Analysis of the California ARB's Scoping Plan and Related Policy Insights

CRA Charles River Associates

March 24, 2010

Charles River Associates (CRA) Performed this Work at the Invitation of and in Collaboration with the California Air Resources Board

We wish to thank the following staff for their guidance and support in this effort:

Michael Gibbs, California Environmental Protection Agency
Steven Cliff, California Air Resources Board

In addition, we thank the ARB and California EPA staff for their help in harmonizing model assumptions and scenario design.

For media inquiries, please contact:
Andrea Goodman at (617) 425-3333 or agoodman@crai.com

Summary – Key Insights

- Allowing offsets leads to significant cost reductions
  - If offsets expand to about 15% levels, costs decline by over 40% from programs with offsets at the 4% offset level
  - Offsets have more power to reduce policy costs when complementary measures are excluded because all emissions are covered by the cap and trade program and hence can be offset by reductions taken outside the program
- Excluding complementary measures could lower cost of achieving AB32 goals by about 40%
  - The higher cost of meeting AB32 targets when complementary measures are also imposed is obscured because these policies lower allowance prices at the same time that they raise total social costs. The renewable energy standard and low carbon fuel standards are the most costly measures
  - Maintaining complementary measures under a national program like Waxman-Markey has a minimal effect on emissions but raises costs to California by more than 50%
- Accounting for likely higher costs of procuring and delivering advanced low carbon fuels to the California fleet results in a 40% increase in total program costs
- Replacing or linking California with a national cap and trade can lower costs
  - Replacing or linking California's AB32 program with a national policy like Waxman-Markey could lead to lower allowance prices, smaller increases in electricity rates, and lower social costs to California while achieving similar long-run contributions to global emission reductions
  - The benefits to California of participating in a national cap and trade program will depend critically on California's allotment of permits

Summary – Comparison of CRA and ARB Findings

- CRA and ARB estimate similar economic costs when considering a case with limited complementary measures and using the same technology assumptions.* In this comparable case, ARB and CRA find the following impacts in 2020:
  - Permit price: $102 (ARB) vs. $80 (CRA) per metric ton of CO2
  - Cost per capita or HH of $270 (ARB) vs. $290 (CRA) (about 0.6% of avg. per capita income)
- CRA and ARB both find that even the 4% offsets significantly reduce costs of meeting an emissions target: lowers permit prices by between 33% (CRA) and 80% (ARB)
  - Such "flexibility mechanisms" are particularly valuable for mitigating cost increases due to higher than expected emissions and higher than expected technology costs
- CRA and ARB differ in how command and control measures affect policy costs
  - CRA finds that measures that reduce flexibility (i.e., "complementary measures"), increase costs of complying with AB32; whereas ARB finds these measures reduce costs
  - CRA finds that including the Scoping Plan's complementary measures could raise costs of achieving AB32 goals by about 50% relative to a pure cap and trade program
  - Avoiding loss of flexibility from complementary measures is also important in case a national policy is enacted; CRA finds complementary measures undercut California's ability to attain cost savings that could otherwise result under a national carbon cap
- CRA's and ARB's models are sensitive to assumptions about economic forecasts, technology costs and development so flexibility in policy design is critical
  - Accounting for likely higher costs of procuring and delivering low carbon fuels to the California fleet raises the costs of complying with the low carbon fuel standard (LCFS) and increases the cost of the overall program by over 40%
  - Costs are about half as much under the IEPR 2009 emissions forecast, than under the 2008 Scoping Plan, which used the IEPR 2007 emissions forecast

*This bullet refers to scenario ARB5, which is described in slides 8 and 9.

Outline of Rest of this Report

- Acronyms
- Description of the ARB-CRA collaborative approach
- Overview of CRA's model system ("MRN-NEEM")
- Description of the scenarios analyzed
- Model results and insights from the scenarios
- Appendices (Model details and key assumptions)

Acronyms

Acronym	Definition
ARB	Air Resources Board
CHP	Combined Heat and Power
CRA	Charles River Associates
DSM	Demand Side Management
EE	Energy Efficiency
EV	Electric Vehicle
IEPR	Integrated Energy Policy Report
LCFS	Low Carbon Fuel Standard
MMT	Million Metric Tons
MRN	Multi-Region National Model
MT	Metric Ton
NEEM	North American Electricity and Environment Model
PHEV	Plug-in Hybrid Electric Vehicle
RES	Renewable Energy Standard
TWh	Trillion Watt-hours
WM	Waxman-Markey Bill

CRA Charles River Associates

Premises of this Study

- In 2008, the California Air Resources Board (ARB) approved the Scoping Plan, designed to reduce greenhouse gas (GHG) emissions as directed by AB 32. At that time, ARB staff released its economic analysis of the Scoping Plan. As part of approving the Scoping Plan, Board Resolution 08-47 was adopted, which directs the ARB staff to examine and report on estimates of overall costs and savings and the cost-effectiveness of reductions in the Scoping Plan
  - The analysis must consider timing of capital investments, annual expenditures to repay investments, and resulting cost savings as well as sensitivity of results to changes in key inputs, including energy price forecasts and estimates of the costs and savings of the Scoping Plan's measures
  - The analysis is to consider the effects of the program on the overall California economy as staff develops the cap-and-trade regulations and the economic implications of different cap-and-trade program design options
- To conduct this analysis, the Resolution directs ARB staff to solicit input from experts to advise ARB on its updated evaluation of the Scoping Plan, including identification of additional models or other economic analysis tools that could be used in the economic analysis.
- As part of soliciting input from experts, ARB staff worked closely with the Economic and Allocation Advisory Committee (EAAC), which was created in part to provide advice on the updated economic analysis of the Scoping Plan
- Also in response to Resolution 08-47, <u>Cal/EPA and ARB staff invited CRA to collaborate</u> with the ARB staff in analyzing the impacts of the Scoping Plan, to provide a range of perspectives on how to conduct such an analysis
  - Cal/EPA staff assisted CRA in assembling the requisite funding by helping define the value of the collaborative working relationship to potential funders
  - CRA began working with ARB staff in November 2009. A summary of the resulting analysis appears in the following pages

ARB's Guidelines for the Collaborative Approach

- Objective

Evaluate the economic impacts of the AB 32 Scoping Plan and policy options for ARB's cap-and-trade program using a diverse set of modeling tools and assumptions with the goal of understanding the sensitivity of costs and benefits of different Scoping Plan measures to different assumptions and different implementations of the Scoping Plan.

- Approach

1. Define a common set of assumptions and inputs for the analysis.
2. Define a common set of policies to examine, such as vehicle standards, renewable portfolio standard (RPS), energy efficiency, Low Carbon Fuel Standard (LCFS), cap-and-trade.
3. Define a "baseline" or "reference case" set of conditions against which policies will be evaluated.
4. Define policy cases to evaluate relative to the reference case.
5. Define the economic impacts of interest.
6. Using the common definitions, each modeling team will use its modeling tools and framework to evaluate the economic impacts of the policy cases relative to the reference case. Sensitivity cases will examine the sensitivity of the impacts to various assumptions.
7. Each modeling team will prepare a summary of its results, highlighting the cases defined in common.

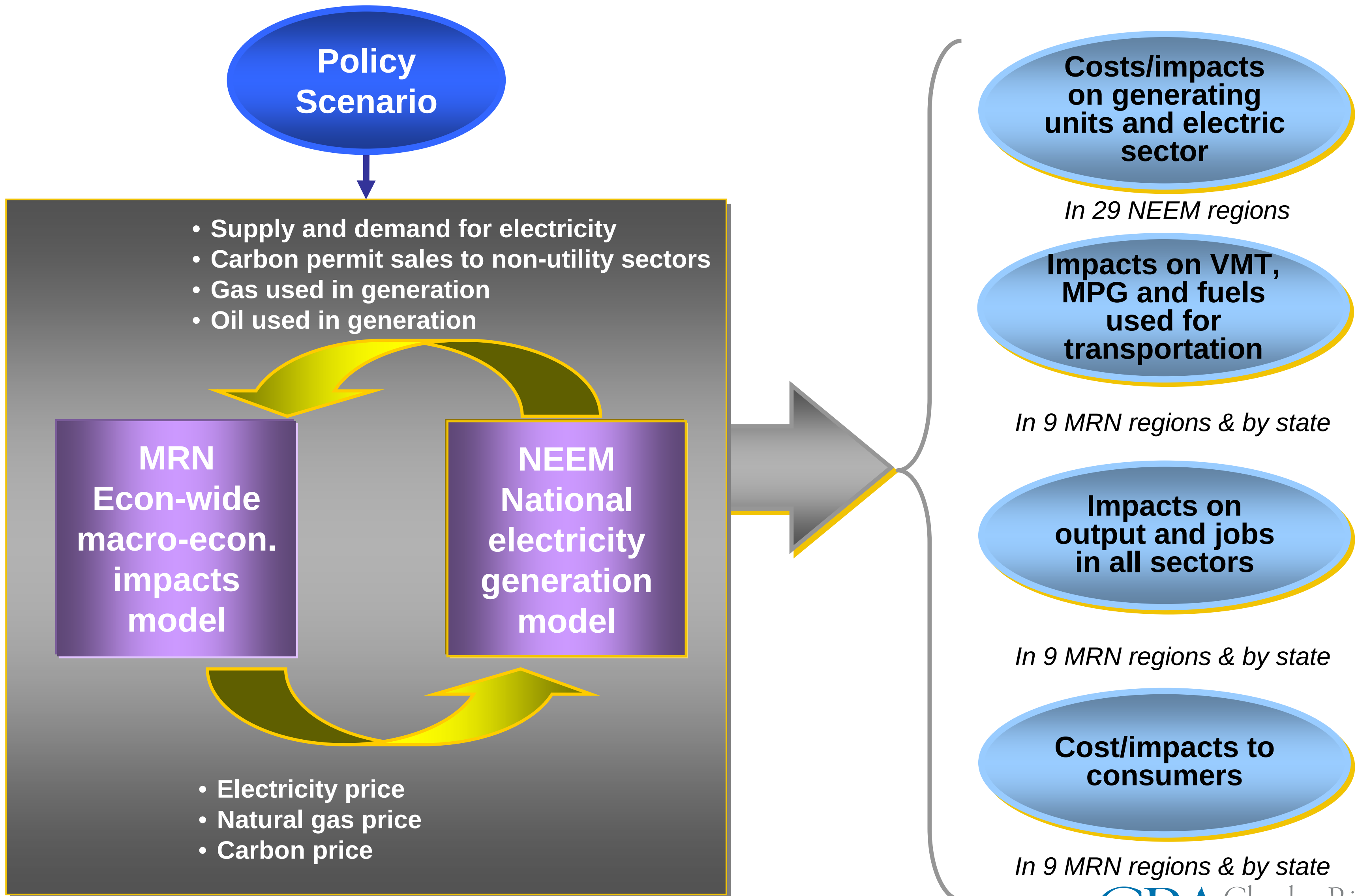
CRA's MRN-NEEM Modeling System

- NEEM – North American Electricity & Environment Model
  - Bottom-up quadratic programming (QP) model of the North American electric sector
  - Simulation of key decisions within the electric sector to represent the likely outcome in competitive electricity markets

