methane Capture measure staff corrected the cost value in this documentation supplement. The cost value published in the Draft Scoping Plan Appendix of $1M is per landfill and not total.

Cost Calculation	
Capital cost	$3,438,000
Capital life	20 years
20 year CRF	0.08024
Annualized capital cost	$275,874
2020 Operating cost	$706,397
Total per facility cost	$982,271
Total cost (for 53 facilities)	$52M
Savings	$0
Net annualized cost (cost-savings)	$52M

High Global Warming Potential

Measure H-1: Motor Vehicle Air Conditioning Systems: Reduction of Refrigerant Emissions from Non-Professional Servicing (Discrete Early Action)

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Sales Restriction on Containers of Refrigerant	0.5	60	0	60$^{\Delta}$
Alternative Proposal	0.25	3	0	3

Overview

This measure reduces GHG emissions from the non-professional servicing of motor vehicle air conditioning systems by do-it-yourself individuals. The basic structure and approach of this measure is essentially the same as that originally proposed in the Early Action Plan. There are two proposals currently undergoing consideration: a sales restriction (can ban) and an alternative approach. The alternative approach would include: 1) the installation of a self-sealing dispensing valve on all small containers of refrigerant, 2) the implementation of a mandatory container recycling and refrigerant recovery program, 3) improved labeling on all containers, and 4) the implementation of a consumer education program. Since this is a Discrete Early Action, the proposed regulation would become enforceable on January 1, 2010. The table above includes two rows, corresponding to the two approaches that were considered by Staff. The Draft Scoping Plan Appendix C includes only the original estimate associated with the Staff recommendation, the Alternative Proposal. The numbers above are refinements based on the most recent information emerging from the public process.

Assumptions for GHG Reduction

The total annual emission reduction from the “Can Ban” amounts to approximately 0.47 $MMTCO_2E$ and is principally due to the prohibition of sales and the significantly reduced do-it-yourself practice in California.

The alternative approach is estimated to achieve a reduction of approximately 0.25 $MMTCO_2E$ in 2020 resulting from the recovery of the unused refrigerant in the containers and an increased consumer awareness of an optimum charging techniques arising from the improved labeling and the education program.

Assumptions for Costs and Savings

Under the "Can Ban," there would be no costs or charges imposed on the small can industry to comply with the ban, but there would be complete loss of revenues which would amount to $25 million in California. Under the small can ban, consumer costs would be affected by the difference between the cost of professional repairs and the cost of DIY recharges. The cost to consumers would increase by $74 million annually.

The industry has estimated that the installation of self-sealing valves and the implementation of the recycling program would result in a cost increase of one dollar per container. At 1.6 million cans per year the increased consumer cost is $1.6 million. Assuming a 95% can return rate and a $10 deposit per can, the 5% of unclaimed deposits amounts to $0.8 million per year and will be an additional cost to the consumers. Total increased cost to the consumer is thus ~$3 million per year.

Measure H-2: SF_6 Limits in Non-Utility and Non-Semiconductor Applications (Discrete Early Action)

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
SF6 Liming in Non-Utility and Non-Semiconductor Applications (Discrete Early Action)	0.3	0.22	0.14	<0.1$^{\Delta}$

Overview

This measure reduces sulfur hexafluoride emissions from non-utility and non-semiconductor-related applications. This includes, but is not limited to, magnesium casting, tracer gas uses, and recreational uses such as magic tricks.

Assumptions for GHG Reduction

ARB estimated a range of estimates for other uses (non-semiconductor, non-utility, and non-magnesium) is 0.13 – 0.34 (ARB 2008). Alternatives are available and a phase-out is possible for magnesium casting, tracer uses, and recreational uses. A reduction is not possible for medical uses. Alternatives are 98+ percent effective for magnesium casting and range from 50-90+ percent for tracer uses (EPA 2006). Recreational uses would either be eliminated or alternatives would have a near 100% reduction (ARB 2008). Based on alternative effectiveness, reductions from magnesium would be 0.99 $MMTCO_2E$. For other applications, an effectiveness of 90% was used to estimate reductions up to 0.2 $MMTCO_2E$. In total, reductions are estimated at 0.3 $MMTCO_2E$.

Assumptions for Costs and Savings

Due to a lack of data for other sectors, ARB was only able to calculate costs for the magnesium sector. The estimate will still be reasonable since alternatives to sulfur hexafluoride are generally either less expensive per pound or per use (less alternative needed per use) and other uses in this measure do not have capital costs since they do not require significant infrastructure changes.

For the magnesium sector, there are two sets of costs associated with alternate gases: upfront and annual costs. Based on Canadian data, upfront costs could run up to $573,000, which is annualized to approximately $94,000 after conversion to 2007 dollars and annualized using a 10 year lifetime (Environment Canada, 1998). The annual costs, based on the same Canadian study, are approximately $126,000 for training.

