Bay Area Air Quality Management District
939 Ellis Street
San Francisco, California 94109

APPROVED MINUTES

Advisory Council Technical Committee
9:00 a.m., Monday, October 1, 2007

1. **Call to Order – Roll Call.** Chairperson Sam Altshuler, P.E., called the meeting to order at 9:17 a.m. Present: Sam Altshuler, P.E., Chairperson, Louise Bedsworth, Ph.D., Robert Bornstein, Ph.D., William Hanna, John Holtzclaw, Ph.D., (9:34 a.m.), Kraig Kurucz.

2. **Public Comment Period.** There were no public comments.

3. **Approval of Minutes of August 6, 2007.** The Committee provided minor revisions to the minutes. After discussion, Dr. Bornstein moved that the approval of the minutes be deferred until Dr. Mark Jacobson reviews that portion of the minutes containing his presentation; seconded by Mr. Kurucz; carried unanimously without objection.

4. **Presentation on Methane Trends in California:** *Dr. Marc Fischer of the University of California Berkeley gave a presentation to the Committee on Methane Trends in California.*

   Chairperson Altshuler introduced Dr. Marc Fischer. Dr. Fischer stated he is a scientist from the Lawrence Berkeley National Laboratory (LBNL) and has been trained in physics and is now working in energy, atmosphere, and environment problems. Dr. Fischer noted he mostly worked in atmospheric science and some amount of bio-geo chemistry (how land surface processes affect atmospheric constituents; in particular green house gases). The Committee members then introduced themselves.

   Dr. John Holtzclaw arrived at 9:34 a.m.

   Dr. Fischer provided background information and stated that the LBNL is doing a wide-range of research in climate and air quality. The climate related studies are broadening from what has been aerosol and green house gas (GHG) measurements and modeling to include climate modeling at both regional and now global scales. The emphasis in GHG's has focused on the terrestrial exchange from ecosystems to the atmosphere. Human emissions are important, therefore, the LBNL is also moving in that direction. The outline of the presentation is:
   - An overview of non-CO_2 GHGs,
   - A snapshot of California and Bay Area emissions,
   - Multiple methods for estimating emissions to verify emission reductions,
   - Initial atmospheric measurement network that is starting this month,
   - Conclusions, and
   - Directions for further work

   Continuing Dr. Fischer reviewed the slide entitled GHGs in Time and Space. The first figure is a map of the earth that shows locations at which the National Ocean and Atmospheric

Administration (NOAA) have been making measurements of GHGs for the past couple of decades. Most of the sites are not in terrestrial areas, but are often in the oceans. The measurements were taken as background monitoring. Interest is now focusing on what the emissions are in the terrestrial and human influence zones, therefore, there is a need for additional measurement points. The main point of the slide is that there is a record for how atmospheric concentrations of GHGs have changed and there are examples globally. Dr. Fischer stated that to understand how changes are occurring one cannot rely solely on models; measurements are essential.

The next plot shows how nitrous oxide (N_2O) has changed both in time (the horizontal axis) and with latitude, and the amount (the vertical axis). Over the period from 1990 to 2000 there has been a steady rise in N_2O and there is a strong latitudinal gradient. Dr. Fischer emphasized that N_2O has a very long lifetime in the atmosphere; the removal mechanisms for it are slow and it is hence fairly well mixed. The gradient from stronger in northern latitudes to weaker in the southern latitudes indicates a northern latitude source.

The second plot shows the same thing for methane. Again, there is a very strong latitudinal gradient where there is much more methane in the northern hemisphere than in the southern. There is a comparatively weaker growth in the last decade. Methane has a much shorter lifetime in the atmosphere and is removed by OH. Methane has a different set of sources from N_2O.