- MRN – Multi-Region National Model
  - Computable general equilibrium model of the US economy
  - Models interactions between profit-maximizing producers and rational consumers in the US economy (captures both the geographic distribution of welfare impacts and across-industry impacts of climate policies)

- MRN-NEEM – integration of MRN and NEEM

MRN-NEEM Includes a Detailed Electric Sector Interacting with All Other Sectors of the US Economy



CRA Charles River Associates

Description of the Scenarios and Their Purposes

- Based on the goals and objectives of this collaborative project, CRA ran a number of different scenarios to test the sensitivities of different assumptions and policy design options.
- To most directly compare CRA's model with that of the ARB, we constructed and analyzed scenarios ARB1 – ARB5, which mirror the ARB's cases 1 – 5, and as best as possible employ the same assumptions as ARB.
- Because of our finding that costs could be greatly reduced if AB32 relied on market-based mechanisms, we ran a pure cap and trade policy to achieve the AB32 targets. As a counter policy, we considered a scenario in which only the complementary measures were in place and no cap and trade program exists to ensure compliance with the AB32 emission targets.
- In reviewing the literature and talking with industry experts, we felt that ARB's cost assumptions surrounding alternative transportation fuels did not include the full costs of procuring and delivering alternative fuels to the California fleet, so we adopted a different set of assumptions that accounted for these costs against which we ran the following scenarios: CRA7a, CRA7b, CRA8a, CRA8b, CRA8c, CRA10, CRA11, and CRA12.
- CRA10 and CRA8c differ from ARB1 and ARB_Cap, respectively only in the cost assumptions about alternate transportation fuels and the availability of CHP.
- In comparing the cases ARB1 and ARB2, one sees the significant benefit offsets offer for reducing policy costs. To this end, we conducted several additional sensitivities to the availability of offsets. These sensitivities included cases in which all the complementary measures were included and excluded. The CRA7 cases included all the complementary measures; whereas all the CRA8 cases excluded them. The "a" cases included a large amount of offsets, the "b" cases included more offsets than in the ARB cases, but fewer than in the "a" cases. Finally, CRA10 and CRA8c included the ARB level of offsets.
- Because of the possibility of national GHG abatement being enacted, we considered two cases in which a national cap and trade program similar to Waxman-Markey was implemented. CRA11 assumes implementation of Waxman-Markey policy and CA adopting **none** of the complementary measures; and CRA12, which also assumes implementation of Waxman-Markey policy but assumes that CA adopts **all** of the complementary measures. For both scenarios, California does not have its own separate cap and trade program.
- Comparing the economic outlook for California in 2008 and today one sees tremendous differences. To understand the difference in impacts of AB32 under different economic forecasts, we considered a sensitivity that analyzed the economic impacts of California under the economic outlook used in the 2008 Scoping Plan.

Tabular Summary of the Scenarios

		Complementary Measures						Cost
Scenario	Cap & Offsets	LCFS	Pavley II	VMT Reduction	Energy Efficiency	33% RES	CHP	Assump.
ARB1	4% Offsets	Full	Full	Full	Full	Full	Full	ARB
ARB2	No Offsets	Full	Full	Full	Full	Full	Full	ARB
ARB3	4% Offsets	Half	Half	Excluded	Full	Full	Full	ARB
ARB4	4% Offsets	Full	Full	Full	Half	Excluded	Half	ARB
ARB5	4% Offsets	Half	Half	Excluded	Half	Excluded	Half	ARB
ARB_Cap	4% Offsets	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	ARB
CRA7a	WM Levels*	Full	Full	Full	Full	Full	Full	CRA
CRA8a	WM Levels	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	CRA
CRA8c	4% Offsets	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	CRA
CRA10	4% Offsets	Full	Full	Full	Full	Full	Full	CRA
CRA11**	WM Levels	Excluded	Excluded	Excluded	Excluded	Excluded	Excluded	CRA
CRA12**	WM Levels	Full	Full	Full	Full	Full	Full	CRA

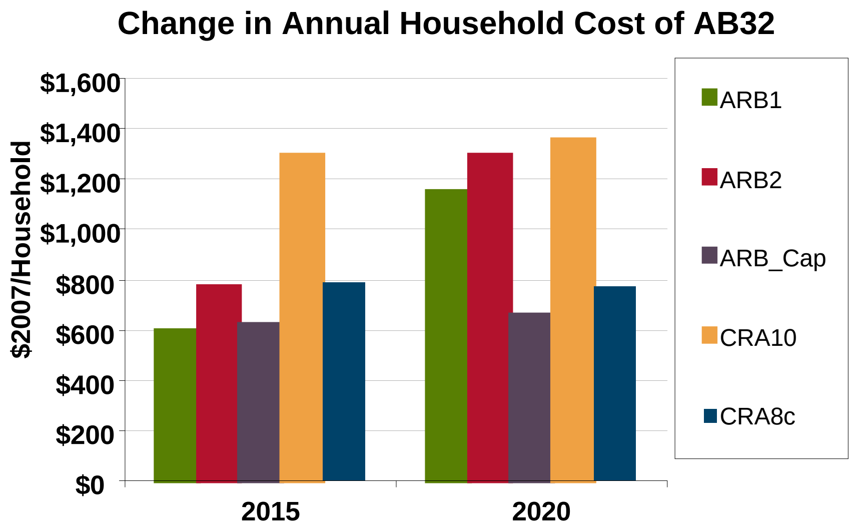
*WM Levels is the amount of offsets available under the Waxman-Markey bill
**The Waxman-Markey bill is a strawman for a national program. The effective cap for California in these scenarios depends on its allocation, which is subject to the individual policy. For CRA11 and CRA12, we assumed the allocations written into the Waxman-Markey bill.

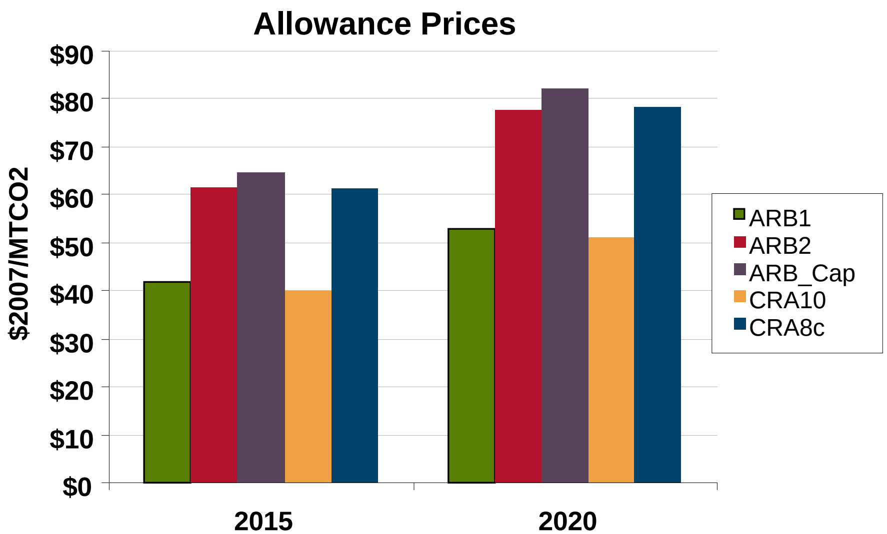
CRA Charles River Associates

Overall Impact of AB32

Overall impacts in 2020 are driven by treatment of complementary measures, offsets, and technology cost assumptions

- Allowance prices range from $50 to $80
- Cost per household ranges from $600 to $1400 per household or $200 to $500 per capita (0.5% to 1.1% of income per capita)
- Total program cost over the next decade ranges from $28B to $97B

