CALIFORNIA AIR RESOURCES BOARD
Assembly Bill 32 Technical Stakeholder Working Group Meeting

COST-EFFECTIVENESS

June 3, 2008
9:00 a.m. – 12:30 p.m.

Sierra Hearing Room
2nd floor of the California Environmental Protection Agency (CalEPA)
Headquarters Building
1001 "I" Street, Sacramento, California

Note: The Sierra Hearing Room at CalEPA Headquarters has limited seating. The meeting will be webcast (http://www.calepa.ca.gov/broadcast/) and open to real-time questions via e-mail (ccplan@arb.ca.gov).

This meeting is part of an ongoing series of program design and economic analysis technical stakeholder meetings. These meetings provide interested stakeholders the opportunity to provide specific technical input concerning various elements of the program design developed to meet the requirements of Assembly Bill (AB) 32. Previous stakeholder meetings have covered specific design issues involving market-based measures. These issues have included rules for offsets and modeling the use of offsets in a cap-and-trade program; analysis of non-economic impacts, such as environmental justice and reductions in co-contaminants; containing the costs of allowances; and program evaluation criteria.

This meeting will focus on potential methodologies for determining cost-effectiveness under AB 32. Staff will present current methodologies that it is evaluating as well as solicit input from the public on other potential approaches that should be considered. The attached white paper considers possible approaches to establish cost-effectiveness criteria.

AGENDA

A. Opening Remarks

B. ARB Staff Presentation: "Cost-Effectiveness"

C. Dr. James Sweeney, Professor, Management Science and Engineering, Stanford University

D. Questions and Answers

Written comments and responses are welcome. Please submit your comments to ccplan@arb.ca.gov by June 17, 2008.

Introduction

An important requirement of the Global Warming Solutions Act of 2006 (the Act or AB 32; Statutes of 2006, Chapter 488) is that cost-effectiveness must be considered. This requirement is found in several provisions of the Act. The Act requires the Air Resources Board (ARB or Board) approve a Scoping Plan for achieving the maximum technologically feasible and cost-effective reductions in greenhouse gas emissions (Health and Safety Code section 38561). The Act also requires the Board to adopt rules and regulations to achieve the maximum technologically feasible and cost-effective greenhouse gas (GHG) emission reductions, and to "consider the cost-effectiveness of these regulations" (Health and Safety Code sections 38560 and 38562). The purpose of this paper is to promote dialogue regarding an interpretation of cost-effectiveness that is economically sound and meets the requirements of the Act.

Establishing the Cost-effectiveness of Regulations

The Act defines "cost effective" or "cost-effectiveness" (C-E) as "the cost per unit of reduced emissions of greenhouse gases adjusted for its global warming potential." (Health and Safety Code section 38505(d)). This definition specifies the metric (e.g., dollars per ton) by which the Board must express cost-effectiveness, but it does not provide criteria to assess if a regulation is or is not cost-effective. It also does not specify whether there should be a specific upper-bound dollar per ton ($/ton) cost that can be considered cost-effective, or how such a bound would be determined or adjusted over time. ARB staff has investigated different approaches that may be used to evaluate the cost-effectiveness of these regulations and has identified a few options for determining if a regulation is cost-effective.

This paper outlines four possible approaches to establish cost-effectiveness criteria:

1. Cost of a Bundle of Strategies;
2. Cost of the Last Ton Reduced;
3. GHG Market Prices as Proxy; and
4. Zero Net Cost.

As a preliminary recommendation to solicit discussion and comment, this paper finds that the preferred approach is the Cost of a Bundle of Strategies which considers the cost-effectiveness of a package of greenhouse gas reduction measures with potential to meet AB32's 2020 target. For reasons discussed in this paper, the other three approaches do not seem to be appropriate frameworks for determining cost-effectiveness under the Act.

To support this paper staff summarized several studies (Appendix A) that show the range of estimates of the costs per ton of GHG control strategies. The Appendix is attached to this paper for illustrative purposes and is not meant to suggest that a specific study should be used to establish C-E.