There could be an associated cost savings since one alternative is less expensive than sulfur hexafluoride. Based on U.S. EPA, the cost savings will be $140,000 in 2007 dollars.

If a change is made in the manufacturing process for certain industries, the caster must go through a requalification process. These costs are not currently included in the analysis but could be significant.

Measure H-3: High GWP Reduction in Semiconductor Manufacturing (Discrete Early Action)

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
High GWP Reduction in Semiconductor Manufacturing (Discrete Early Action)	0.15	2.6	0	2.6^{Δ}

Overview

This measure targets a reduction in emissions of several high global warming potential gases uses in the semiconductor manufacturing industry. Reductions are expected from process optimization, alternative chemistries and abatement technologies. This measure is currently in the regulatory process.

Assumptions for GHG Reduction

The proposed measure is designed to achieve at least a 50% reduction in emissions of high GWP gases from the semiconductor manufacturing industry. ARB recently conducted an industry survey of GHG emissions from more than 100 semiconductor and related devices facilities. This bottom-up accounting revealed approximately 0.3 $MMTCO_2E$ of emissions in 2006. Staff is proposing to target an emissions reduction of 0.15.

Assumptions for Costs and Savings

The cost of the proposed measure is based on the assumption that abatement technologies are used for compliance. The $2.6 million total annualized cost estimate ($3.3 million in 2007 dollars) was derived from a June 2001 U.S. EPA report[20]. This value included the capital, operating and maintenance costs as a single figure for etch abatement systems. The annualized cost is calculated assuming $23.4 million in capital costs, a 5% discount rate, and a 9 year life for the abatement systems.

Measure H-4: Limit High GWP Use in Consumer Products (Discrete Early Action)

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Limit High GWP Use in Consumer Products (Discrete Early Action)	0.25	0.06	0.23	<0.1

Overview

The objective of this measure is to reduce the use of high GWP compounds in consumer products when alternatives are available. To achieve these reductions, consumer product formulations would need to be changed to reduce or eliminate the use of high GWP compounds.

Assumptions for GHG Reduction

The potential reductions for this measure for 2020 were estimated based on the perceived opportunities for reductions of GHG emissions from specific categories of Consumer Products. Emissions of GHG from the specific Consumer Products were determined from formal surveys of manufacturer's sales and formulation data that were conducted for the 2001, 2003 and 2006 sales years. Further, in June 2008, the Board approved a measure to reduce the GHG emissions from Pressurized Gas Dusters. This measure achieved approximately 0.20 $MMTCO_2E$ in 2020. It is anticipated that the remainder of the emission reduction goal could be achieved by adopting GHG standards for other categories of Consumer Products in future rulemakings.

Assumptions for Costs and Savings

The estimated costs attributed to this measure were based on previous consumer products regulations affecting similar categories of products from which emission reductions were anticipated to occur. Specifically, for the Pressurized Gas Dusters, it was estimated that the total costs of the regulation will be approximately $450,000 over ten years or $45,000 a

[20] U.S. EPA June 2001, U.S. High Global Warming Potential (High GWP) Emissions 1990-2010: Inventories, Projections, and Opportunities for Reductions, Chapter 6 Cost and Emission Reduction Analysis of PFC, HFC, and SF_6 Emissions from the Semiconductor Manufacturing in the United States, pg. 6-6, June 2001.

year.[21] Additional costs to manufacturers and consumers will likely occur for additional categories that are regulated for GHG emissions.

Measure H-5: High GWP Reduction from Mobile Sources

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Low GWP Refrigerants for New Motor Vehicle Air Conditioning Systems	2.5	20.86$^{\Delta}$	0	16
Air Conditioner Refrigerant Leak Test During Vehicle Smog Check	0.5		TBD	TBD
Refrigerant Recovery from Decommissioned Refrigerated Shipping Containers	<0.1		TBD	TBD
Enforcement of Federal Ban on Refrigerant Release During Servicing or Dismantling of Motor Vehicle Air Conditioning Systems	0.07 – 0.3		TBD	TBD

Low GWP Refrigerants for New Motor Vehicle Air Conditioning Systems

Overview

This measure would reduce greenhouse gas emissions by replacing high GWP refrigerants used in California's MVACs with lower GWP alternatives that also represent better lifecycle climate performance than the current refrigerant. This measure is meant to initially cover those classes of vehicles not included in the AB 1493 (Pavley) regulation: heavy duty and off-road vehicles. The principal benefit of this measure is the reduction of the GWP impact of refrigerant releases through direct and indirect emissions. The measure is fundamentally the same and as proposed in the Early Action Plan.