The three slides show what contemporary measurements look like. There is a network of global monitoring stations which are detecting the background methane, CO_2, and N_2O. The next slide, Overview of non-CO_2 GHG, is a plot that shows the total non-CO_2, CO_2, and other forcings of the atmosphere on the globe. The graph shows the change in forcing from pre-industrial times to present. The graph indicates that from pre-industrial times, there have been very significant increases in GHG concentrations. Over the period from pre-industrial times to the present, the increase in radiative forcing caused by increased atmospheric concentrations of non-CO_2 greenhouse gases (e.g., CH4, N2O, and High Warming Potential Gases) is comparable to (within a factor of 2 of) that caused by the increase in CO_2. The non-CO_2 gases, which are much stronger absorbers than CO_2 by mass, have increased enough that their combined effect for forcing is comparable to CO_2. It is also important to note that in the last 20 years or so, the increases in CO_2 have accelerated while the non-CO_2 GHG's have slowed. Hence, it is vitally important to work toward effective controls in CO_2 emissions from human activities. Regarding the ozone on the chart, Dr. Fischer stated that it is an increase in tropospheric ozone from pre-industrial to current times and it is part of the IPCC assessment on climate forcing. This forcing may be a combination of tropospheric and stratospheric ozone. Dr. Fischer reviewed the potency of GHGs and stated that methane is about 20 times as potent as CO_2, N_2O is about 300 times as potent on a mass weighted basis, and high Global Warming Potential (GWP) gases that include CFCs, HFCs, and SF_6.

Dr. Fischer discussed the recent trends in global warming gases and where they may head in the future. The top panel of the slide shows the increase in the gases over the 1990 to 2010 period. The blue dots indicate measurements and the yellow and red lines indicate what future increases might look like for CO_2, methane, N_2O and GWPs. The middle set of plots on the slide are the same gases, but are noted as a per year increase in concentration. At the bottom is the sum and where things are potentially headed. The plot on the bottom right goes out to 2050. How people conduct themselves will have different affects on the forcing. Dr.

Fischer stated that there have been very strong increases in both CO_2 and N_2O in the last 15 year period; the future for N_2O depends on agricultural practices; and on fuel combustion. CO_2 is predominately emitted by fossil fuel combustion and a small amount by other industrial processes.

The picture is different for methane. Methane was increasing from 1990 to 2000, but it started to level off after about the year 2000. This indicates that something different is going on with methane. It has not, in the very recent past, been increasing as quickly and there is active research going on to try to understand what is causing the global methane cycle to diverge from a steady growth. In response to a question from Chair Altshuler, Dr. Fischer stated that he felt that, in a statistical since, the trend is significant. In a long-term perspective of where things are going, it is too early to tell. Because methane has a complicated bio-geo chemistry -- there are many different sources -- it is difficult to say what is causing the trend. Methane is emitted largely by anaerobic decomposition processes. Many people believe that the decreased methane emissions come from thawing tundra which used to be under water. It is now drying and that may be causing this trend. Another thought is that it is possible that the sources of methane coming from human activities has slowed, but it is too soon to determine what the cause is.

Continuing, Dr. Fischer provided information on what can be done in terms of monitoring a GHG if measurements and models are used together. How can one infer the sources and sinks of methane? The plot, entitled Inferring Global CH_4 Sources from 2003 Variances in CH_4, shows the results from a global inversion of atmospheric methane. Using the NOAA flask network data, an inverse model has been run where prior estimates are taken of methane emissions that are combined with a global transport model. This indicates what the surface emission is that is most consistent with the observations. The plot shows a year, per month, of surface methane concentrations models using prior estimates of what methane emissions look like and adjusting that prior estimate to be most consistent with the observations. There is a consistent trend of higher methane in northern latitudes and lower methane in southern latitudes. The plot also shows little spots of high methane showing up at different places in the map. These are regions where the model finds there must have been more methane in order to be consistent with the observations. The peaks are generally in the northern latitude summers.

Dr. Fischer emphasized that by combining actual measurements of concentration, with models of transport and prior estimates of emissions, one can get a better feeling for where the emissions are occurring and how strong they are. There is now a problem with dealing with emissions on a national, state, regional, or county-level scale. The argument is to move down and scale from global to these smaller scales using the same kind of techniques, but with improved measurement and modeling methods.