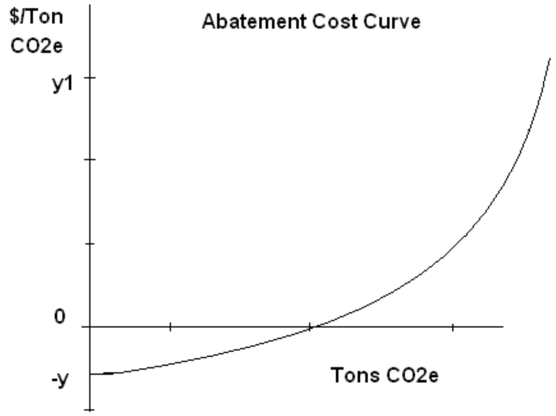
Technical Notes on Cost-Effectiveness

For purposes of this paper, staff interprets cost-effectiveness for an individual emission reduction measure as "the annualized costs of reducing one ton of CO2 equivalent (CO_2e) net of any savings and co-benefits." This interpretation has been used historically to compare the cost-effectiveness of criteria pollutant measures considered by the Board. Staff is proposing to continue this approach for C-E calculations of the proposed measures or regulations in the Scoping Plan and in the regulatory process. Staff's interpretation of the definition of cost-effectiveness and its historical approach of including co-benefits is the most economically rational and practically workable.[1]

Cost-effectiveness is used in regulatory development to compare the C-E (the \$/ton CO_2e reduced) of one regulation to the C-E of another regulation. The regulation with the lowest dollar cost per ton delivers emission reductions at lower cost per ton as compared to other regulations intended to reduce the same amount of emissions. That is, the regulation with a lower C-E is more cost-effective than a regulation with a higher dollar per ton cost. For a range of GHG abatement strategies, the \$/ton cost can be plotted on a graph against the tons of emission reduction for each control measure to develop a GHG marginal abatement cost curve. An illustration of a marginal cost curve is shown in Exhibit 1. Looking at Exhibit 1, GHG abatement strategies that are more cost-effective (have lower or negative dollar per ton cost) will be lower on the cost curve (relatively closer to the y axis) than regulations which are less cost-effective and have higher dollar per ton costs. The marginal abatement cost curves only reflect cost per ton, and do not consider other factors such as ease of implementation or the degree to which a strategy has established a proven track record for reductions.

[1] Anthony E. Boardman et al., Office of Management and Budget, "Circular A-4: Regulatory Analysis," (September 17, 2003), p. 10, available at http://www.whitehouse.gov/omb/circulars/a004/a-4.pdf. See also Climate Action Team, "Updated Macroeconomic Analysis of Climate Strategies Presented in the March 2006 Climate Action Team Report: Final Report," (October 15, 2007), p. 21, available at http://www.climatechange.ca.gov/events/2007-09-14_workshop/final_report/2007-10-15_MACROECONOMIC_ANALYSIS.PDF.

Exhibit 1: Marginal Cost of GHG Abatement



Four Approaches to Defining Cost-Effectiveness

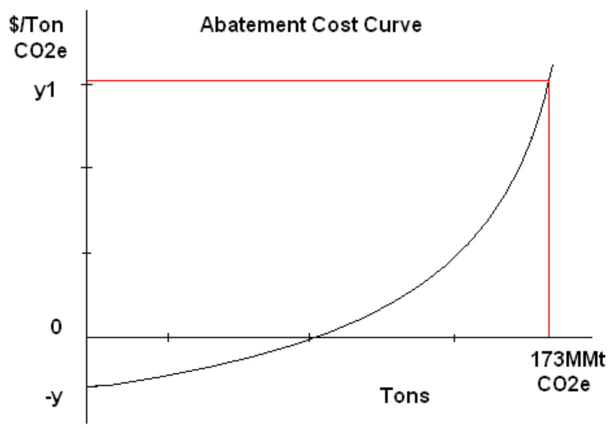
1. Cost of a Bundle of Strategies

To achieve the AB32 2020 emission limit of 427 million metric tons of CO_2e ($MMTCO_2e$), ARB has preliminarily estimated that emission reductions from business-as-usual of 173 $MMTCO_2e$ will be needed, through a broad spectrum of strategies including performance-based regulations. A graphical representation of the cost of abating 173 million metric tons is presented in Exhibit 2.