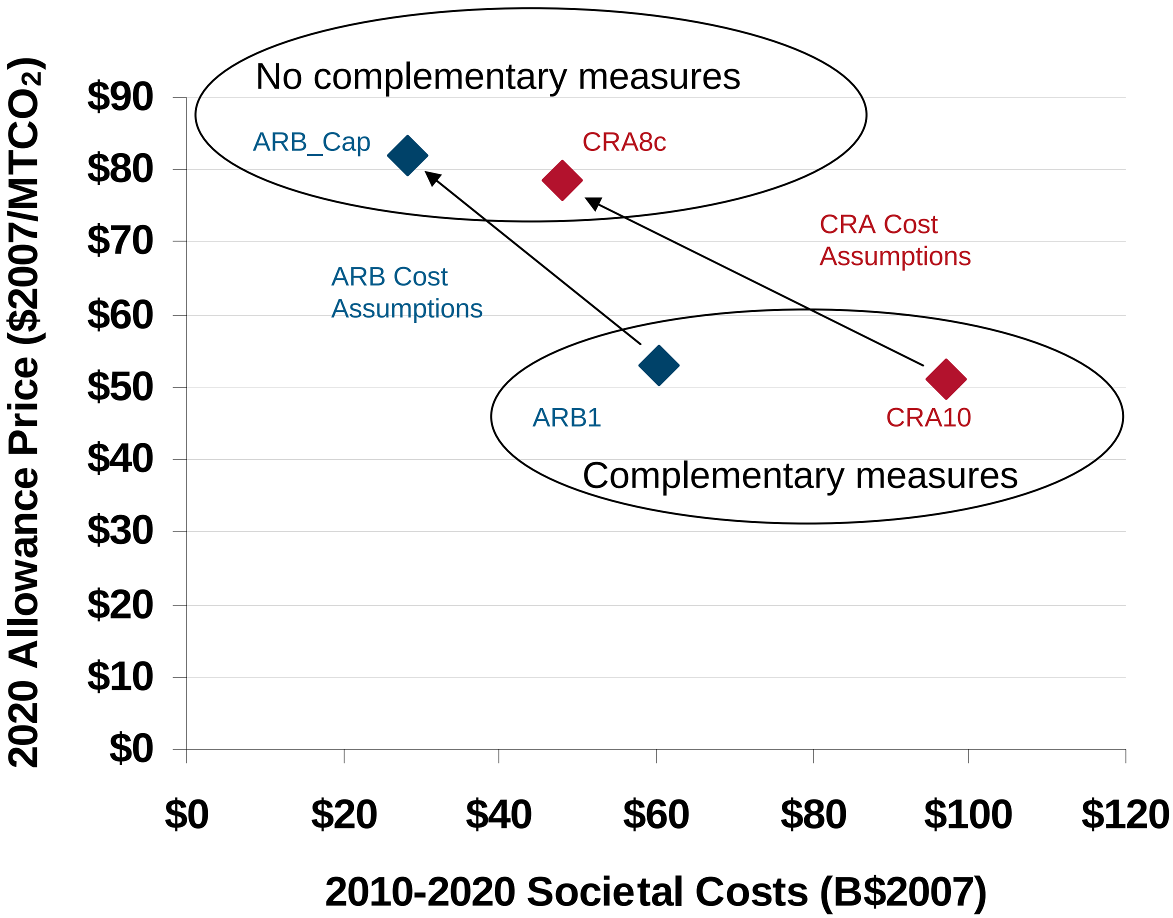




- ARB1 w/cap and trade and a full set of complementary measures has nearly the highest total program costs, despite the lowest permit prices
- Pure cap and trade scenarios (ARB_Cap and CRA8c) have the lowest total program costs despite the highest permit prices
- ARB2 w/ no offsets has 15% higher program costs and 50% higher allowance prices than ARB1
- Scenarios (CRA8c and CRA10), which account for the likely higher costs of procuring and delivering advanced low carbon fuels to the California fleet have higher total program costs

CRA Charles River Associates

Excluding Complementary Measures Cuts Costs by 50%

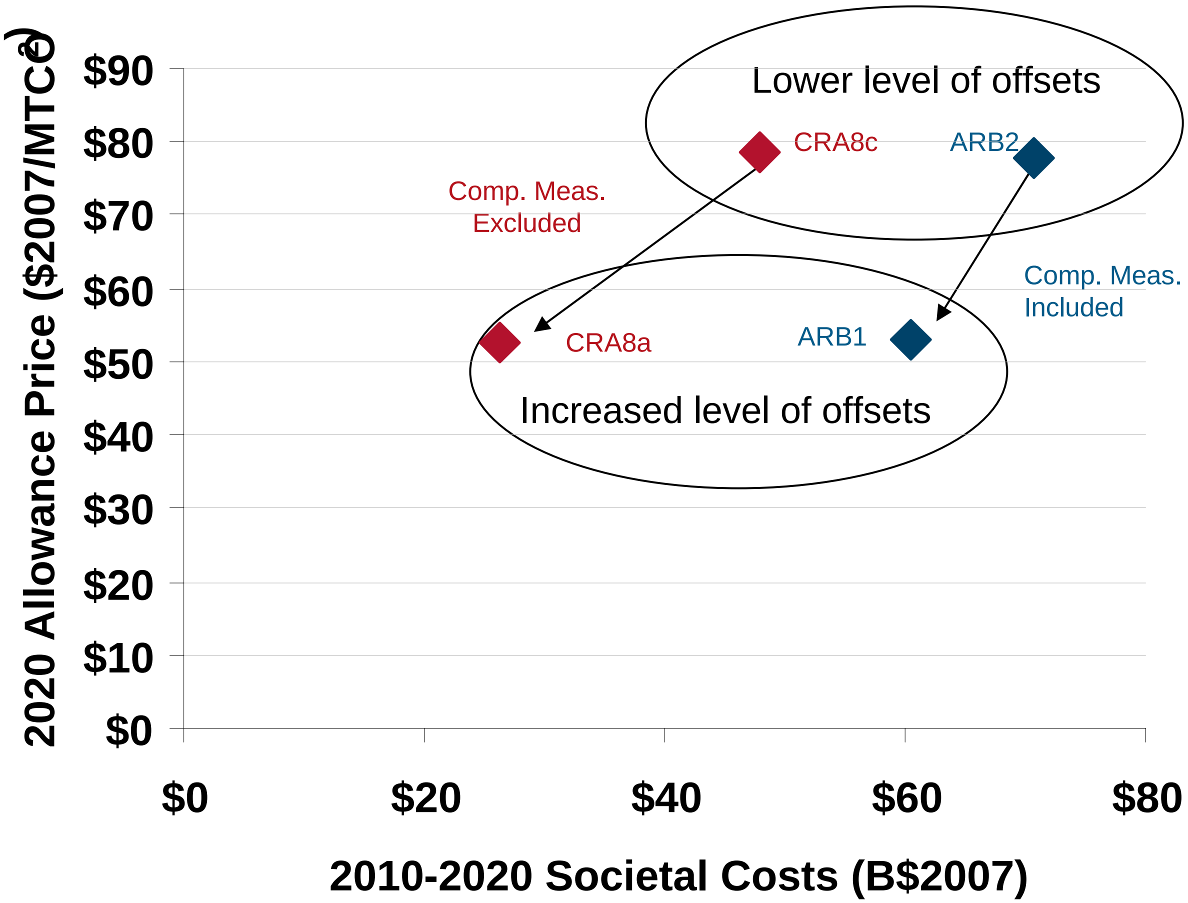


- Overall policy costs cannot be inferred from the CO_2 allowance price -- because AB32 combines a market-based program to reduce carbon emissions (*e.g.*, cap-and-trade) with command-and-control mandates (*e.g.*, the complementary measures)

- Under either CRA or ARB assumptions, the complementary measures prescribe more expensive carbon emission reductions than cap-and-trade program alone -- resulting in lower allowance prices, but higher total compliance costs.

	ARB1	ARB_Cap	CRA10	CRA8c
Complementary Measures	Included	Excluded	Included	Excluded
Cost Assumptions	ARB	ARB	CRA	CRA

Offsets Reduce Costs of AB32 Implementation by $7 to $24 Billion and Allowance Prices by about $25/MTCO$_2$

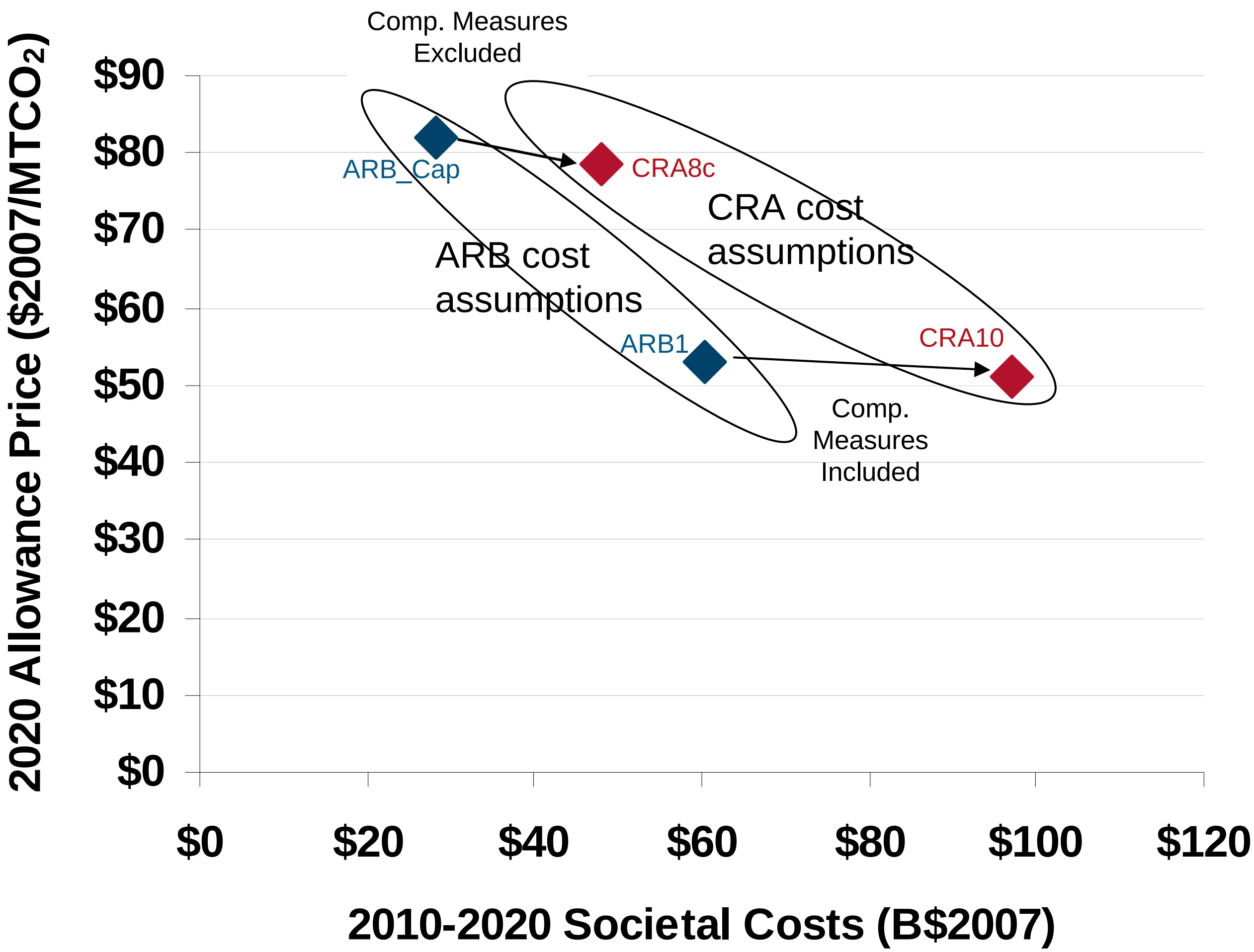


- Allowing use of more offsets from a broader range of sources can cut costs in half while preserving emission reductions
- Flexible mechanisms are valuable for mitigating cost increases due to higher than expected emissions and technology costs
- Offsets provide greater benefits when complementary measures are excluded, because offsets cannot undo the effect of costly regulatory requirements and mandates
- Offsets lessen incentives for investment to leave California by lowering allowance prices