Chair Altshuler observed that, from an energy perspective, the plot shows that West Virginia and the east coast might be the “hot spots” in the United States. These are areas in which coal is used. In California and the west coast the tendency is the use of natural gas. Chair Altshuler questioned if there a correlation. Dr. Fischer stated that this plot is not emissions, but surface level concentrations. Western North America uses a lot of natural gas, but there is a lot of ocean air diluting that source to the atmosphere from natural gas use. In this model, it is being diluted away; the model also may underestimate how much emission is occurring at the Western boundary. There is only one station at Trinidad Head, which is

north of the Bay Area and is a "clean" environment to judge what the methane concentrations of the West Coast should look like.

Dr. Fischer stated that measurements of methane gas will be put up at Sutro Tower in San Francisco for a more localized measurement. Dr. Holtzclaw noted that the largest concentration, and possibly source, tends to be in Russia, but there are no monitors in that area. Therefore, there is more speculation in that area as to the source of emissions. Dr. Fischer stated that this information is a combination of a model that is making an estimate of where the emissions are based on where they believe wetlands occur. The hot spot in northern-central Asia is, in fact, due to assumed methane emission from wetlands.

The next plot shows the total California GHG emission trends. This is total emissions converted into CO_2 equivalent units, million metric tons (MMT) of CO_2. Data was taken from the California Energy Commission's (CEC) GHG inventory that was compiled in 2006. The vertical scale has been truncated and it only shows from 300 up to about 550 MMTs. CO_2 is the largest forcing estimated from inventories for California and it is also the largest source of variation in the trend. CO_2 is where the need is to start controlling GHG emission. The non-CO_2 GHGs constitute about 10% of the total emission. Presently the CO_2 from California is much bigger than the annual increased forcing due to the other gases.

Dr. Fischer made the argument that while CO_2 must be controlled first, the non-CO_2 GHGs have benefits in terms of controls that are not just climate related. Methane is emitted in California by landfills and by agricultural sources, principally animal live stock. If the methane emitted from these sources could be captured, it could be used for energy, rather than just mitigating climate warming by burning the methane to CO_2, which is done currently.

For 2004, Dr. Fischer showed what the non-CO_2 GHG emissions are for a number of different source categories. There are a number of different sources of both methane, a couple of sources for N_2O and the high GWP gases that are all together. All of the estimates are uncertain, it is not known for better than 30% how big any of these sources are. One thing that can be done to reduce the uncertainty is to try to use another method of measuring and inferring what the emission had to have been.

The plot entitled Bay Area GHG Balance was shown next. Dr. Fischer acknowledged that the information for the chart was assembled by the Air District. It shows that the estimated non-CO_2 GHG emissions for the Bay Area are approximately 10% of the total. This is similar to the estimates that the CEC has for the breakdown for the state. The message is that increased transportation fuel efficiency should be a first priority if GHG forcing emissions are to be controlled. CO_2 from transportation is the dominant source. A second message is that rural counties are likely to be different from the average picture. Rural counties will have less transportation and a greater portion of emissions from agricultural GHG emissions. The individual inventory-based emission estimates are likely uncertain at a 20-40% level. Alternatively, looking from the top down, using atmospheric measurements, there is another way of saying how much emission is coming from California.

There was a brief discussion on what changes might occur 20 years from now regarding the rise in GHG emissions and different scenarios on curtailing GHGs. Dr. Fischer stated that if the climate changes enough, there are potential "positive" feedbacks to climate. An example

is the large stores of methane in methane ice shelves in very northern latitudes in marine boundary environments called methane clathrates. If it destabilizes and the methane boils off into the atmosphere it could cause a large and rapid "positive" increase in forcing.

