Edward C. Myers, Consultant
456 Vine Avenue
Sebastopol, CA 95472

Office: 707-861-6649
Mobile: 707-575-3303
Email: ecmc@sonic.net

Climate Safe Modeling and Graphics Methodology Summary

Project: Preliminary GHG Modeling and Visualization for Climate Safe California 2030

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Background

The Climate Center is initiating a Climate Safe California policy program to promote the fast reduction of in-state greenhouse gas (GHG) emissions. This effort requires visual communication graphics to enable interested allies and policymakers to more readily grasp the strategy of the program, and how the state economy and infrastructure will have to evolve for an 80% reduction from 1990 emissions levels by the year 2030, along with sufficient carbon sequestration to meet net zero GHG going into the atmosphere.

The primary approach for a visual communications tool is the "wedges" graphic concept employed first by Pacala and Socolow to illustrate how the various components of GHG reduction strategies combine to achieve an overall level of emissions reduction. This project augments the Pacala wedges approach, intended to show future action, to include wedges for past successful energy efficiency policies, such as auto and electrical efficiency policies, that also reduced GHG emissions. We also augment the wedge graphics with a stacked column graphic approach, to allow easier comparisons of different emission reduction and sequestration scenarios.

Methodology

To the extent feasible, modeling of the GHG emissions required to develop the graphics is based on available data that has been accepted by the scientific and policy making community. This data is retrieved from various government and other websites, imported into Microsoft Excel 2010 spreadsheet software, and analyzed in a single modeling spreadsheet to produce visuals in wedge trend and bar chart graphic sheets. The data sources are documented in footnotes in the modeling spreadsheet.

The GHG emissions scope is limited to direct California emissions, as enumerated in the 2017 California Air Resources Board (CARB) GHG Inventory report. No consumption based or other indirect emissions are included in the modeling and graphics. The modeling and graphics baseline is the measured 1990 – 2017 emissions inventories prepared by CARB. All GHG estimates, such as pre 1990 and post 2017 emissions, hypothetical cases such as what emissions might be no policy impacts, and the Climate Safe program modeling, use the CARB inventory data as a "springboard".

The GHG emissions used in the Climate Safe modeling are broken down by economic sector, as defined by the CARB inventories: Agriculture and Forestry, Commercial, Residential, Electricity, Industrial, and Transportation. Since Commercial and Residential are relatively small emitters compared to the others, and similar efforts will be required to reduce their emissions, in this model they were lumped together as one category for modeling and graphics - Commercial+Residential.

The time frame for the modeling and graphics is 1960 to 2050. In the 1960s, no significant energy conservation policies had been enacted, which could have impacted GHG emissions. There were plenty of petroleum reserves, no geopolitical constraints, or effective supply cartels – a free-market, no energy policy baseline of sorts. Then, the oil price shocks of the 1970s birthed the Corporate Average Fuel Economy (CAFÉ) policy standards to improve auto efficiency, and in turn, reduce CO2 GHG exhaust emissions. In the same time frame, California adopted electrical end-use efficiency standards, and related programs, which made a significant dent in the growth of electricity demand over time, and consequently, slower GHG emission growth, as fewer fossil fueled thermal power plants were needed. The year 2050 was chosen as the endpoint, as it is the timeframe when, according to GHG reduction targets of the last 20 years, we must drastically reduce or stop emitting GHG's into the atmosphere, to prevent the worst outcomes.

<u>Excel Workbook Modeling Summary</u>

The modeling and graphics workbook filename is Wedges Calculation Visualization.xlsx. The spreadsheet model used to create the graphics is in the Data Analysis tab. The first four columns (A-D) are the actual and estimated GHG baselines. To go back in time, we assumed GHG emissions grew with population at the 1990 per capita emissions rate. The population data for California use each decade's census with linear interpolation between decades. To provide a future GHG baseline from which the Climate Safe program would reduce emissions, we assumed the 2017 emissions would stay constant to 2050.