Assumptions for GHG Reduction

An estimate of the statewide emission inventory is under development for MVAC refrigerants in 2020. Anticipated reductions for 2020 are expected to be 0.7 $MMTCO_2E$ for light duty vehicles and 1.8 $MMTCO_2E$ for heavy duty vehicles for a total of 2.5 $MMTCO_2E$ for a universal phase out of HFC-134a in new and in-use MVACs in California. These projections were based on the current estimated annual leakage rate of R-134a for light duty vehicles and heavy duty trucks. These estimations will be refined as a more robust emission

[21] See "Initial Statement of Reasons for Proposed Amendments to the California Consumer Products Regulation, May 9, 2008. http://www.arb.ca.gov/regact/2008/cp2008/cp2008.htm.

inventory is developed and the likely replacement refrigerants are selected and the split in the market is predicted.

Assumptions for Costs and Savings

Only capital costs were considered in this cost estimate. Additional staff analysis is needed to determine operating costs, cost savings, and economic impacts. The life of potentially new air conditioning systems is expected to be the same as current systems. Capital costs for the introduction of new refrigerants in the California fleet were estimated to be on the order of $150 million by 2020 based on assumptions that changes begin to phase in around 2013. This estimate is based on a European incremental cost per vehicle of $23 to $28 (at an average exchange rate for the following mentioned year) per LDV in 2003 with a six percent annual increase in cost. The estimate includes several vehicle categories: light duty vehicles, heavy duty vehicles, and off-road vehicles. The detailed information for the intermediate years needs to be determined. Actual costs for maintenance will vary depending on the low GWP refrigerant selected. Significant additional analysis is needed to enable and improve cost and performance estimates of the various alternative technologies.

Air Conditioner Refrigerant Lead Test During Vehicle Smog Check

Overview

As originally conceived, the proposed measure may add a refrigerant leak check to the “pass” criteria for the California vehicular inspection and maintenance (I/M) program, Smog Check, for all vehicles that undergo the test. However, additional staff analysis indicates new issues associated with the technical feasibility of the measure that were not originally considered. Thus, further technical assessment is needed. If put in place, all vehicles that pass Smog Check would have motor vehicle air conditioning (MVAC) systems that either leak at or below natural leak rates (to be determined in the measure) or are empty and precluded from further use unless the identified excessive leak is repaired. Inspections of MVACs would be conducted by the Smog Check technician with a portable refrigerant “sniffer” that detects HFC leakage or other means to be determined in the measure. Protocols would be developed for the test, including use of equipment and identification of threshold values to establish repair criteria. Vehicle owners who choose not to repair a leaky MVAC can pass I/M by agreeing to have the remaining refrigerant recovered and their MVAC rendered inoperable.

Assumptions for GHG Reduction

The potential for annual reductions are thus estimated to be from 0.95 $MMTCO_2E$/year as a standalone measure, to 0.48 $MMTCO_2E$/year when considered as an addition to other measures. The estimates are preliminary; realistic values could range from one half to twice the estimates provided. The estimates are based on the following:

- The program would begin in 2011
- All vehicles will use HFC-134a (GWP=1300) in 2011.

Annual sales of R-134a refrigerant in California are assumed to be emitted into the atmosphere annually due to service losses and due to leaking vehicles. These sales are approximately 1.9 $MMTCO_2E$ per year.

To determine order of magnitude estimates, it assumed that implementation of an MVAC test and repair requirement would reduce leaks and service losses by 50% to an annual leak rate of 0.95 $MMTCO_2E$/ year. (More detailed analyses of the potential reductions are currently underway).

Refrigerant entering the state as OEM charge is not included in the emission rate; and refrigerant captured at end of life is not subtracted from the emission rate. (More detailed analyses of the potential reductions are currently underway).

Reductions obtained by implementation of this measure might overlap with reductions obtained by other MVAC related measures. To determine order of magnitude estimates, it is assumed that 50% of the MVAC direct emissions will already have been mitigated by other measures, reducing the potential reduction from 0.95 $MMTCO_2E$/year to 0.48 $MMTCO_2E$/year. (More detailed analyses of the potential reductions are currently underway).

Assumptions for Costs and Savings

Each Smog Check station would have to spend about $200~$300 for each hand-held HFC detector. This assumes the hand-held detector approach proves to be the correct approach. Station owners or technicians would have to pay up to $280 per person to train the Smog Check technicians. The initial cost to Smog Check station owners and technicians would be $2M (Instrument costs) + $4M (Training costs) = $6M. These are one time start up costs. Continuing annual costs are not considered because they are assumed to be covered by increases in the consumer price of a smog check.

Due to the increased time required by technicians to test MVAC systems, the consumer price of a Smog Check is expected to increase by an amount that has yet to be determined.