The range of cost-effectiveness of a number of strategies can serve as background for establishing the reasonableness of a proposed regulation's cost-effectiveness. The highest cost-effective strategy and the least cost-effective strategy can form the range representing the bundle that in total demonstrate a path for reaching the emission reduction target. In the example shown in Exhibit 2, the lowest value would be $ -y and the highest value $ y_1. Any proposed regulation falling within this range or, depending on additional factors required by AB 32, reasonably close to this range would be considered cost-effective and would meet the AB32 cost-effectiveness requirement. That is because the suite of strategies or "the bundle" demonstrates how the 2020 emission reduction target can be reached in conjunction with other approaches. As the actual BAU 2020 emissions level may be greater or less than the current estimate, the range of the bundle of measures should remain flexible and be able to accommodate a higher or lower upper end of the range of cost-effectiveness.

In addition, the bundle can be updated as additional technological data and strategies become available. As ARB moves from developing the Scoping Plan to developing specific regulations, and as regulations continue to be adopted, updated cost-effectiveness estimates will be established. The bundle would gradually shift from proposed strategies and estimated costs to actual regulations, and the comparison of cost-effectiveness would move toward the well established practice of comparing the C-E of new regulations to the C-E of previously enacted and/or similar regulations, which is consistent with how cost-effectiveness for strategies to reduce criteria and toxic pollutants is evaluated.

Exhibit 2: Marginal Cost to Meet AB 32 Mandate



The advantage of the Cost of a Bundle of Strategies Approach is that proposed regulations do not need to be brought to the Board in any particular order. The bundled approach confirms that a wide range of cost-effective strategies and implementable regulations exist and that these strategies need to be adopted by the Board to meet the AB32 target. The scheduling of the regulations would be based on practical reasons such as the complexity of the regulation, the size of the potential reductions, distribution of burden among industry sectors, or lead time required for compliance. Given the time constraints imposed by AB32, scheduling regulations for adoption based on any other metric would not be practical and could lead to missed opportunities for achieving early reductions.

An example of such a bundle is the 2006 Climate Action Team (CAT) report, which proposed a collection of emission reduction strategies. The CAT proposed about forty GHG reduction strategies developed by ARB and several other state agencies. The costs of these strategies were estimated in 2006, and subsequently updated in the 2007 report entitled *Updated Macroeconomic Analysis of Climate Strategies Presented in the March 2006 Climate Action Team Report*[2] by the agencies. The report reflects the best information available at the time for a collection of strategies for reaching an emission reduction target consistent with that called for under AB 32. The CAT strategy cost estimates were prepared by several agencies using a consistent methodology formalized by the CAT Economics Subgroup. Several of the strategies are a continuation and extension of current statutory mandates whose costs or funding for the costs were established by regulatory process. Of particular note is that many of the

[2] *Updated Macroeconomic Analysis of Climate Strategies Presented in the March 2006 Climate Action Team Report*, Final Report, Climate Action Team, Economic Subgroup, October 2007, http://www.climatechange.ca.gov/events/2007-09-14_workshop/final_report/2007-10-15_MACROECONOMIC_ANALYSIS.PDF

emission reduction and mitigation cost estimates are being updated as part of the Scoping Plan.

The CAT's strategies costs range from a negative $528 (i.e., savings) to $615 per ton of CO_2e. The wide range needs to be put in perspective with the weighted average of about negative $47 (i.e., the CAT bundle averages at a savings per ton reduced). In fact, all but three strategies, accounting for 97 percent of the emission reductions, have net cost-effectiveness estimates of less than $55 per ton.

