San Diego County Greenhouse Gas Inventory

An Analysis of Regional Emissions and Strategies to Achieve AB 32 Targets

# Industrial Processes and Products Report

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# Industrial Processes and Products Report Acknowledgements

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For an electronic copy of this report and the full documentation of the San Diego Greenhouse Gas Inventory project, go to www.sandiego.edu/epic/ghginventory.

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# 1. Introduction

Industrial activities generate greenhouse gas emissions in a variety of ways, such as from the use of electricity and natural gas energy supplies to provide power and heat (indirect emissions). Industrial emissions also result from the processing of materials to manufacture items including mineral aggregate products, chemicals, metals, refrigerants, electronics and other consumer goods such as paper and food items. Furthermore, high global warming potential gases are used in air conditioning and refrigeration systems, and during the manufacture of electronics, fire protection equipment, insulation, and aerosols. This report, a component of the San Diego County Greenhouse Gas Inventory project, focuses on industrial processes that directly release carbon dioxide and other greenhouse gases by processes other than fuel combustion, and on the use of industrial products, mainly refrigerants, by all sectors – in vehicles, in homes, and in commercial and industrial facilities. These sources are currently responsible for about 5% of the total greenhouse gas emissions in San Diego County. Greenhouse gas emissions associated with fuel combustion activities of industrial processes are captured in other sections of the inventory.

This report provides an estimate of historical GHG emissions associated with industrial processes and products from 1990 to 2006 and projects future emissions to 2020 for San Diego County. Using emissions reduction targets codified in California's Global Warming Solutions Act of 2006 (AB 32) as a guide, this report also establishes emissions reductions targets for the region's industrial sector. Although AB 32 does not require individual sectors or jurisdictions (e.g., cities and counties) to reduce emissions by a specific amount, the project team calculated the theoretical emissions reductions necessary in each emissions category (e.g., transportation, electricity, etc.) for San Diego County to reduce emissions to 1990 levels by 2020 – the statewide statutory target under AB 32. Finally, the report identifies and quantifies potential emissions reduction strategies to determine the feasibility of reducing industrial emissions to 1990 levels by 2020.

To the extent possible, the project team followed the same calculation methodology used by the California Air Resources Board (CARB) to develop the statewide GHG inventory. In some instances, when county-specific data was not available, the project modified the CARB method.

This report, which is intended as an overview of the findings from research and analysis conducted for the industrial processes and products category, includes the following sections.

- Section 2 provides an overview of industrial GHG emissions in San Diego County, including total emissions, a breakdown of emissions by subcategory, a summary of the highest emitting products and activities, projections to 2020, and reduction targets.
- Section 3 discusses the strategies necessary to reduce industrial emissions to 1990 levels by 2020.
- Section 4 provides a detailed discussion of the method used to estimate emissions for this category.

## 1.1. Key Findings

The key findings of the report are summarized below.

- In 2006, GHG emissions from industrial processes and products (defined above) totaled 1.6 million metric tons of carbon dioxide equivalent (MMT CO2E), about 5% of San Diego County's overall emissions.

- 80% of the current emissions in the category are from the use of HFC refrigerants, which are replacing banned CFCs and soon-to-be-phased-out HCFCs. (CFCs and HCFCs are not included in GHG inventories.)

- Because HFCs were not in wide use in 1990, emissions in this category have more than tripled since 1990.

## 2. Greenhouse Gas Emissions From Industrial Processes and Products

Emissions from industrial processes and products totaled 1.6 MMT $CO_2E$ in 2006, about 5% of the total emissions from San Diego County, as shown in Figure 1. In 1990, emissions in the category totaled only 0.5 MMT $CO_2E$, or about 1.6% of total county emissions. Eighty percent of current greenhouse gas emissions in this category (in $CO_2E$) are due to hydrofluorocarbon (HFC) refrigerant gases that have replaced banned chloroflurocarbons (CFCs), and are replacing hydrochlorofluorocarbons (HCFCs), which are being phased out as part of the Montreal Protocol on the Protection of the Ozone Layer. (Although they are significant greenhouse gases, neither CFCs nor HCFCs are included in GHG inventories because their use has already been restricted.) The rapid increase in HFC use in San Diego County since 1990 accounts for the large increase in emissions from this category.

Major 2006 emissions in this category are shown in Figure 2. HFC emissions, especially HFC 134a from automobile air conditioners, constitute the largest source of industrial GHG emissions in the County. While HFCs do not harm the ozone layer, the C-F bonds they contain powerfully absorb infrared radiation and thus are significant greenhouse gases (see Table 1 for global warming