Dr. Fischer discussed what is being done to try to estimate the non-CO_2 GHG emissions. The essential ingredients for an independent verification method for GHG emissions include:

- Start with a priori inventory estimates of GHG emissions of interest. Dr. Fischer emphasized that one needs to have the best number and an estimate of how certain that number is.
- A model for atmospheric transport and surface influence "footprints." If a measurement is made at a given point in space and time, how much measured at that point came from what region in the Bay Area.
- A way to combine the emissions and atmospheric influence functions -- what should the "signals" measured in the atmosphere look like.
- Quantitative GHG boundary conditions for what comes from outside of California. What is measured in California is not just coming from California.
- Continuous long-term measurements of the GHG of interest and other species that one can help associate specific sources with the measurements made.
- A statistical framework in order to evaluate whether emission inventories one started with are consistent with the measures; or if the emission inventories need to be revised to be more consistent with the measurements.

The next slide, entitled *A priori* CH_4 Emission Inventories, shows an average year in the year 2004 of methane emissions by county in California. The counties far from urban areas have low emissions and the counties either in, or surrounding, the urban regions have higher emissions. The sources of emissions included landfills, animal agriculture, natural gas distribution and use, wetlands, and crop agriculture.

Attributing a given source to an atmospheric measurement can be done by using isotopic signatures. Natural gas and gasoline have different C13 isotopes. Most carbon is carbon 12; there is a small fraction that is carbon 13. If the carbon 13 content is measured, it can be determined if the CO_2 is more likely gasoline than natural gas. Similarly, carbon 14 is an unstable isotope of radio carbon that is produced in small quantities in the upper atmosphere. Carbon 14 only has about a 5,700 year lifetime and fossil fuels, which are millions of years old, have lost all of their carbon 14. Work is being done to distinguish methane emissions based on these isotopes of methane.

Carbon monoxide and VOCs also help determine what an air mass might have had as a source. The radon content of atmospheric air samples has started to be used to estimate atmospheric mixing. The map on the slide shows an estimate of how much radon is emitted from soils to the atmosphere as a function of space in the Western United States. Radon has a short half life of 3.8 days, therefore if radon is measured in the atmosphere it had to have come from some soil surface in the recent past. Radon will be used as a tracer for how much the air is in contact with the surface. When soils are dry, radon diffuses out of the soil readily; when soils are wet, it is trapped.

Dr. Fischer discussed the measurement sites that are being set up in an effort to measure GHG on a fine spatial scale that can determine regional emissions. The project is being funded by the California Energy Commission and will look at non-CO_2 GHGs. One of the two sites chosen for the first part of the study is Sutro Tower in San Francisco. Measurement tubes will be installed on Sutro Tower and air will be collected in flasks at the bottom of the Tower. The second site is the KCRA Tower in Walnut Grove, where the tubes have already been installed.

The type of instruments being used on the Towers was reviewed. There will be a flask sampling system and samples will be collected twice a day. NOAA will analyze the samples with very precise and accurate instruments to produce methane, CO_2, nitrous oxide, CO concentrations, SF_6, halo carbons, and, hopefully, $^{13}CO_2$, $^{13}CH_4$, and CDH. The samples will provide information on what the GHG concentrations are above an urban environment influenced by marine processes (at Sutro) and samples from the central valley (KCRA).

In addition, at the KCRA Tower, there will be a continuous methane and CO_2 analyzer that will make a measurement every three minutes. There will also be a CO_2/CO rack system and a radon monitor. In collaboration with the LLNL, flasks full of air will be collected which will be measured to determine the radiocarbon content of the CO_2 in that air.

Dr. Fischer next showed a plot that is a simulation of fossil fuel CO_2 in the surface layer atmosphere as a function of time for the month of July 2005. The simulation was done using an emission inventory constructed by the Environmental Protection Agency (EPA) for nitrogen oxide emission and scaled to CO_2 with a constant factor. The model is the NCAR-MM5 model run at 10 km. resolution. It shows that, with respect to computer modeling, that the emission inventories can be taken and propagated into the atmosphere and it can be determined what the concentrations of fossil fuel CO_2 should look like as a function of time. The same thing can be done for methane with all the sources mentioned and a picture can be generated on what concentrations should look like at different places from different sources. Work will be done to make a better representation for transport. Two main sources of CO_2 in California are the Los Angeles Basin and the San Francisco Bay Area.