Refrigerant Recovery from Decommissioned Refrigerated Shipping Containers

Overview

The purpose of this measure is to mitigate any impacts from releases, either intended or accidental, of refrigerant from decommissioned refrigerated shipping containers. Refrigerated shipping containers may accumulate in major ports and that the refrigeration systems on these containers may leak high-GWP refrigerants such as HFC-134a. In particular, the refrigerant remaining in the decommissioned containers, the leakage from these containers, and refrigerant disposal as the containers approach end-of-life (EOL).

Assumptions for GHG Reduction

It is essential that a needs assessment be performed to get an accurate estimate the annual amount of refrigerants that are available for recovery from decommissioned refrigerated shipping containers. It has been estimated that shipping container activity could double by 2020. If it is assumed that this applies to the decommissioned refrigerated shipping containers as well, then the bank becomes 160,000 to 320,000 $MTCO_2E$ based on staff analysis. This estimate represents the upper bound for the possible reduction potential of this mitigation.

Assumptions for Costs and Savings

Very little information on costs and economic impacts is known today about this proposed measure. As part of measure development, an assessment will be performed in order to get a better understanding of the number of refrigerated shipping containers decommissioned each year, the amount of refrigerant remaining, whether there is refrigerant recovery, and the costs associated with the recovery and recycling processes for the remaining refrigerant.

Enforcement of Federal Ban on Refrigerant Release During Servicing or Dismantling of Motor Vehicle Air Conditioning Systems

Overview

An existing federal regulation (40 CFR 82.154) bans the release to the atmosphere of high-GWP refrigerant substance at the end-of-life or during equipment servicing. The current degree of compliance with 40 CFR 82.154 is poorly documented but under review. The goal of this non-regulatory strategy is improved compliance with this regulation prohibiting the venting of certain types of refrigerant, including HFCs, to the atmosphere when MVACs equipment is serviced or dismantled. Venting is avoided by recovering refrigerants with specialized equipment before dismantling or servicing. The recovered refrigerant can be re-used by the owner or transferred to re-processors approved by U.S. EPA for proper disposal.

The anticipated approach would emphasize enhanced enforcement of existing federal requirements for recovery via audits of activities and documentation. ARB will be involved in implementing the measure. The appropriate offices of the U.S. EPA, and the local air districts where dismantling activity is taking place will also participate in developing and enforcing the measure. The Department of Motor Vehicles and the Bureau of Automotive Repair will be involved because vehicle scrapping facilities are under their jurisdiction.

Assumptions for GHG Reduction

Reductions from dismantling operations could be expressed as a baseline emission rate times the fraction that is practically recoverable times a goal for fraction of vehicle dismantlers who would be prompted to comply with the federal regulation. None of these values is well known at present.

A rough approximation of the potential reductions from dismantling (as presented in the March 2006 Climate Action Team Report and usable until a better alternative is developed) is 0.1 to 0.6 $MMTCO_2E$ per year in 2010 (assuming the program will be in effect then) and 0.07 to 0.3 $MMTCO_2E$ per year in 2020.

Assumptions for Costs and Savings

Some dismantlers may not have the latest compliant hardware for recovering refrigerants or any equipment at all. Each dismantler who must purchase the equipment would have to spend approximately $3000 to $5000 per unit. The number of units needed would depend on the size of the operation (vehicle throughput). However, this would be an expense that the dismantler has so far avoided only through failure to comply with the existing federal regulation. Thus, this is not a cost burden associated with the proposed strategy.

The same statements apply to obtaining certification for technicians who use the recovery equipment, but with minimal anticipated costs. Training for the U.S. EPA's certification program is offered by various commercial schools. In addition, the Mobile Air Conditioning Society offers free training (a downloadable pamphlet) and a nominal exam fee, so the expense for operator certification should be minimal.

There are costs for storage of recovered refrigerant, record-keeping, and the operators' labor. Again, however, these are expenses already obliged by the federal regulation.

Recovered HFC may have some salvage value, but it is slight.

Measure H-6: High GWP Reduction from Stationary Sources

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
High GWP Recycling and Deposit Program	6.3	1.0	3.6	-2.6[Δ]
Specifications for Commercial and Industrial Refrigeration	4.0	1.24	0.66	1[Δ]
Foam Recovery and Destruction Program	1.0	94.8	0	95
SF_6 Leak Reduction and Recycling in Electrical Applications	0.1	0.3	0.4	-0.1
Alternative Suppressants in Fire Protection Systems	0.1	2	0.2	2
Residential Refrigeration Early Retirement Program	0.1	18.9	24.8	-6

Stationary Equipment Refrigerant Management Program

The high-GWP Stationary Equipment Refrigerant Management Program integrates two AB 32 early action measures: High-GWP Recycling and Deposit Program and Specifications for New Commercial and Industrial Refrigeration Systems. These two measures, discussed below, target different areas of the refrigerant value chain for stationary equipment. The Stationary Equipment Refrigerant Management Program approaches the challenge of high-GWP gases management in a more holistic manner integrating all sectors of the value chain.