	ARB1	ARB2	CRA8a	CRA8c
Complementary Measures	Included	Included	Excluded	Excluded
Offsets in 2020 (MMTCO2) or (%)	4%	None	55	4%

Charles River Associates

Results Are Sensitive to Assumptions about Alternative Transportation Fuels



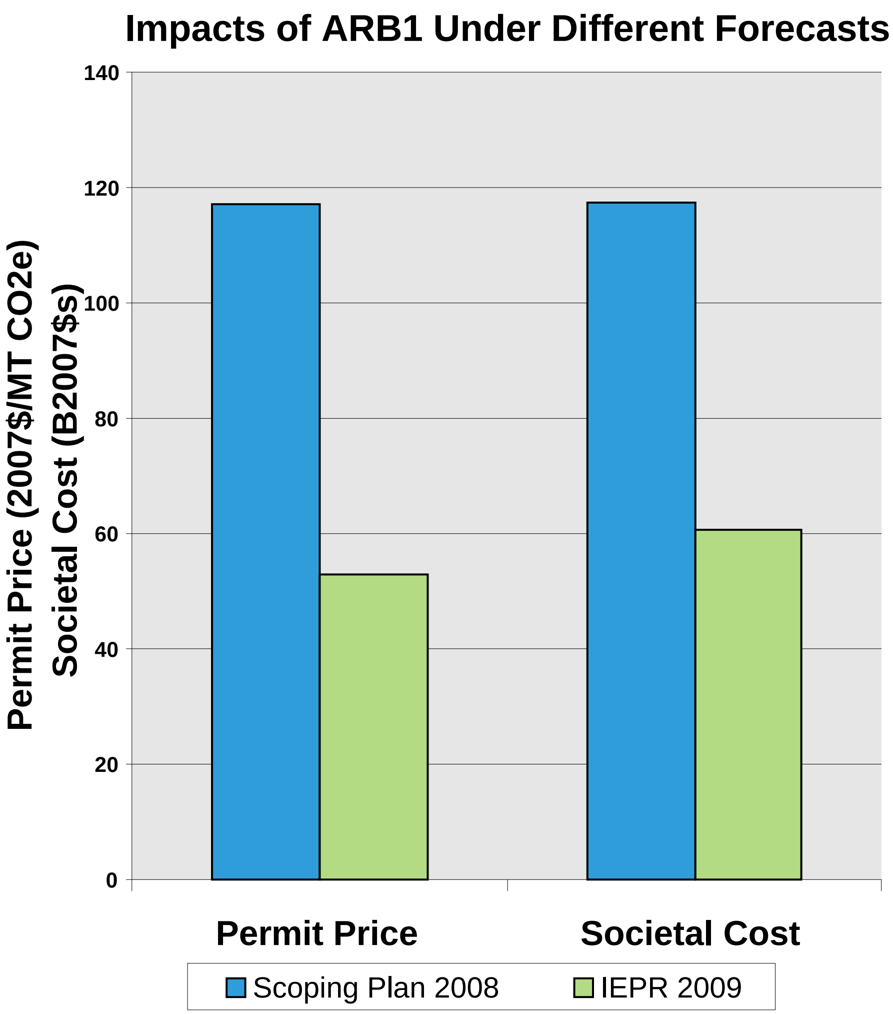
- Accounting for likely higher costs of procuring and delivering advanced low carbon fuels to the California fleet adds $20 to $40 billion dollars to the overall program costs
- When complementary measures are excluded program costs are less sensitive to technology uncertainty because the market is no longer constrained in its choice of technologies

	ARB1	ARB_Cap	CRA10	CRA8c
Complementary Measures	Included	Excluded	Included	Excluded
Cost Assumptions	ARB	ARB	CRA	CRA

CRA Charles River Associates

Economic Forecast Uncertainty Creates a Wide Range of Possible Permit Prices and Impacts

- Revisions to economic outlook based on IEPR2009 reduce projected allowance prices in 2020 from over \$100/MTCO_2e to about \$50/TCO_2e
- Social costs fall from over \$100B over 2010 - 2020 to \$60B
- Such large changes from one forecast to the next imply large uncertainties and a high value to cost containment measures, such as offsets, price collars, or safety valves



CRA Charles River Associates

Electricity and Fuel Costs Impacts Smaller when Complementary Measures are Excluded

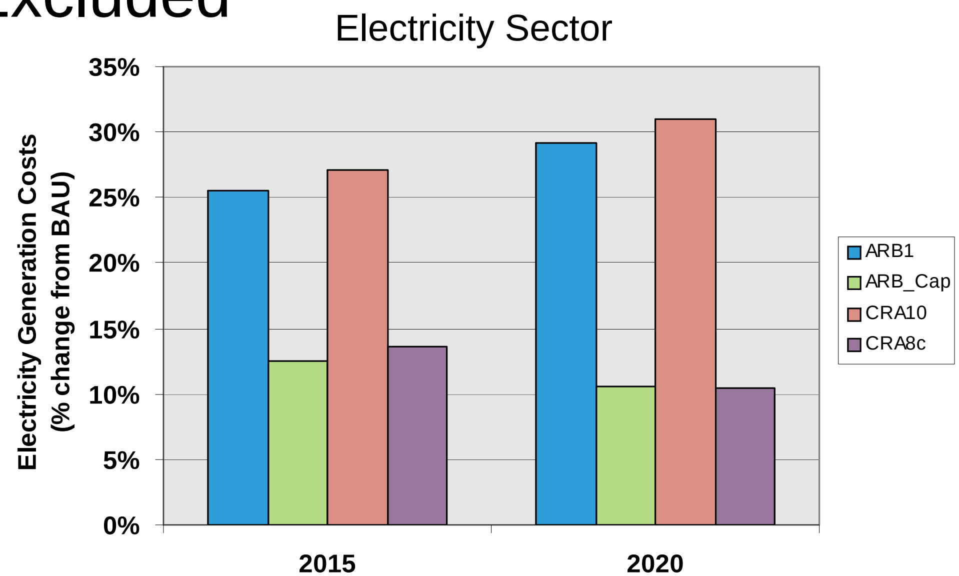
Increase in the cost of generating electricity is only half to a third as great when RES 33%, DSM, and CHP measures are excluded

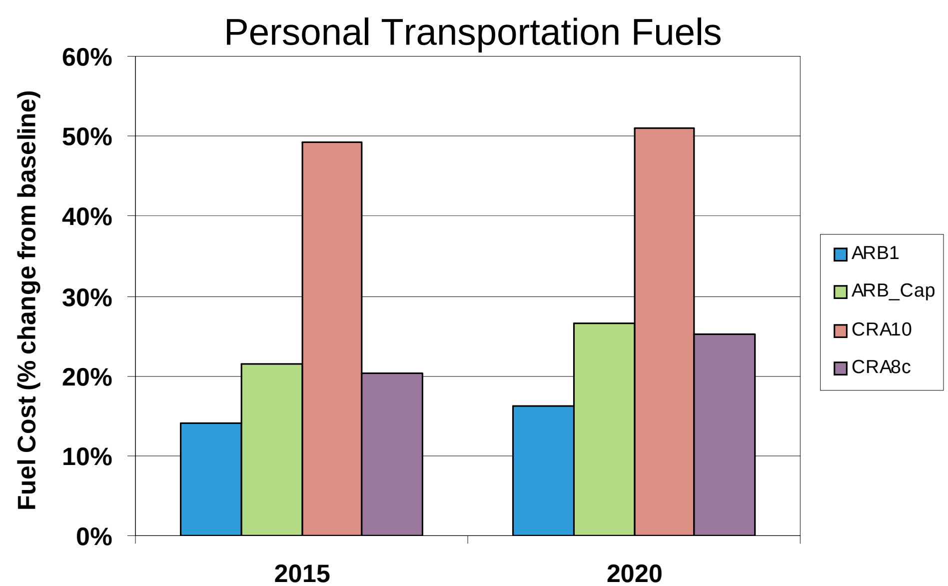
Note: Customer bills are impacted by many factors, including changes in generation costs. Electricity generation costs represent the % change in total costs to produce one MWH of electricity.