The strategies include many energy efficiency, forestry, renewable energy sources, refrigeration, vehicular, and land use measures. Though the strategies reduce GHG emissions their motivation was not necessarily climate change (e.g., RPS of 20%). The total GHG reduction from the strategies is about 132 $MMTCO_2$e. Although the total emission reductions fall short of the estimated total of the current estimated reduction of 173 $MMTCO_2$e needed to achieve the 2020 target, the reductions are sufficiently large to be a representative of the bundle needed to meet the target. ARB's Scoping Plan is expected to include a broader range of measures that provide more reductions than were identified in the CAT report, and will provide updated cost data from which to construct a range of cost-effectiveness.

The Intergovernmental Panel on Climate Change, McKinsey & Company, the states of Arizona and New Mexico, and others have proposed reduction strategies. Their cost estimates are presented to indicate the range in GHG control costs estimated by other entities and not to suggest that these numbers be used in lieu of California-relevant estimates being developed for the Scoping Plan. While the estimates from these other studies provide a useful reference, they are not directly applicable or comparable to California C-E because they target different levels of emission reductions in different geographical regions and use different cost estimation methods and assumptions. Exhibit 3 summarizes the cost-effectiveness ranges for these organizations' mitigation strategies or research efforts.

The costs for Arizona's strategies range from a savings of $90 per ton to a cost of $65 per ton. Arizona has set a State goal to reduce GHG emissions to 2000 levels by 2020 and to 50% below 2000 levels by 2040. Arizona has more opportunities for low cost efficiency improvements than California given California's historical leadership on energy efficiency.

New Mexico's C-E ratio ranges from savings of about $120/ton to costs of about $105/ton. The State's goal is to reduce GHG emissions to 2000 levels by year 2012, 10 percent below 2000 by 2020, and 75 percent by 2050.

McKinsey and Company, a consulting firm, has estimated the cost-effectiveness of several strategies around the world. Their cost-effectiveness estimates for the United States range from a savings $ -93/ tCO_2e (commercial electronics) to $91/

tCO_2e (car hybridization). Globally, the range is from a savings of about $225 per ton to costs of about $91 per ton. At the industrial level (Exhibit 4), The Intergovernmental Panel on Climate Change and the Center for Clean Air Policy costs range from a savings of $20 per ton for the California cement industry to costs of less than $100 per ton for global primary aluminum production. Overall, when looking across the GHG $/tons cost studies included in this analysis, the CAT strategies currently provide the largest range, from $-528/ton CO_2e (cost savings) to 615 $/ton CO_2e. However, it should be noted that the primary motivation for several of the strategies was not to reduce GHG emissions. For example, the strategy with the highest cost estimate in the previous study, the California Solar Initiative, produces multiple benefits, some of which are not quantified in the cost-effectiveness calculation. The Scoping Plan will include a more complete list of measures, with updated estimates of reduction potential and costs.

The range of California's C-E costs is lower and higher in each direction than the other costs presented in Exhibits 3 and 4. Many factors contribute to the lower and higher range. California may have used a different estimating methodology, discount rate, and/or other assumptions to compute the cost estimates. The methods to estimate CO_2e reductions may also be dissimilar. In addition, California has a more aggressive target requiring more extensive control measures applied to a very clean baseline. Further, California has already captured many of the low cost savings historically.

To conclude, the Cost of a Bundle of Strategies Approach confirms that a wide range of cost-effective strategies and implementable regulations exist and that these strategies need to be adopted by the Board to meet the AB32 target. Also, as the actual 2020 emissions level may be greater or less than the current estimate, the range of the bundle of measures can be made flexible to offer guidance and accommodate a higher or lower upper end of the range of cost-effectiveness. Staff recommends using the Cost of a Bundle of Strategies Approach for cost-effectiveness comparison and discussion in the Initial Statement Reasons for AB32 regulations.

As the Scoping Plan methodology is consistent and was specifically developed to address the requirements of AB32, Staff suggests the $/ton CO_2e cost range that will be presented in the Scoping Plan be considered to form the range of the Cost of a Bundle of Strategies Approach.