California's electrical efficiency policies, and the US government's CAFÉ auto mileage standards, were not originally implemented with GHG reductions as the main driver. However, our modeling demonstrates that these policies to reduce primary energy demand (mainly from burning fossil fuels) have already made a significant dent on GHG emissions. Therefore, these were included to show that energy policy has already had a significant real world impact. This may help convince skeptics that further policy oriented approaches, such as Climate Safe, can also have a real impact.

Today, California has significantly lower electricity usage per capita than the US as a whole. This is believed to be due in large part to California's electrical end use efficiency standards and programs that were started in the 1970s. We have used this usage gap to estimate how much greater hypothetical emissions would be if Californians used electricity at the same level as all US citizens. Columns E through G calculate the per capita difference each year, based on US Energy Information Administration data that extends from 1960 to present day. This is scaled by population to produce a statewide energy usage reduction (column H), then converted to GHG reduction using the average GHG intensity of electricity generation between 2000 and 2005 (column I), which is added to the baseline GHG for plotting as the hypothetical GHG emissions if Californians used as much electricity as the rest of the US (column J). On the "Wedge Net GHG" chart the gap between this trend and the baseline GHG trend forms a historical wedge (albeit ragged) which we attribute to California's electrical efficiency policy.

To model the GHG impact of auto mileage standards, we start with EPA data on US average light vehicle emissions starting in 1975 (column K), assuming California has the same vehicle mix. There was a steady reduction in emission rates after 1975, so we use the 1975 emission rate as a baseline for the CAFÉdriven reduction in all subsequent years (column L). This reduction is scaled by Caltrans vehicle miles data (column M) to produce an estimate of how much more GHGs we would emit if we were still driving the 1975 vehicle fleet (column N). To create a second historical wedge, column N is added to the "no electrical efficiency" GHG trend (column J) to create the upper trendline (column O) for this wedge. On the wedges graphic, this wedge is attributed to Vehicle Efficiency.

The third and final historical wedge is for the impact of the state's Renewable Portfolio Standard (RPS) for electricity generation, which was implemented to directly address GHG reduction. California's progress toward cutting back on non-renewable primary energy sources (such as coal and natural gas) for electricity generation has been significant. There is some uncertainty how much progress can be attributed directly to RPS and not market forces, as power from utility scale wind and solar PV is now less costly than power from new natural gas thermal plants. For this model, we relied on a state legislative analyst report that attributed 17-18 million metric tonnes (MMT) of GHG reduction to RPS between years 2006 and 2018. We took the 18 MMT reduction, and used linear interpolation to cover the intervening years (column P). The trendline for the upper limit of the RPS wedge (column Q) is the sum of columns J and P.

The Climate Safe wedge graphic modeling follows (columns S through AD). As with the historical wedges discussed above, we use trendlines to form the wedge boundaries. The wedges consist of the five sectors of emitters from CARB's inventory, as delineated above, plus a wedge for sequestration by carbon sinks. Each emitter sector has the baseline for reduction starting in 2020, based on the 2017 inventory's GHG emissions. We assume there will be linear percentage per year reduction between 2020 and 2030, which is the key input parameter to generate the desired 2030 emissions endpoint. Sequestration, conversely, starts at zero and increases to reach the 2030 target. Its rate of increase is linear, again with a %/year input parameter to drive the rate of increase. We assume 100 MMT/year of sequestration as the maximum available, based on input from The Climate Center. Each sector model generates a GHG reduction trend increasing with time, which in turn reduces the baseline GHG accordingly.

Trendlines are the graphic elements used to locate the wedge boundaries on the "Wedge Net GHG" tab graphic. The first sector, Agriculture and Forestry, is bounded on the top by the 2020-2030 baseline, and the baseline less its GHG reduction on the bottom. Each successive sector in the model accumulates the reductions of the previous sectors to form its lower boundary, and thereby delineate the wedge graphic displays shown.