With LCFS in place, increase in prices of personal transportation fuels is about 2.5 times greater under alternative cost assumptions

With no LCFS provision, price of transportation fairly invariant to costs of alternative transportation fuels

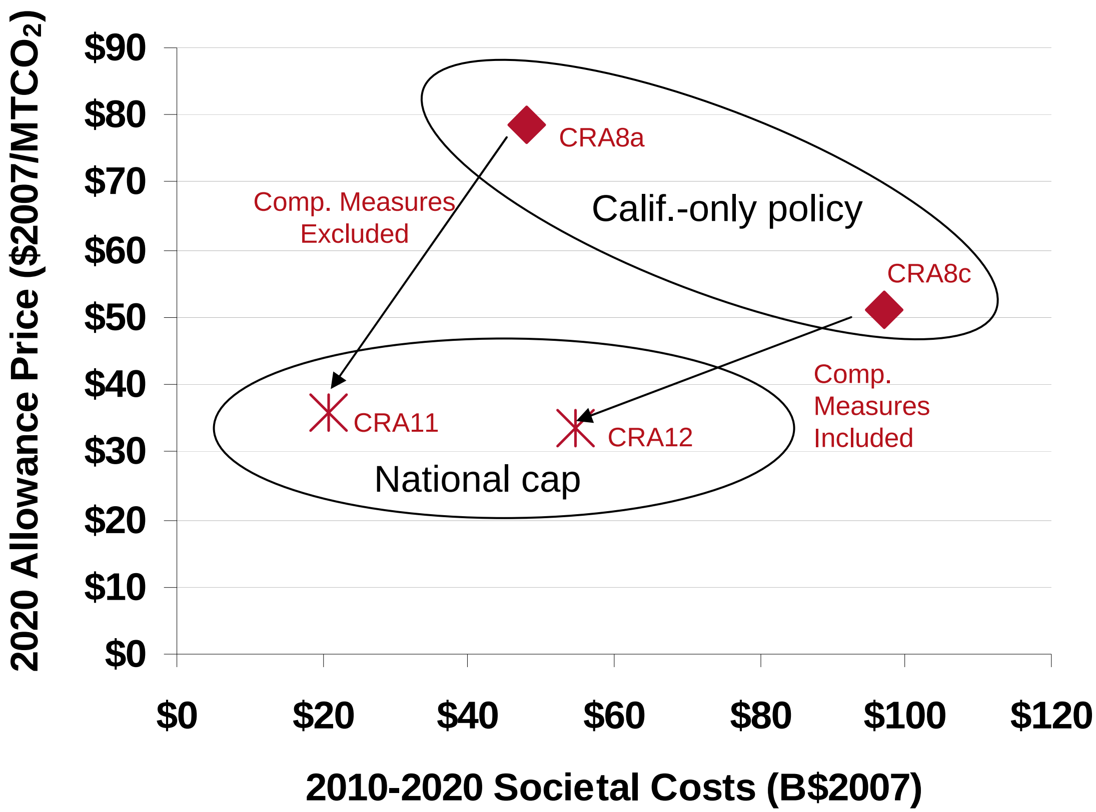
	ARB1	ARB_Cap	CRA10	CRA8c
LCFS in place	Yes	No	Yes	No
Cost Assumptions	ARB	ARB	CRA	CRA





CRA Charles River Associates

Linking California with a National Cap and Trade Policy Can Lower Costs

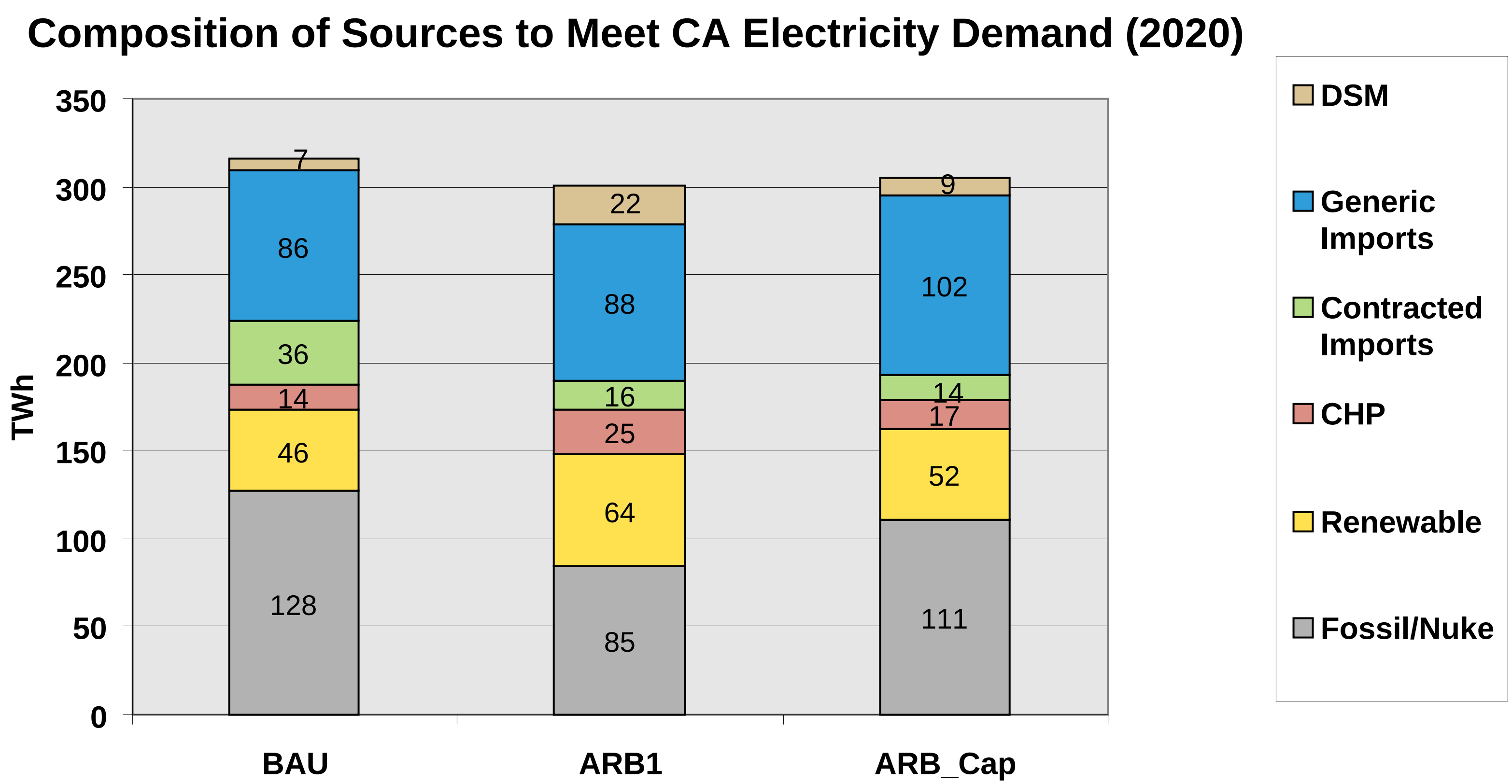


- Replacing or linking California's AB32 program with national cap like Waxman-Markey could lead to lower allowance prices, smaller increases in electricity rates, and lower social costs to California while achieving similar contributions to global emission reductions in the long run
- However, California's well-being under a national cap and trade program would depend greatly on its allocation of permits
- Higher offset limits as in Waxman-Markey lower allowance prices and reduce social costs
- Impacts will vary depending on whether California's complementary measures continue after the national cap starts

	CRA8c	CRA10	CRA11	CRA12
Complementary Measures	Excluded	Full	Excluded	Full
Policy Coverage	CA Only	CA Only	National	National

CRA Charles River Associates

Sources to Meet California's 2020 Electricity Demand



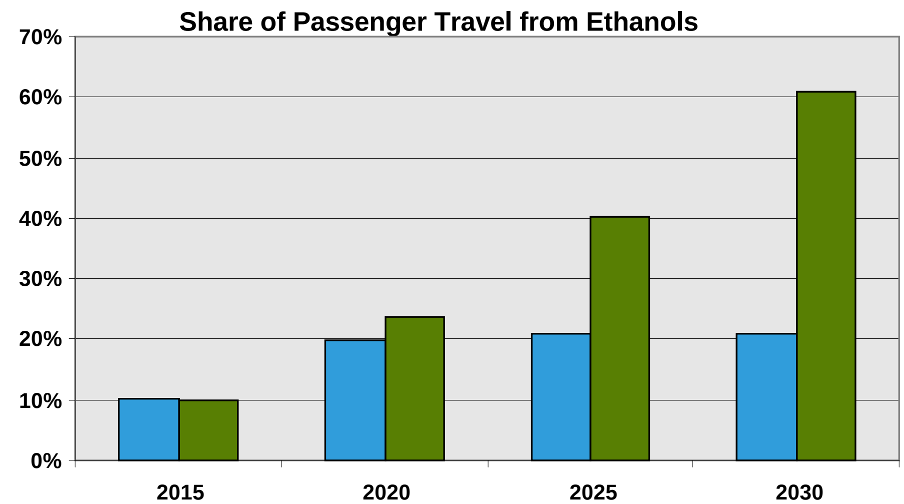
Under our assumptions, the cost-effective levels of new CHP and DSM/EE (those achieved under pure cap and trade, ARB_Cap) are below the levels required by the complementary measures:

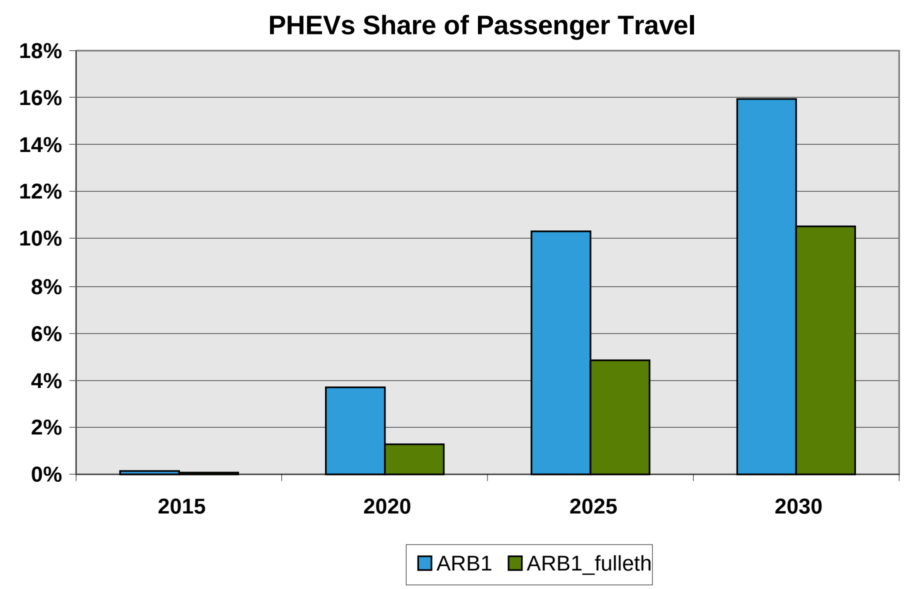
- Cost-effective CHP 17 TWh vs. Complementary measure's 30 TWh
- Cost-effective DSM 9 TWh vs. Complementary measure's 22 TWh

Given the great uncertainty in DSM/EE and CHP costs, further analysis should be conducted to estimate the likely range of cost-effective levels of DSM/EE and CHP.