Exhibit 3: Cost-effectiveness Range for the CAT Macroeconomic Analysis, Selected States, United States, Global -

State	Cost-effectiveness Range $/ ton CO_2eq	Tons Reduced MMtCO_2e/yr	Percent of BAU
California 2020 (CAT[1], CEC[2])	- 528 to 615	132	22
Arizona[3] 2020	- 90 to 65	69	47
New Mexico[4] 2020	- 120 to105	35	34
United States (2030)[5]	-93 to 91	3,000	31
Global Total (2030)	-225 to 91	26,000	45

Source:
1. Climate Action Team Updated Macroeconomic Analysis of Climate Strategies, Presented in the March 2006 Climate Action Team Report, September 2007.
2. California Energy Commission, *Emission Reduction Opportunities for Non-CO2 Greenhouse Gases in California*, July 2005, ICF ($/MTC$0_2$eq).
3. Arizona Climate Change Advisory Group, *Climate Change Action Plan*, August 2006, ($/MTC$0_2$eq).
4. New Mexico Climate Change Advisory Group, Final Report, December 2006.
5. McKinsey & Company, *Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?* December 2007.
6. The McKinsey Quarterly, McKinsey & Company, *A Cost Curve for Greenhouse Gas Reduction,* Fall 2007.

Exhibit 4: Global, Cost-effectiveness Range for Industry, GHG Emissions from Processes & Energy Use -2030

Industry (Global)[1]	Cost Range $/Mton	Tons Reduced MMTCO_2e/yr
Steel	20 - 50	420 -1,500
Primary Aluminum	Less than 100	50 - 80
Cement	Less than 50	480 – 2,100
Ethylene	Less than 20	60
Ammonia	Less than 20	110
Petroleum Refining	Less than 20	140 - 300
Pulp and paper	Less than 20	40- 420

Source: 1. IPCC, Climate Change 2007 Mitigation, Chapter 7, Industry, 10/2007.

Supporting documentation for the cost data in Exhibits 3 and 4 are provided in the Appendix.

2. Cost of the Last Ton Reduced

This method varies only slightly from the “Cost of a Bundle of Strategies”. The same C-E calculation completed for the Bundled Cost Approach can be used to arrive at the cost of the last ton, (Exhibit 2). That is, the dollar/ton cost of the last ton reduced (Exhibit 2, $\$y_1$) represents the most costly GHG reduction strategy the Board would have to adopt to meet the AB32 target of 173 MMt/yr. The dollar/ton cost of the last ton ($\$y_1$) establishes the C-E threshold.

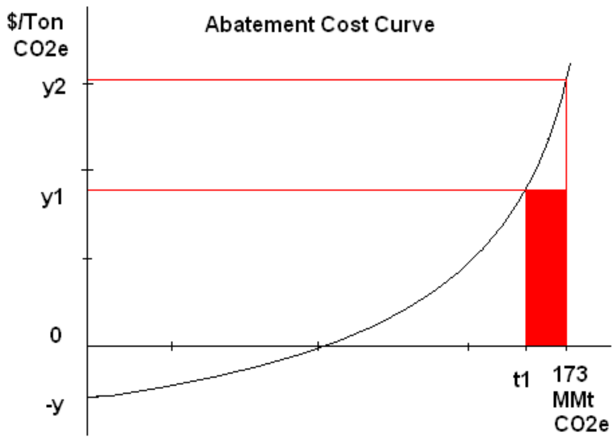
As with the Bundled Cost Approach, proposed regulations do not need to be brought to the Board in any particular order. The Cost of the Last Ton approach confirms the dollar/ton cost that is necessary to achieve the mandates of AB32 and that a wide range of more cost-effective (i.e., lower $ per ton) strategies and implementable regulations exist and that these strategies and regulations need to be adopted by the Board to meet the AB32 target. By establishing the C-E threshold, the Board would establish that all proposed regulations with lower $/ton are cost-effective since they have lower $/ton cost and, by definition, are more cost-effective that the threshold. Because the Board needs to adopt a wide range of strategies in a three year regulatory window (2008 - 2011), the scheduling of the regulations for Board adoption would be based on practical reasons such as the complexity of the regulation, the size of the potential reductions, distribution of burden among industry sectors, or lead time required for compliance, and not on the $/ton cost of the regulation.