High GWP Recycling and Deposit Program (also known as High GWP Refrigerant Tracking, Reporting, Repair, Deposit, and Recovery)

Overview

The goal of this measure is to reduce leaks of high-GWP refrigerants from stationary refrigeration and air-conditioning systems and improve service practices that maximize reclamation and recycling of refrigerant. The proposed regulatory action would include facility registration; refrigerant leak detection, monitoring, reporting, and recordkeeping; refrigerant distributor, wholesaler, and reclaimer reporting and recordkeeping; refrigerant sales restrictions to only certified technicians; and a refrigerant cylinder deposit program.

Assumptions for GHG Reduction

Business as usual emissions are based on the U.S. EPA Vintaging Model adjusted to the California population, as provided below:

Business As Usual	Non-Kyoto	Kyoto	Total
Statewide annual emission estimate: 2004	18	5.3	23.3
Statewide annual emission estimate: 2020	15.3	6.6	21.9

The determination of potential GHG emission reductions from business as usual is based on a year-by-year estimate of 1) compliance rates for leak repair and monitoring, and 2) system retrofitting or retirement. Because the refrigeration and air-conditioning industries are already regulated for ozone depleting substances (ODS), the compliance rates are assumed to be higher for these refrigerants. The range of assumptions for the compliance rates with monitoring, leak repair, and system retrofit and replacement are as follows:

- ODS compliance rates begin at 10% and increase from 5% to 15% each year to reach 100% in 2020.
- HFC compliance rates begin at 5% and increase from 5% to 20% each year to reach 100% in 2020.

The replacement rate for ODS systems is high due to the phase-out of use of ODS as a result of the Montreal Protocol.

The incremental annual emission reduction would be the estimated BAU emissions multiplied by an incremental compliance rate. Take HFC as an example, the incremental annual emission reduction in 2011 is:

5.3 $MMTCO_2E$ x 5% = 0.26 $MMTCO_2E$

The incremental annual emission reduction in 2012 is also:

5.3 $MMTCO_2E$ x 5% = 0.26 $MMTCO_2E$

The total emission reduction for 2012 would be:
0.26 $MMTCO_2E$ + 0.26 $MMTCO_2E$ = 0.52 $MMTCO_2E$
The total emission reduction for 2019 would equal the sum of the incremental annual emission reductions for years 2011 through 2019 = 5.0 $MMTCO_2E$

The incremental annual emission reduction in 2020 based on the 2020 BAU emissions is:
6.6 $MMTCO_2E$ x 20% = 1.3 $MMTCO_2E$

The total emission reduction for 2020 would be:

Total 2019 emission reductions of 5.0 $MMTCO_2E$ + 1.3 $MMTCO_2E$ =
6.3 $MMTCO_2E$

Assumptions for Costs and Savings

Labor and capital costs for monitoring and leak repair and equipment replacement vary for air-conditioning versus refrigeration equipment.

The assumptions for cost and cost savings are as follows:

Monitoring Costs	Cost per Year / Installation
General Cost for Monitoring	$100
Monitoring Equipment	$2,500

Leak Repair Costs		
	Air Conditioning	**Refrigeration**
Labor	$2,000	$3,000
Parts & Refrigerants	$500	$8,000
Replacement	$20,000	$500,000

Facility Inventory		
	Air Conditioning	**Refrigeration**
Total Number of Systems	86,000	10,000
Assumes 10,000 facilities have both air condition and refrigeration.		

Specifications for Commercial and Industrial Refrigeration

Overview

The primary analysis to estimate possible direct emissions reductions was to assume new refrigeration systems installed would use secondary loop refrigeration technology, or technologies that meet the same performance standards as secondary loop technology. Additionally, ARMINES' also reviewed the energy savings impact of technical options being applied in all installations, e.g., floating head pressure controls and closed display cases.

Assumptions for GHG Reduction

Although commercial and industrial refrigeration inventory research remains in progress, ARB's refrigeration and air-conditioning (RAC) contractor, ARMINES', preliminary work (available at: http://www.arb.ca.gov/cc/commref/armines_report_03_625.pdf) suggests that the Total Equivalent Warming Impact (TEWI) of current direct expansion refrigeration systems commonly used is 0.0307 $MMTCO_2E$ (approximately two to three times that of a secondary loop system).