The Climate Safe model is set up allow different combinations of emissions reductions and sequestration scenarios to be tested, and the resulting 2030 net GHG emissions observed, which is calculated in cell AD76, and displayed in the stacked bar charts. In order to facilitate this, the Excel Scenario Manager has been implemented. It allows the model input cells to be simultaneously changed as a group to program, store, and easily compare different scenarios (variations of inputs). The Scenario Manager is accessed by selecting the Data Analysis tab, showing the Data ribbon, clicking on the What-if Analysis button, and opening Scenario Manager. Four sample scenarios are included; they can be activated by clicking on one and hitting the Show button at the bottom. New Scenarios can be added by manually changing the

%/year emissions reduction and sequestration ramp-up input cells, which are colored in bold red, and clicking the Add… button. When changing Scenarios, always return to the Baseline scenario before closing the Scenario Manager, for reasons that will be stated later.

Currently, California has in place statutory statewide total GHG emissions targets, based on percentage reductions from the 1990 baseline. These are: Return to 1990 levels by 2020, 40% below 2020 by 2030; and 80% below 2020 by 2050. These are developed into a trendline data source in column AG using linear interpolation between the statutory years. Furthermore, a governor's executive order in 2018 called for a more aggressive schedule, to achieve net zero emissions by 2045. Trendline data for this plan is similarly calculated in column AH.

The final modeling effort (columns AI through AP) estimated the impact of Community Choice Aggregation (CCA) on the emissions from the electricity sector. CCA's have been formed in many jurisdictions, with a central goal of steering community power purchases toward renewable sources faster than planned by the large investor owned utilities (Large IOU's). This modeling was done for only one year (2018) to determine its magnitude, and whether it was feasible to include it as a historical wedge. The California Renewable Portfolio Standard Annual Report of 2019 provided sufficient aggregate data on the CCA and Large IOU's 2018 renewable content and market shares to allow a rough estimate of the impact of CCA's to date. Basically, first we calculate the non-renewable power generated by both groups, and the resulting GHG emissions. Then we develop a hypothetical case where we assume if the CCA's didn't exist, the Large IOU's would be serving all their demand at the same aggregate power content as they currently have. The results show a 2018 reduction of less than one MMT/year that can be attributed to the CCA's. This is a consequence of their small market share (13%), and only a marginal aggregate improvement in renewable power content over the Large IOU's (46% vs. 40%.). This small GHG reduction would not result in a visible historical wedge on the diagram, so it was not plotted.

Excel Workbook Graphics Summary

The graphics provided consist of two versions of trendline based wedge diagram charts, and three versions of stacked bar charts. The primary wedge chart is the "Wedge Net GHG" tab. As noted, wedges are based on graphics trendlines, which are sourced in the model calculations. In this Net GHG presentation, we show sequestration adjacent to the sector emission reduction wedges, as we are treating all factors according to their impact on the atmosphere, regardless of whether they are adding to, or pulling out, GHGs. The advantage of this chart is it shows the most comprehensive view of the historical and future impacts of energy policies. Its downside is the annotation and the Climate Safe wedge coloration are static; if the model is changed (for instance, changing Scenarios as discussed above), the static elements (including the colored wedges themselves) stay fixed while the trendlines move. Of course, the static elements can be moved manually if desired. This is the reason for the recommendation noted above on the use of the Scenario Manager; returning the model to the Baseline scenario restores the Climate Safe sector trendlines, so they match up with the wedge coloration and annotation.

The “Wedge with Minus GHG” tab is an attempt at showing sequestration as a negative value. We conclude this approach is not easily comprehended, unless there is a better way to present it.

To accommodate the desire to have a graphic that would better accommodate different Climate Safe scenario presentation, Excel “Stacked Column” (aka Stacked Bar) charts were chosen. Three variations were provided, with varying numbers of columns (tabs Stacked Bar Chart, Stacked Seq Bar Chart, Stacked Seq Net Bar Chart). These charts require the input data to be tabulated in a particular format, so each has its own spreadsheet tab (Stacked Bar Data, Stacked Separate Bar Data, Stacked Seq Net Bar Data). These data cells in these spreadsheets reference the Data Analysis tab model, so no changes should be made to these spreadsheets. Any chart input data changes must be made with manual changes in the Data Analysis tab model, or scenario changes in the Scenario Manager. The charts are formatted so as model changes are made, they can adjust without losing the integrity of the annotation.