Staff does not recommend the Cost of the Last Ton reduced as the preferred strategy because it would be very difficult to define at the outset of the regulatory process a precise C-E threshold for the entire bundle of control measures. Also, a precise upper threshold could give the erroneous impression that there is a fixed level that would not change over time. We expect changes in the level to occur as better information becomes available.

3. GHG Market Prices as Proxy

The price of carbon as established in a carbon market is another approach that could potentially be used to set a cost-effectiveness threshold. In this case, similar to the previously reviewed approaches, the $/ton price of carbon selected as the threshold directly establishes the volume of emission reduction. In Exhibit 5, the market price of carbon is $\$y_1$ and if $\$y_1$ is established as the C-E threshold, the resulting statewide emission reduction will be less than necessary to meet AB32 requirements. However, unlike the previous approaches, the market established price of carbon most likely will not provide the amount of emission reductions needed to reach the AB 32 target. This is because any market is likely to cover a subset of the emitting sectors covered by AB 32's economy-wide target, and complementary regulatory measures and other policies will also achieve reductions in those sectors. Therefore the marginal cost of the emission reductions in the sectors in the market is unlikely to be the same as the marginal cost of the emission reductions from all sectors needed to meet AB 32.

Exhibit 5: Market Price of Carbon vs. AB 32 Mandate



There are two general categories of carbon markets: offset markets that sell credits for GHG emission reductions, and allowance markets in cap and trade programs.

Difference between an allowance and credit:

> Credits (often referred to as Offsets) are emission reductions that an emitter in a sector outside the scope of any cap and trade program has achieved in excess of any required reductions. The excess amount is the credit and can be sold on the market either to voluntary purchasers or sometimes to regulated entities if they are allowed to use credits for compliance with a regulatory program (like a cap and trade program).
>
> Allowances are the unit of compliance that is created by the regulator in cap and trade programs. Regulated sources are generally free to buy, sell, or trade allowances among each other or non-regulated entities with the requirement that each source must have sufficient allowances in its account at the end of each compliance period to cover its emissions during that period. The aggregate quantity of allowances represents the upper limit on the emissions (i.e. the cap) from the regulated sources for a specified compliance period.[3]

In theory a carbon emitter will pay the cost to clean up GHG emissions as long as the per ton marginal abatement cost is below the market (marginal) price established for GHGs. As the cost of abatement exceeds the price of carbon, the GHG emitter will purchase an offset or allowance in the carbon market if allowed by their regulator.

[3] Taken from the *International Emission Trading Association*, with modification,http://www.ieta.org/ieta/www/pages/index.php?IdSitePage=369, December 2007.

There are currently two main government backed market devices. The first, the Clean Development Mechanism (CDM), allows parties to the Kyoto Protocol to offset their emissions by investing in emission reduction projects in developing countries or purchasing the resultant Certificates of Emission Reduction (CERs) from such projects. The second is a cap and trade program that was adopted by the European Council in 2003 and is called the European Union Emission Trading Scheme (EU ETS).[4]

The EU ETS is in its Phase II and allowances to emit one ton of CO2e currently trade for about $45.75[5] per ton. This price plus an amount to account for transaction costs and enforcement could be considered to set a threshold for cost-effectiveness of AB 32 regulations. But this approach has problems.

First, the ETS is only one policy tool that the EU is using to reduce emissions and meet its Kyoto economy-wide commitment (just as any cap and trade program would only be one tool in the toolbox to meet California's statewide AB 32 limit). Therefore, a better comparison would be the marginal cost-effectiveness of all the measures the EU will use to meet its Kyoto commitment.