Based on literature review it is assumed that 250 new commercial refrigeration systems will be installed in California in the 2012 through 2020 time period – approximately 30 per year from 2012 to 2016 and then 25 from 2017 to 2020. The potential emissions from these new stores are estimated as:

Direct Expansion (BAU)	= 250 stores * 0.0307 = 7.7 $MMTCO_2E$
Secondary Loop (Low Range)	= 250 stores * 0.0085 = 2.1 $MMTCO_2E$
Secondary Loop (High Range)	= 250 stores * 0.0126 = 3.1 $MMTCO_2E$

The range of potential emissions reductions are determined based on the difference between the total BAU emissions and the secondary loop systems, or similar technology, emissions – or 2.6 to 5.2 $MMTCO_2E$. This range is averaged and rounded resulting in the potential GHG emission reductions of 4.0 $MMTCO_2E$.

In addition to installation of secondary loop systems, ARMINES' also reviewed the energy savings impact of technical options being applied in installations of all commercial refrigeration equipment within a supermarket, e.g., floating head pressure controls and closed display cases. The preliminary estimation of energy savings is 1.6 TWh per year (1,600 GWh per year) or 30% below baseline. This energy savings impact is a component of the 4.0 $MMTCO_2E$ discussed above.

Assumptions for Costs and Savings

Based on literature review and discussions with industry stakeholders, the following assumptions were made:

The installation costs increase for a secondary loop refrigeration system is 15-20%, or around $100,000, above current DX systems. Increased costs are due to contractor unfamiliarity with new technologies; installation costs are anticipated to reduce to equal installation costs of direct expansion systems after 2016.

Operation and maintenance costs for a secondary loop refrigeration system are up to 40% lower than direct expansions systems (annual cost savings of approximately $25,400).

<u>Final Cost Estimates are determined as follows:</u>
Total Capital Cost per Year = 30 stores * $100,000 = $3,000,000
Total Cost Savings per Year = 30 stores * $25,400 = $762,000 (2012 to 2016)
Total Cost Savings per Year = 25 stores * $25,400 = $635,000 (2017 to 2020)

Foam Recovery and Destruction Program

Overview

Plastic insulating foams containing high-GWP blowing agents are used in refrigerators, freezers, building insulation, transport refrigerated units, and miscellaneous sources. When the product or material has reached the end of its useful life, the insulating foam emits high-GWP GHGs after it is shredded or broken during recycling, or disposed of in landfills. The goal of the measure is to reduce these end-of-life emissions to as close to zero as possible, by recovering waste foam prior to disposal and landfilling, and destroying the high GWP GHGs within the foam.

Assumptions for GHG Reduction

Staff estimates for GHG reductions apply a best-case scenario that virtually all potential GHG emissions from waste insulating foam can be reduced at end-of-life by recovering waste foam and destroying the GHGs within the foam before it is recycled or landfilled. Based on literature review and discussions with industry stakeholders, the following assumptions were made:

Based on the U.S. EPA Vintaging Model estimates, the estimated annual emissions in the U.S. in 2006 from insulating foam were 71.4 $MMTCO_2E$, with 2.6 $MMTCO_2E$ from HFC, and the remaining from ODS.

Estimated based on the percent of U.S. population residing in California, HFC emissions in California from foams are estimated as 0.3 $MMTCO_2E$ in 2006.
2.6 $MMTCO_2E$ * 12.2% = 0.3 $MMTCO_2E$

The amount of HFC-containing waste foam has increased about 9 percent per year. By 2020, the estimated emissions of HFCs from waste foam in California will be approximately 1 $MMTCO_2E$ annually.

$0.3\ MMTCO_2E * (1 + 9\%)^{14} = 1.1\ MMTCO_2E$

Staff assumes 100 percent foam recovery and destruction by 2020, or 1 $MMTCO_2E$, rounded from 1.1 $MMTCO_2E$.

Assumptions for Costs and Savings

Cost estimates are preliminary and will be known with greater precision by July 2010 when an ARB research study will be completed for lifecycle analysis cost of recovery and destruction of high-GWP GHGs.

Based on literature review the following assumptions and determinations are made in the cost and savings estimate:

<u>Foam Processing Facility Investments</u>
36 million pounds of waste appliance and building foam is generated each year; for every 10 pounds of foam there is 1 pound of foam blowing agent used. An appliance foam processing facility can process up to 2.1 million pounds of insulating foam.

17 foam processing facilities are required (36 million pounds foam / 2.1 million pounds per facility). There are currently three facilities in California, so 14 will be required.
There are 14 facilities existing in California that could destroy waste foam (3 waste-to-energy plants, and 11 cement kilns); 8 of the existing destruction facilities will accept and destroy foam waste.

As a great volume of building foam can go directly to destruction facilities, the need for foam processing facilities is reduced to six.