Effect of Blend Wall Constraint* on LCFS Requirement

- Imposing LCFS no longer allows the market to determine where emission reductions will occur
- With low costs and assuming no blend wall, low carbon fuels are adopted in response to allowance prices, and penetration of PHEVs/EVs is greatly reduced
- Accounting for costs to exceed the blend wall, low carbon fuels are restricted and emission reductions come through forced reductions in fuel consumption and switch to PHEVs/EVs





	ARB1	Fulleth
Blend wall constraint exists	Yes	No

(*) "Blend wall" is the maximum possible volume of ethanol that can be blended into U.S. motor gasoline. Exceeding a volume of 10% to 15% is considered to exceed the current blend wall.

Comparison of ARB and CRA Results

	Modeling Team	Scenario		
		ARB1	ARB2	ARB5
Allowance Prices (2007$ Per $MTCO_2e$)	CRA	$53	$78	$83
	ARB	$21	$106	$102
Change in Household Income (2007$ Per Capita)	CRA	-$414	-$467	-$298
	ARB	$30	-$60	-$270
Change in Household Income (%)	CRA	-0.9%	-1.0%	-0.6%
	ARB	0.1%	-0.1%	-0.6%

- ARB and CRA find similar costs under ARB5 – the ARB scenario which has the most limited degree of complementary measures
- Adding in complementary measures – moving from ARB5 to either ARB1 or ARB2 – result in increased costs under the CRA modeling system and decreased costs under the ARB modeling system

Difference in Assumptions about Market Failures Explain Much about Differences Between ARB and CRA Results

- ARB and CRA models embody different views about the prevalence of market failures:
  - ARB's model assumes that market failures are pervasive in individuals' and businesses' decisions regarding energy use. That is, individuals and corporations make incorrect decisions because they either do not understand or do not bear the full cost of those decisions. With this perspective, there are benefits to imposing the complementary measures -- or energy efficiency standards in general -- because they can correct these market failures (if such measures are designed well). Thus, standards can lower a policy's net costs, i.e. the benefits measured in forgone energy payments would exceed the costs of the more efficient technology.
  - CRA's model reflects a different theoretical perspective. Much economic literature supports the opposite view that market failures, though present, are relatively small.[1] Thus, market-based approaches that have maximal flexibility are more efficient than technology standards that reduce the compliance options available to individuals and corporations. Furthermore, imposing efficiency standards leads to market distortions.
- As a result of these differing methodological assumptions, ARB and CRA models project opposite cost implications for scenarios containing complementary measures. Relative to a pure cap and trade policy, CRA finds that policies that also include complementary measures have higher costs; ARB finds that layering complementary measures onto a cap and trade policy produces lower costs than under pure cap and trade.
-

  [1] For example, see "Analyses of California Climate Change Policy: Are They Too Good to Be True?," by Robert N. Stavins, Judson Jaffe, and Todd Schatzki, September 2006 and "Demand-Side Management and Energy Efficiency in the United States" by Loughran and Kulick, *The Energy Journal* (Vol. 25 No. 1), 2004.

Key Insights

- Allowing offsets leads to significant cost reductions
  - Allowing use of offsets from a broader range of sources can reduce costs substantially while preserving global emission reductions
  - The potential cost continues to fall as more and more offsets are made permissible.
  - Offsets also lower allowance prices and thus reduce disincentives for investment in California
- Sensitivity of impacts to technology costs and to emission forecasts
  - Meeting the AB32 goals is about 40% more costly when accounting for overcoming the blend wall and the likely higher costs of procuring and delivering advanced low carbon fuels to the California fleet
  - Costs are about half as much under the IEPR 2009 emissions forecast, than under the 2008 Scoping Plan, which used the IEPR 2007 emissions forecast
  - Cost containment mechanisms such as offsets and price collars can help manage the uncertainty around the cost of complying with AB32
  - The more costly it is to meet the AB32 goals the greater the benefits of having offsets available

Key Insights (cont.)

- Complementary measures raise costs of achieving AB32 goals substantially
  - The higher cost of meeting AB32 targets when complementary measures are also imposed is obscured because these policies lower allowance prices at the same time that they raise total social costs
  - The most costly of the complementary measures are the 33% RES and LCFS; eliminating these two measures would have the largest benefit to the economy of California under AB32
  - Maintaining complementary measures under a national program like Waxman-Markey has a minimal effect on emissions but raises costs to California by more than 50%
- Interaction of offsets with complementary measures
  - Offsets have less power to reduce policy costs when complementary measures are in place because some of the flexibility that offsets provide is eliminated by the direct mandates for certain control measures under the complementary measures

Key Insights (cont.)

- 33% renewable energy standard (RES 33)
  - RES 33 in isolation causes a 10-15% increase in the total cost of generation
  - The model finds some purchasing of RECs from other California programs to be cost-effective (4%-5% of obligation)
  - Intermittent resources comprise between 12%-15% of generation suggesting integration of intermittent resources may be manageable
  - Cap & trade lowers the average cost of emission reductions in the electricity sector compared to a 33% RES mandate, so that the electric sector adopts larger emission reductions that are made economic by the allowance price
- Low carbon fuel standard (LCFS)
  - LCFS in isolation causes transportation costs to increase California by 25%
  - During the 2015 – 2020 time frame, limited availability of qualifying fuels causes large pump price increases to reduce total transportation fuel use to levels consistent with low carbon fuel supply
- Energy efficiency and demand side management (EE/DSM) mandate
  - Some EE/DSM measures are cost-effective, but it appears that attaining this complementary measure's 22,000 GWh requires adoption of EE/DSM measures that are not cost-effective at the prevailing allowance prices
- Combined heat and power (CHP) goal
  - Some CHP options are cost-effective in the baseline and under cap and trade, but it appears impossible to achieve the 30,000 TWh goal using only cost-effective CHP projects, even at the allowance prices under cap and trade

Key Insights (cont.)

- Alternative transportation fuels
  - If low carbon fuels are abundant and available at low cost with no additional cost impacts for introducing them into the fleet, then:
    - Costs of compliance are greatly reduced: LCFS is not restrictive
    - Penetration of PHEVs/EVs is greatly reduced
    - Smaller reductions are required in electric sector, which means electricity imports can remain closer to baseline levels
  - If costs for infrastructure and vehicles to go past the blend wall are included:
    - Costs of compliance are greater
    - PHEVs/EVs are the main method of complying with LCFS in the long-run
    - More reductions are required from other sectors
- Electric sector operations
  - The higher the cost of reductions are in the non-electric sector relative to the electric sector, the more reductions will be required from the electric sector, which means more in-state zero or low emitting generation must be built or more direct contracts are needed for units with emission factors less than the average emissions factor associated with imported electricity

Key Insights (cont.)

- Replacing or linking California with a national cap and trade can lower costs
  - Higher offset limits as in the Waxman-Markey Bill lower allowance prices and reduce social costs.
  - Replacing or linking California's AB32 program with a national cap like Waxman-Markey could lead to lower allowance prices, smaller increases in electricity rates, and lower social costs to California while achieving similar contributions to global emission reductions in the long run
  - Impacts of such a replacement or linking with a national cap depends on whether or not California's non-cap and trade programs are continued
    - If California excludes its complementary measures, then we find total societal cost from 2010-2020 falls by about $75 billion
    - But if California retains its complementary measures, then we find total societal costs from 2010-2020 fall by $42 billion or only about 60% of the drop when measures are excluded
  - The benefits of California participating in a national cap and trade program will depend critically on California's allotment of permits

CRA Performed this Work at the Invitation of and in Collaboration with the California Air Resources Board

In response to Resolution 08-47, Cal/EPA and ARB staff asked CRA to collaborate with the ARB staff in analyzing the impacts of the Scoping Plan, to provide a range of perspectives on how to conduct such an analysis

Cal/EPA staff assisted CRA in assembling the requisite funding by helping define the value of the collaborative working relationship to potential funders

The following organizations provided funding that enabled CRA's collaboration with California ARB to proceed: BP North America, Chevron, ConocoPhillips, Pacific Gas & Electric, Sempra Energy, and Southern California Edison

The following CRA staff contributed to this analysis: Paul Bernstein, Scott Bloomberg, Ken Ditzel, Julian Lamy, David Montgomery, Michael Neimeyer, Anne Smith, Sugandha Tuladhar, Mei Yuan

About Charles River Associates (CRA)

Charles River Associates® is a global consulting firm specializing in litigation, regulatory, financial, and management consulting.

CRA advises clients on economic and financial matters pertaining to litigation and regulatory proceedings, and guides corporations through critical business strategy and performance-related issues. Since 1965, clients have engaged CRA for its unique combination of functional expertise and industry knowledge, and for its objective solutions to complex problems.

Headquartered in Boston, CRA has offices throughout North America, Europe, the Middle East, and Asia. Detailed information about Charles River Associates, a registered trade name of CRA International, Inc., is available at http://www.crai.com.