Second, three key factors affect market prices for European Union Allowance (EUA) in the EU ETS:

- policy and regulatory issues;
- market fundamentals; and,
- technical indicators

These three factors do not lend themselves to establishing a practical C-E threshold for California.

Decisions concerning policy and regulatory issues have a key impact on market and prices. For instance, EU policymakers have determined the total supply of allowances for the first period of the EU ETS (2005-2007) through the National Allocation Plans (NAPs). Half way through this first phase, in June 2006, the whole process started again - with negotiations for the new NAPs for the second period (2008-2012). The number of allowance issued is also based on the implemented and planned EU climate policies and control measures.[6] In addition, the stringency of the cap in any cap and trade program is a primary determinant of the market price. It is widely accepted that the EU set the cap for the ETS too high during its learning period (as many say, they "over-allocated emissions allowances") thereby leading to low prices during that period.

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[4] *The Carbon Market*, http://www.energyandcapital.com/articles/carbon+trading-emissions-credits/513, December 2007.

[5] €29.14 for December 2012 allowance as traded on May 28, 2008 (1€ = $1.57).

[6] The European Climate Change Programme, EU Action Against Climate Change, European Commission, 2006. http://ec.europa.eu/environment/climat/pdf/eu_climate_change_progr.pdf

Market fundamentals also play an important role. Among the key fundamentals in this market is GHG output, which in turn is a function of weather, fuel prices and economic growth.

Technical indicators are used by market timers to devise future market action, and their use can influence market prices. Technical indicators are mathematical or graphical representations of recent market activity. Most technical indicators are based solely on movements in price, but some also incorporate trading volume into the calculation.

The price of EUA is heavily influenced by the size of the initial allocation of allowances and the current internal policies of the 27 participating countries in the EU ETS. In addition, another complicating factor, which makes the price of the EUA an inadequate proxy for the price of greenhouse gas reductions, is that the year in which the allowances are traded is relevant to their price, because the EU did not allow banking between the first two compliance periods. A proper comparison of the EUA prices with the cost-effectiveness of ARB proposed GHG reduction regulations would also require prediction of the EUA market prices for the year that the ARB regulation would be implemented.

The current EU ETS program is scheduled to end in 2012. However, the cap and trade program is likely to continue. Negotiations are underway to determine the cap and market rules for beyond 2012 which would heavily influence the market price. Prediction of the market prices would be difficult and quite conditional because of the changing circumstances. The difficulty arises from the myriad factors and assumptions needed to predict the future carbon market prices for comparison with a California proposed regulation. Some of the complicating factors are the lack of similar market size and reduction requirements, similar sector participation, and similar offset provisions.

4. Zero Net Cost: Enact only those measures with zero or negative costs

Another approach to determining cost-effectiveness would be for ARB to adopt only those measures with zero or negative net costs (i.e., those measures for which the savings are equal to or greater than the costs). No provision in AB 32 limits ARB to adopting measures that have a negative cost. There is no reason to infer that measures are cost-effective only if they have a negative cost. Cost-effectiveness is a relative term – it requires only that the lower dollar per ton alternatives be chosen, not that the less expensive alternatives have a zero or negative cost. Further, based on the evaluation of the mitigation options as part of the development of the Scoping Plan it is extremely unlikely that the ambitious target called for under AB 32 could be met with strategies having a negative or zero cost.

Conclusion

The Cost of a Bundle of Strategies Approach appears to be the best approach to comply with the AB 32 cost-effectiveness requirement. The Cost of a Bundle of Strategies Approach is compatible with the Scoping Plan in that it can incorporate all measures to meet the 2020 target. Staff recommends that the cost-effectiveness of all measures (e.g., regulatory, market mechanisms) in the Scoping Plan be used to develop the C-E range for the Cost of a Bundle of Strategies Approach. Using the Cost of a Bundle of Strategies Approach, proposed regulations can comply with AB 32 C-E rulemaking requirements.