Six new facilities would have to be constructed, at an average cost of 3.6 million dollars each to process waste foam (6 Facilities * $3.6 = $21.6 million). Each facility would last about 20 years, for an annualized facility construction cost of about $1 million per year.
Cost of HFC reduction is approximately $100/MTCO$_2$E; annualized to $94/ MTCO$_2$E.
Annual cost is $94 million (1 MMTCO$_2$E reduced * $94/ MTCO$_2$E * 1,000 MT/MMT = $94 million).

Total cost per year to reduce HFCs from waste insulating foam would be about $95 million ($1 million in facility construction costs + $94 million in foam collection, recovery, and destruction cost, which includes all recovery labor, transportation, and facility operating costs).

SF_6 Leak Reduction and Recycling in Electrical Applications

Overview

This measure will reduce emissions of SF_6 within the electric utility sector and at particle accelerators by requiring the use of best achievable control technology for the detection and repair of leaks, and by the recycling of SF_6.

Assumptions for GHG Reduction

Staff estimates an annual emission reduction of 0.07 MMTCO$_2$E calculated from a U.S. EPA reduction estimate of 20% for leak detection and repair and 10% for recycling and recovery based on 2020 projected emissions of 0.22 MMTCO$_2$E in California.

Assumptions for Costs and Savings

Annual operating cost is estimated to be $300,000 for leak detection and repair and recycling. It is assumed that all SF_6 saved during leak detection and maintenance activities represents a cost savings because the facility SF_6 purchase and consumption rate will decrease. The cost savings from reduced consumption and purchase is estimated at $420,000 annually, yielding a net cost savings of $120,000.

Alternative Suppressants in Fire Protection Systems

Overview

This measure will reduce greenhouse gas emissions from fire suppression systems through a variety of potential reduction options including a GWP threshold for fire suppression agents in new systems, leak reductions strategies, and end of life requirements.

Assumptions for GHG Reduction

The goal of the measure is to reduce emissions to less than 0.1 MMTCO$_2$E by 2020 with an effort to ensure that HFC banks grow no more than about 10% between 2012 and 2020. Leak reduction efforts could address installed capacity while alternative suppressants may be used to address emissions from future banks. The impact on emission levels will be greatest once a large percentage of the systems have moved to low GWP agents.

Assumptions for Costs and Savings

Costs will differ depending on the implementation of this measure. Costs presented here will be for using low/no GWP alternatives in new total flooding systems instead of HFC-227. Portable systems and leak reduction strategies are expected to be less expensive.

Based on U.S. EPA data and assuming replacement lower GWP agents in systems coming on-line between 2010 and 2015, one-time costs vary from $10 million to $12 million for 2012-2015 with annual costs ranging from $200,000 to a savings of $200,000, depending on the substitute gas. For systems coming online between 2015 and 2020 the one-time cost is approximately $3 to 4 million with annual costs ranging from $70,000 to a savings of $70,000. These estimates are in U.S. 2000 dollars. Converting these to 2007 dollars and annualizing the costs using a 15 year lifetime, the annualized capital costs are approximately $1.8 million. Annual operating costs are approximately $0.2 million and savings are approximately $0.2 million.

Residential Refrigeration Early Retirement Program

Overview

This measure involves establishing a voluntary program to upgrade pre-2000, less energy efficient residential refrigeration equipment such as refrigerators and freezers and ensure proper recovery of refrigerants and blowing agents that have a high-GWP. The measure would include developing strategies to support appliance take-back/upgrade and early retirement programs such as the U.S. EPA Responsible Appliance Disposal (RAD) program and EnergyStar program, in addition to programs administered by local utilities to address direct and indirect GHG emission reductions from domestic appliances.

Assumptions for GHG Reduction

Based on literature review and data available through the U.S. EPA RAD Program the following assumptions and determinations are made in the GHG reductions estimate:

- Currently in California up to 1.2 million refrigerators and freezers are disposed of annually.
- Appliances manufactured prior to 1996 used CFC-12 as the refrigerant and CFC-11 as the blowing agent; appliances manufactured from 1996 to 2002 used HFC-134a as the refrigerant and HCFC-141b as the blowing agent; appliances manufactured after 2002 used HFC-134a as the refrigerant and HFC=245fa as the blowing agent
- For domestic appliances the average refrigerant charge is estimated to be 0.5 pound; the average foam blowing agent used is estimated to be 1.0 pound.
- The primary result of this measure is a 25% increase in recycling of appliances to total 1.5 million per year; an increase of 300,000 appliances per year.
- At an appliance end of life 90% of the original refrigerant charge is recovered.
- At an appliance end of life 65% of the initial blowing agent is released – 25% during shredding and an additional 40% after disposal; this GHG emission is mitigated by this measure.