Appendices

Additional Detail on MRN-NEEM Model Components

Multi-Region National (MRN) Model Overview

- MRN is a Computable General Equilibrium (CGE) model
- MRN models interactions between profit-maximizing producers and rational consumers in the US economy
- It is a fully dynamic forward looking model
  - Producer and consumer expectations are consistent with future model outcomes
  - No unanticipated shocks along the way
- The model solves for prices and quantities such that all markets clear (demand = supply)
- Sectoral detail (flexible)
  - Developed with energy sector detail needed for climate policy analysis
  - Sectoral breakdown was developed to reflect range of vulnerability to climate policy
- Regional detail *(*flexibility*)*
  - US divided into 8 regions plus California
- Currently run in 5-year time steps through 2050 *(*flexibility*)*

MRN Inputs Based on Public Macroeconomic Data

Data	Source
Input-output tables of US economy at state level	IMPLAN *
Energy flows and prices	EIA
Tax rate and revenue data	National Bureau of Economic Research's TAXSIM model
Forecasts of energy prices and quantities	EIA (AEO)

*** CRA corrects IMPLAN's regional economic data to make them usable for energy analysis**

- **Raw IMPLAN data are inconsistent with energy quantities and prices reported by EIA**
- **CRA modifies the IMPLAN energy accounts to match EIA's state-level energy data**

CRA Charles River Associates

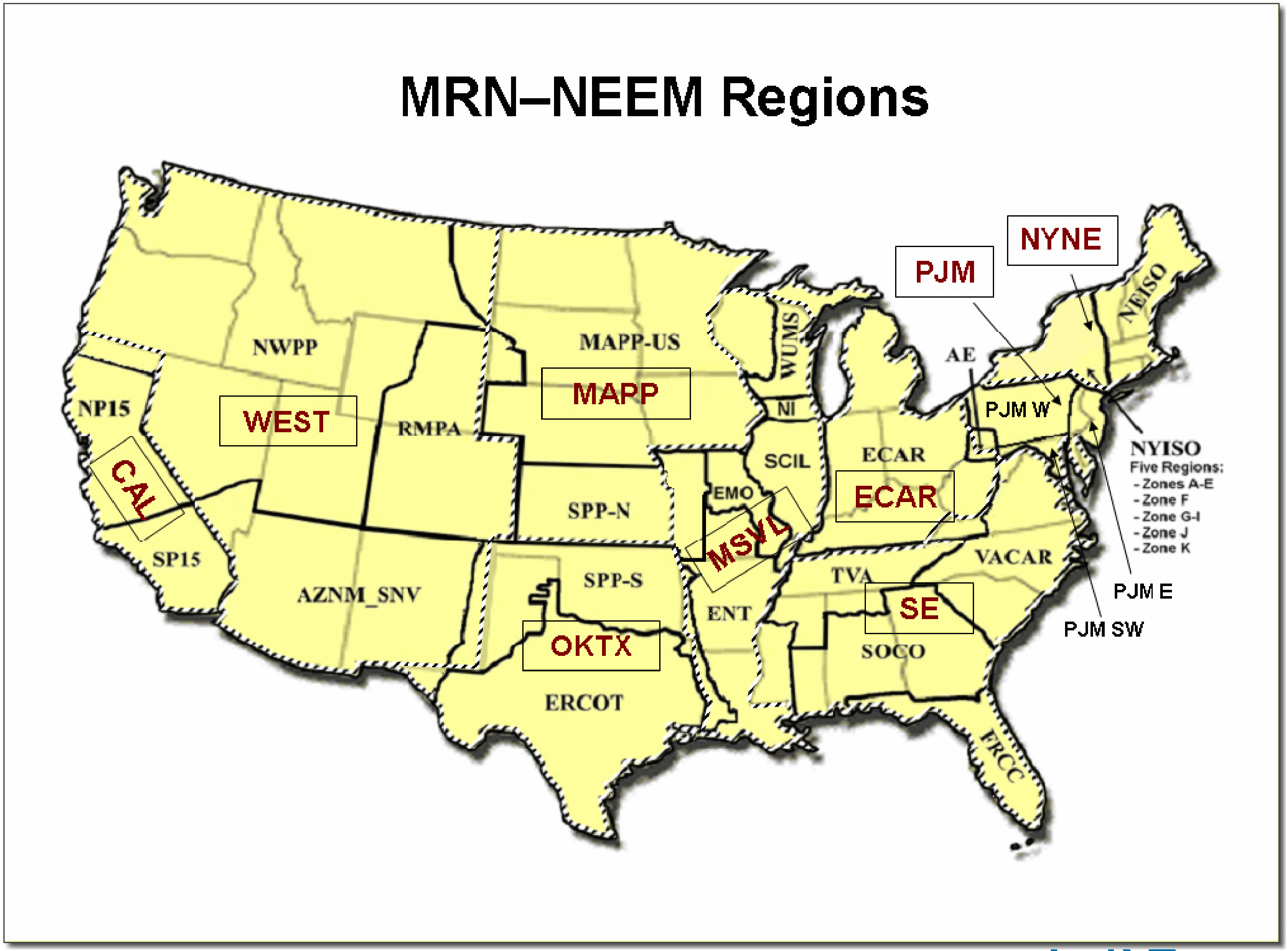
Typical MRN Outputs

- Consumer impact
  - "welfare change"
  - consumption change
- CO2
  - Emissions
  - Carbon price
- Macroeconomic
  - Consumption
  - Investment
  - GDP
  - Wages
  - Real consumption per household
  - Employment
- Sectoral
  - Output by region
  - Prices by region
  - Employment by region
- Energy (crude oil, refined products, natural gas, coal and electricity)
  - Wellhead (and ex-refinery prices) by region
  - Delivered prices by sector and region
  - Quantity produced by region
  - Quantity consumed by region
- Government Budget
  - Required tax change to maintain budget balance
- Trade
  - Terms of trade with other regions and abroad
  - Imports and exports
  - Capital flows

NEEM Overview

- NEEM stands for “National Environmental and Electricity Model”
- Covers entire US electric power system – and associated coal supplies
- NEEM builds new capacity (and adds environmental retrofits) and dispatches generation assets to minimize cost of meeting demand for electricity subject to environmental regulations and reserve margin requirements
- Designed to simulate impacts of policy changes on:
  - Decisions about the timing and mix of new generating capacity
  - Retirement and mothball decisions
  - Environmental compliance: RES, MACT, tax, cap and trade
  - Fuel choice in new units and fuel switching in existing units
  - Dispatch decisions (20 period load duration curve)
- 27 US and 4 Canadian regions (flexible)
  - Determined by transmission interfaces - 28 NERC regions/sub-regions including North of Path15 and South of Path 15
  - Additional geographic structure within and across regions as needed for policy simulation
- 20 Load blocks in which electricity is dispatched
- Time steps (flexible)
  - Operates over a 40 year time horizon matching MRN; some flexibility for additional time steps between MRN equal intervals.

MRN-NEEM Region Map

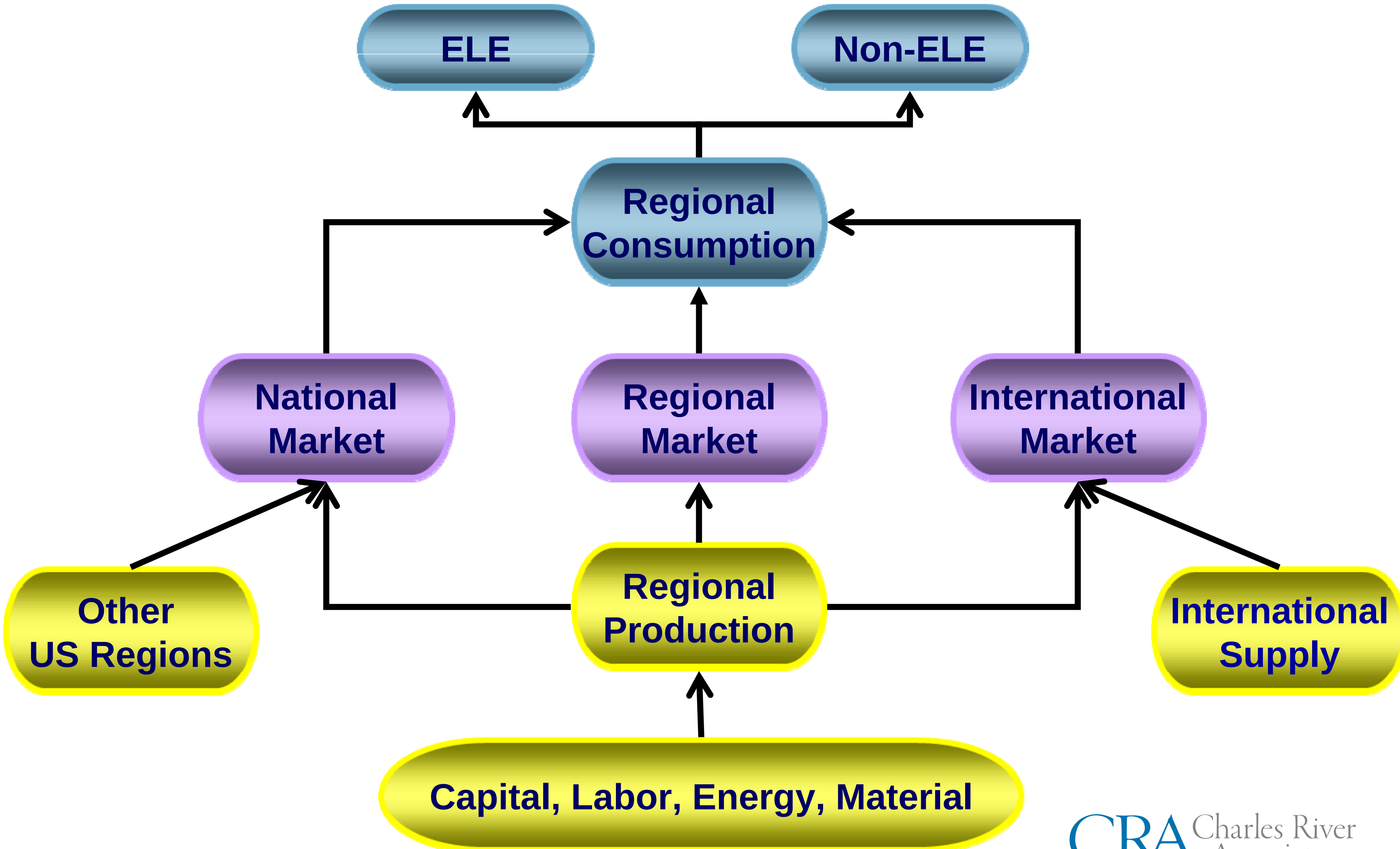


River Associates

Key Outputs from NEEM

- Electric sector results (national and regional)
  - New capacity additions and retirements
  - Electricity prices (total and by component) by region, year & load block
  - Environmental allowance prices
  - Capacity prices
  - Coal prices by coal type
  - Environmental retrofits
  - Transmission between power pools
  - REC prices (for RPS)
- Unit-level results
  - Generation and capacity factor
  - Emissions and emission rates
  - Fuel consumption
  - Energy and capacity revenues
  - Costs (fuel, VOM, FOM, allowance costs, depreciation on incremental capital)