A footprint model is used to attribute emissions from a given location to a measurement point later. The footprint model works by releasing imaginary particles at the place the measurement is made and running them backward in time following the air velocity and turbulence characteristics back to the location on the land surface that the sources are present. Dr. Fischer presented a slide showing the areas that are affecting a measurement at Sutro Tower at 230 meters for July 2004. The simulation is being done every three hours of the month of July using a particular implementation of a transport model called the BRAMS model. The goal is for highly resolved and very accurate meteorology for this purpose. If the meteorology is wrong, there will be an incorrect inference about where the emissions are coming from and how strong they are. Dr. Fischer noted that the plume changed with time and that sometimes the plume is just air coming off ocean, other times it is air that is in contact with California.

Continuing, Dr. Fischer presented a plot combining the emission inventories previously discussed and the footprint function. The purpose is to determine what the concentrations of methane at Sutro Tower will look like as a function of time for the month of July 2004 from the different sources (landfills, livestock, wetlands, natural gas, and radon). There are very

low concentrations, with a spike every so often. The reason for this is that most of the time the air coming to Sutro Tower comes off the ocean and contains only background methane. The spikes are due to the footprint having some contact with a land surface where there are emissions from the sources as listed above. The KCRA plot was discussed and it shows a diurnal cycle each day. The KCRA Tower is surrounded by land surface influences and constantly reads methane from relatively local and regional sources. If the predicted signals are taken and are compared with the signal of estimated radon, for the Sutro Tower, many of the sources have a tight correlation.

In summary, Dr. Fischer stated that California and Bay Area GHG emissions are dominated by CO_2, therefore reductions should start there. Non-CO_2 GHG (methane, N_2O, CH_4, and high GWP) emissions are significant (at the level of 10% of the total emissions currently) and uncertain and beneficial opportunities exist for reduction. Long-term measurements provide an independent and complementary method to verify reductions. The inventories should not be relied on solely, although they need to be done first, but there has to be a way to check them. The initial numerical modeling suggests that the GHG signals are clearly going to be measureable and may provide a strong handle on the emissions. It remains to be seen how much the uncertainties can be reduced. The inverse statistical model will provide a quantitative method to improve the inventories; in particular, assuming an accurate representation of the errors going into the inverse problem can be obtained, there should be an objective way of understanding the errors and the uncertainties in the final emissions. Multiple measurement of multiple tracers are required to more uniquely attribute measured concentrations to a given source estimates. Nested high resolution (approximately 1 kilometer) atmospheric transport models are essential for locations with complicated terrain.

Chair Altshuler recommended that the rate of change be noted in Dr. Fischer's summary (at the second bullet) and stated that while CO_2 is still the largest "piece of the pie," it is also rising. Dr. Bornstein provided additional suggestions, which have been incorporated into the minutes. Chair Altshuler suggested that the Summary page be divided into two pages where the first three bullets would be on the first page as a policy perspective and the last four bullets are more the science and how to get there.

Saffet Tanrikulu, Research & Modeling Manager, stated that CO and CO_2 are already included in the District's modeling exercise. Methane is not explicit so the District can look at CO and CO_2 concentrations through the simulation. Dr. Bornstein noted that the CO_2 estimates were for more traditional air quality and may not capture other sources as discussed at today's meeting. Dr. Tanrikulu stated that Dr. Bornstein's statement is true, partly because CO is not a strong precursor for ozone and the focus has been on ozone and PM.

Dr. Fischer commented that the District's modeling could include CO_2 from fossil fuel combustion. It will be increasingly important and it is currently an area of active research to understand the uptake of CO_2 and the release of CO_2 from the terrestrial biosphere; that is plants growing and dead organic matter decaying.