The total reduced emissions for a given year is calculated as follows:

Total Pre-1996 Refrigerator Emission Reduction	=	Total Refrigerators * % Pre 1996 Refrigerators * (½ pound CFC 12 * GWP * 90%) + (1 pound CFC-11 * GWP * 65%)
Total 1996 to 2002 Refrigerator Emission Reduction	=	Total Refrigerators * % 1996 to 2002 Refrigerators * (½ pound HFC-134a * GWP * 90%) + (1 pound HCFC-141b * GWP * 65%)
Total post 2002 Refrigerator Emission Reduction	=	Total Refrigerators * % 1996 to 2002 Refrigerators * (½ pound HFC-134a * GWP * 90%) + (1 pound HCF-245fa * GWP * 65%)
Total Emission Reduction	=	Total Pre-1996 Refrigerator Emission Reduction + Total 1996 to 2002 Refrigerator Emission Reduction + Total post 2002 Refrigerator Emission Reduction

Assumptions for Costs and Savings

Based on literature review and data available through the U.S. EPA RAD Program the following assumptions and determinations are made in the cost and cost savings estimate:

- Incremental costs for purchasing an EnergyStar appliance is $62, so consumer costs = 300,000 * $62, or $19 million.
- Energy savings during the life of an EnergyStar appliance is 700 kWh per appliance, so total energy savings is 700 kWh * 300,000, or 210 million kWh.
- Total utility company costs for appliance recycling programs is $0.03 per kWh saved * 210 million kWh, or $6.3 million.
- In a three-year budget cycle, the total investment in energy efficiency programs in California is $2.7 billion.
- Ratepayer resource savings are $5.4 billion over the life of the programs.
- The cost savings equals total investment of $2.7 billion – total resource savings of $5.4 billion, or $2.8 billion.

Agriculture

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Methane Capture at Large Dairies	1	156	0	156[22]

[22] The methane capture at large dairies measure is voluntary and therefore not considered in the economic modeling calculations.

Measure: Methane Capture at Large Dairies

Overview

This is a voluntary measure to encourage the installation of methane digesters to capture methane emissions from the decomposition of solid and liquid waste at large dairies. The methane could be used as an alternative to natural gas in combustion, power production, or as a transportation fuel.

Assumptions for GHG Reduction

Manure Management Emission Reduction Assumptions (dairies with 1,000 head or more)

1,781,799 Head	Total California Herd
6.55 Million Metric Tons	Uncontrolled GHG emissions from California Herd
1,392,888 Head	Total SJVAPCD Herd*
78%	SJVAPCD percentage of total California Herd
330,028 Affected Head	Assumes 73% of dairy cows at dairies with 1,000+ head will already be feeding digesters through voluntary action.
1,223,854 Head	Dairy cows, heifers, calves, and bulls at dairies with 1,000+ head not feeding an existing digester
3.676 tonnes CO2e/head	Includes CH4 and N2O
1.2 Million Metric Tons	Uncontrolled emissions from 330,028 head
86%	Control
1.0 Million Metric Tons	Reductions from 330,028 head
330	Dairies with 1,000 or more dairy cows, heifers, calves, and bulls not already feeding a digeser
1,628	Total dairies in California (2006 CDFA data)

*: Includes all cows in Kern County

Assumptions for Costs and Savings

Staff estimates an operating cost of $33M and an annualized cost for installation of digesters at $123M for this measure based on an average capital cost of $3.9M per digester. No savings is assumed. However, the cost for this voluntary measure is not included in the economic modeling as the reduction is not required as part of the AB 32 GHG emissions reduction program.

Cost and Savings Calculation	
Cost per digester	$3.9M
# of large dairies (with more than 100 head)	330
Capital cost	$1,280M
Capital life	15 years
15-year CRF	0.09634
Annualized capital cost 2020 (capital cost x CRF)	$123.3M
Operating cost 2020 ($100k)	$33M
Total cost 2020	$156M

Forests

GHG Reduction Measure	Potential 2020 Reductions $MMTCO_2E$	Annualized Cost ($Millions)	Savings ($Millions)	Net Annualized Cost ($Millions) [Cost-Savings]
Sustainable Forest Target	5	50	0	50

Measure: Sustainable Forest Target

Overview

Reductions from this target will be achieved through conservation, forest management, reforestation, afforestation urban forestry and fuels management projects. The forest net flux, that is the balance between uptake and emissions, is currently -5 $MMTCO_2E$.

Assumptions for GHG Reduction

A target reduction of 5 $MMTCO_2E$ is required forest sector to maintain the current net flux based on inventory projections.

Assumptions for Costs and Savings

Staff estimates a net cost of $50M to achieve a 5 $MMTCO_2E$ reduction based on the current voluntary offset price of approximately $10 per $MTCO_2E$.