How Goods Flow in the Economy



Comparison of CRA and ARB Model Approaches

Model Scope: MRN-NEEM vs. ENERGY2020-EDRAM

	ARB	CRA
Industries	More detailed than CRA	Energy: Coal, Crude, Ele, Nat gas, RPPs; Non-Energy: Agr, Construction, EIS, Man, M_V, Services, Trucking, Other Trn
Dynamics	ENERGY2020 recursive dynamic simulation to 2020 EDRAM static Soft link btwn Energy and Macro models	Dynamic 2010-2050 Fully integrated energy and macro models
Regions	ENERGY2020 – WECC (can include the US and Canada); EDRAM – California	U.S. - 9 regions w/ CA as one region

Model Assumptions: ARB vs. CRA

	Harmonized	CRA
Emissions Forecasts	IEPR 2009	IEPR 2009 2008 Scoping Plan
Generation Characteristics	October E3;	Same
Ele Demand	IEPR 2009	Same
Low Carbon Fuels	LCFS ruling for emission factors ARB/ICF fuel costs	Higer Emission Factors Higher Fuel Costs
Fuel prices	IEPR 2009	Same
PHEVs	Excluded	Included
Veh. Eff.	On-road	Same

CRA Charles River Associates

Market Efficiency: MRN-NEEM vs. ENERGY2020-EDRAM

- ENERGY2020 (ARB):
  - Does not represent the economy as a competitive market equilibrium based on choices of informed, utility and profit maximizing agents; therefore efficiency standards can be welfare improving
  - The calculations regarding the adoption of energy efficiency investments by residential and commercial customers are based in part on the cost and savings calculation, but also incorporate qualitative choice theory. So, residential customers do not all immediately adopt all measures that appear to be cost effective. The rate of adoption increases as the cost effectiveness improves. As a result, the penetration of energy efficiency measures slowly ramps up in response to improved cost effectiveness.
- MRN-NEEM (CRA):
  - Assumes no market failures except as addressed by DSM; therefore, energy efficiency standards must cause welfare to decline
  - Energy efficiency standards are represented as a constraint that forces a higher capital to energy ratio in a particular activity. This higher ratio exceeds the optimal ratio that would be observed in the market in the absence of standards and hence must raise costs
  - DSM supply curve provides for some conservation measures with cost of energy savings less than the avoided cost of electricity.
  - Allowances: Assume 100% auction. Flexibility in how to recycle revenues (e.g., can return lump-sum to households, can return to sectors, can use to lower pre-existing taxes, or can use to fund government programs)

Complementary Measures:
MRN-NEEM vs. ENERGY2020-EDRAM

Measure	ARB	CRA
CHP	Costs represented in similar manner as other techs. in ENERGY2020	Generation represented in NEEM. Resources required for CHP accounted for in MRN
DSM/EE	Marginal device efficiency is increased. Cost equal device costs at greater efficiency. Savings equal decrease in fuel cost for higher efficiency device	Supply curve for efficiency included in NEEM. Resource costs accounted for in MRN. Efficiency target for non-electric gas consumption set in MRN by requiring a higher capital to gas ratio in production. DSM allows possibility of negative cost options
RES	Represented in ENERGY2020 Allow for purchases of RECs	Represented in NEEM as a linear constraint on % of renewable generation Allow for purchases of RECs
Pavley	Standard represented in ENERGY2020 Costs and emissions passed to EDRAM	Costs represented in MRN as a trade-off between capital and energy; fully integrated
VMT	VMT reduction included based on anticipated savings from improved land use planning related to SB 375 implementation and related efforts	Represented as a cost adder on travel to reduce VMT
LCFS	Satisfied with composite biofuels no EVs	Two biofuels for trucking and personal transportation; PHEVs available for LDVs

CRA Charles River Associates

Details of Key Input Assumptions

Transportation Fuel Assumptions

	Emission Factor (g CO2e/MJ)	Fuel Costs relative to Gasoline/Diesel				
	2020	2010	2015	2020	2025	2030
Gasoline	96	1.0	1.0	1.0	1.0	1.0
ARB - Ethanol	43	1.2	1.2	1.1	1.1	1.1
CRA - Corn Ethanol	82	2.0	2.0	1.9	1.8	1.7
CRA - Low GHG	19	4.0	3.2	2.7	2.5	2.4
Diesel	95	1.0	1.0	1.0	1.0	1.0
ARB - Biodiesel	32	1.2	1.2	1.1	1.1	1.1
CRA - Soy Biodiesel	79	1.9	1.9	1.8	1.8	1.7
CRA - Adv. Biodiesel	21	4.0	3.2	2.7	2.5	2.4

CRA Charles River Associates

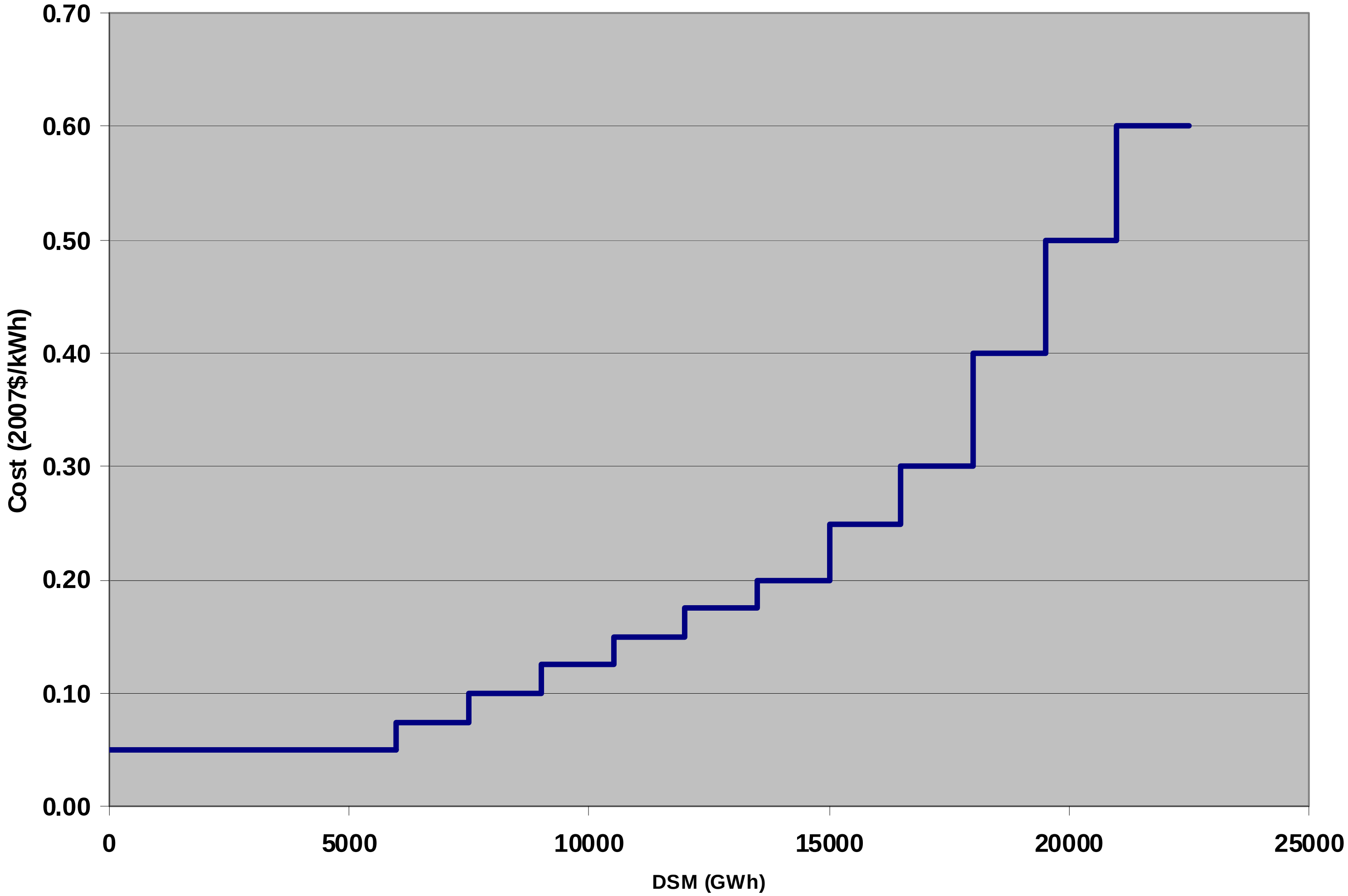
CRA's CHP Assumptions

	CHP Technologies			
	Tier 1	Tier 2	Tier 3	Tier 4
Capital Cost ($2007/kW)	$3,716	$1,654	$1,516	$1,290
FOM (2007$/kW-yr)	25	7.5	6.0	5
VOM (2007$/MWh)	6.0	6.0	4.0	3.5
Net Heat Rate	7013	6007	5427	5180
Overall efficiency	49%	57%	63%	66%
Capacity Factor	41%	75%	75%	88%
Capacity Assumptions under ARB Scenarios				
Potential Capacity (MW)	1606	515	579	1700
Generation (TWh)	5.7	3.4	3.8	13.0
Capacity Assumptions under CRA Scenarios				
Potential Capacity (MW)	1967	630	710	1200
Generation (TWh)	7.0	4.1	4.7	9.2

Sources: http://www.epa.gov/CHP/documents/catalog_chptech_gas_turbines.pdf;
ARB 2008 SP App. VOL I: App. D: Sept 23, 2008 Western
Climate Initiative Design Recommendation. App. B: Econ. Modeling Results. P.10
E3 33% RPS data base

CRA Charles River Associates

CRA's Energy Efficiency/DSM Supply Curve Assumption



Sources: California energy demand 2010-2020, staff revised forecast Second Edition (CEC 2009)
DSM Findings Program Evaluations for NorthWestern Energy (Nextant 2006)
DSM and EE in the US (Loughran and Kulick 2000)

CRA Charles River Associates