Mr. Altshuler stated that there is some radon in natural gas and that the amounts differ depending on where the gas comes from. There is more radon in California gas and Dr. Fischer noted that if the gas travels, even for a couple of days, to get to California than some radon will be lost to natural decay.

Dr. Fischer stated that if a lot of fuels are shifted to a plant based source; radio carbon cannot be used as a unique tracer of that fuel combustion.

Dr. Fischer highlighted the further work to be done and stated that the first step would be the concentration measurements of GHG's at Sutro and Walnut Grove Towers, which information will be available later in the year. Another item being worked on is an upgrade of the meteorological modeling in collaboration with other groups to include the nested grids. Developing and testing high resolution meteorological fields for tower sites using MM5 and Weather Research Forecast (WRF) model outputs. Further work also includes incorporating the additional tracer and species for source attribution analysis. Finally, to initiate inverse model-data-synthesis estimates of regional GHG emissions and uncertainties.

Chair Altshuler thanked Dr. Fischer for his presentation.

5. **Discussion and Summary of Issues Related to Global Warming:** *Committee members discussed issues related to energy and global warming.*

Chair Altshuler initiated the discussion and asked for suggestions on key points the Committee could discuss in the coming year. Chair Altshuler stated that Dr. Fischer talked about the bookmarks and the non-CO_2 gases. He noted that there has been a strong message regarding ethanol not being the "cure all" for climate change. At the September 21st Climate All Stars conference it was recommended that everyone stop burning coal.

Suggestions from the Committee included the following:

- Focusing on policy levers that the Air District may or may not have control over.
- Trying to narrow it down to what does it mean for what the District is doing and how does it relate to the Air District's air quality planning efforts.
- A summary of the technical information the Committee has heard is useful in terms of the state of the science, but it should be narrowed down to what is the Air District's day-to-day practice.

Henry Hilken, Director of Planning, Rules and Research Division, interjected that in terms of the Air District's Climate Protection Program, one of the key points is harmonizing everything the District is doing already – the traditional air quality programs with climate protection. Identifying areas where the District's air quality monitoring could incorporate some impacts of climate change. On the policy side, it would be what the District does about it and looking at co-benefits of mitigation strategies.

Additional discussion items included:

- Possible discussion on how the state incentivizes energy or fuel use – this would give the Committee a few more levers to try to put into play if the Committee does not mind making recommendations that are not strictly the scope or charter of the Air District.
- Things that would incentivize different fuel choices, wind energy or efficiency moves that could be made at utilities or at the user end. This was done on the smog check program.

- The Committee could be broad in that respect.
- Some of the things that work just for the Bay Area are things that need to be done on a state-wide level and might not be able to be done in the Bay Area without legislative interaction.
- The last 3 to 4 speakers have provided a lot of technical information and a summary of their presentations would be useful.
- One of the findings to be able to make is the sources that the District has concentrated on in order to address ozone
- The appropriate sources for GHGs as far as the Bay Area is concerned.
- Agricultural emissions and emissions from combustion sources
- Looking at the sources of methane that the Air District might have some influence over; landfill is one, other methane from natural gas methane.
- Looking at an action that will cause an unintended consequence and looking at actions that have cumulative good consequences.
- Energy conservation solving a lot of pollution problems in addition to a lot of climate change issues.
- Black carbon.
- Focus on CO_2 as the gas that should have the most concern and continue supporting research to make sure that that is the most effective way.
- MTBE-type issues should be flagged. Ethanol is getting close to that; in particular the health effects.

Dr. Bornstein recommended that the Committee members prepare a list in advance and bring it to the next meeting. The final list could be divided into recommendations that would go to the other Committees.

6. **Committee Member Comments/Other Business.** Dr. Holtzclaw thanked Chair Altshuler for an interesting meeting and for keeping the Committee on track this year.

7. **Time and Place of Next Meeting**. 9:00 a.m., Monday, December 10, 2007, 939 Ellis Street, San Francisco, CA 94109.

8. **Adjournment.** 11:40 a.m.

/s/Mary Romaidis
Mary Romaidis
Clerk of the Boards