**Figure 1. San Diego County GHG Emissions by Category (2006)**

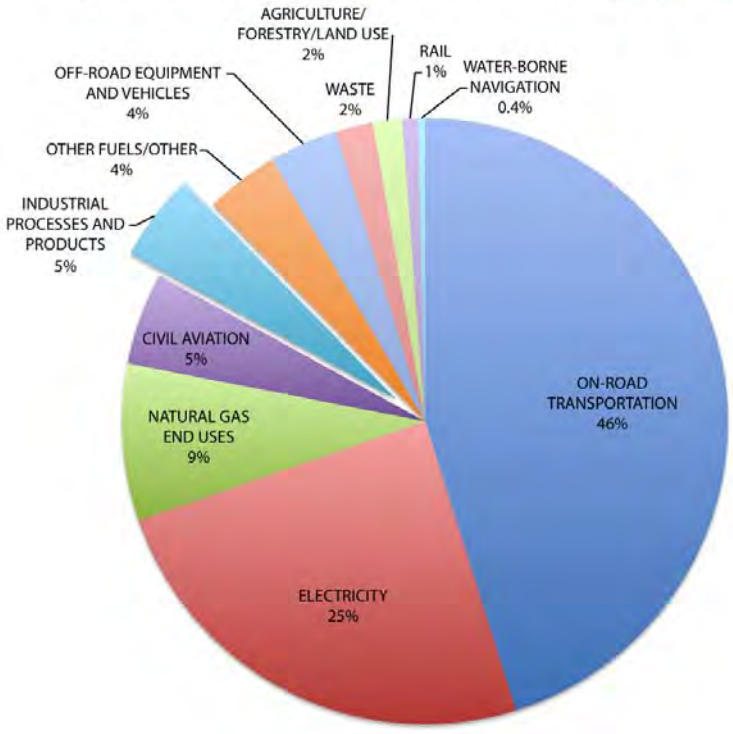
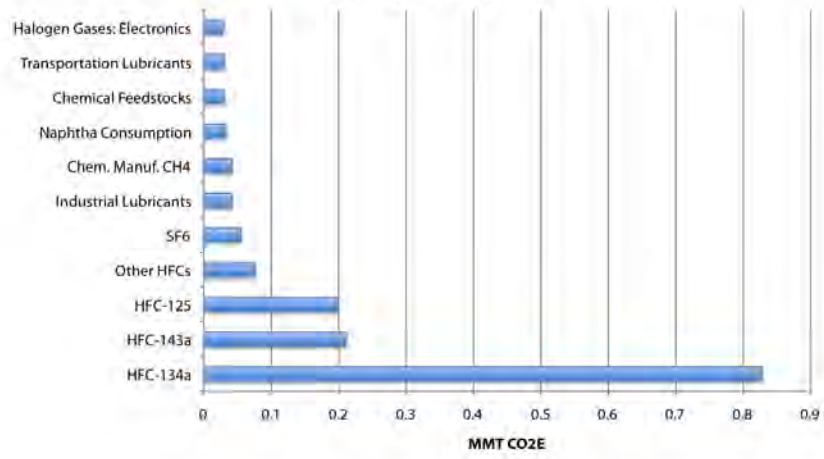



**Figure 2. Top 11 GHG Sources, Industrial Process/Products San Diego County 2006**



potential (GWP) data).[1] HFCs are used in automobile, home and commercial air conditioning, home and commercial refrigeration, and industrial process refrigeration.

**Table 1. Global Warming Potential of Industrial Gases**

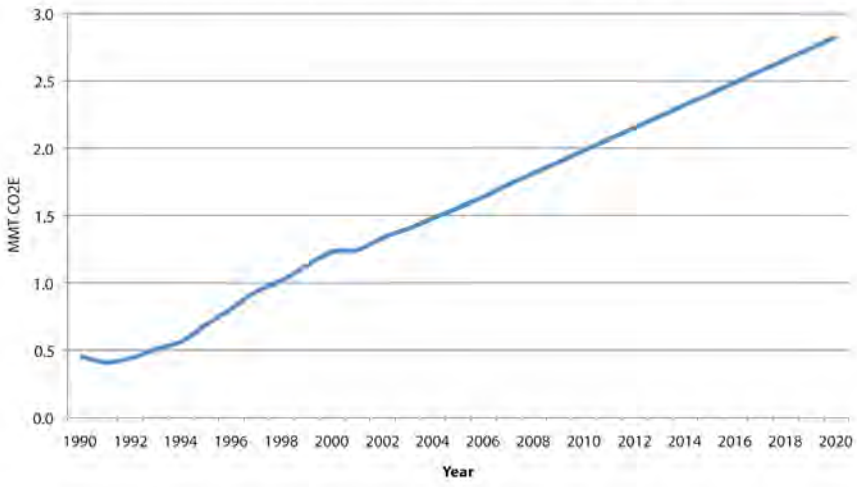
| Greenhouse Gas | Global Warming Potential (GWP, 100-year) |
|---|---|
| $CO_2$ | 1 |
| $CH_4$ | 21 |
| HFC-134a | 1300 |
| HFC-125 | 2800 |
| HFC-143a | 3800 |
| $SF_6$ | 23,900 |

After HFC refrigerant gases, the next largest contributor to global warming in this category is sulfur hexafluoride ($SF_6$). The release of this compound is associated with gas-insulated switch gear used in electricity transmission. Because of an extremely long atmospheric lifetime and high GWP, the release of even a small amount of $SF_6$ is significant, and these releases constituted 3.4% of the total carbon dioxide equivalent emissions in this category in San Diego County. High-GWP halogenated gases are also released during the manufacture of electronics. This source is responsible for 2.3% of the county total in this category. Carbon dioxide emissions were smaller contributors to this category: industrial lubricant consumption (2.6%), natural gas consumption by chemical manufacturers (2.6%), industrial naphtha consumption (2.0%), and petroleum feedstock consumption by chemical manufacturers (2.0%). All other sources were less than 2% of the category total as of 2006.

## 2.1. Emissions Projections and Reduction Targets

Because HFCs were not in use in 1990, emissions in the industrial processes and products category have already tripled. Figure 3 shows a linear trend extrapolated beyond 2004. By 2020 under a business-as-usual scenario, we predict emissions of 3 MMT $CO_2E$ – more than a six-fold increase over 1990 levels (0.5 MMT $CO_2E$).

**Figure 3. Projection of GHG Emissions from Industrial Processes and Product Use (non-fuel), San Diego County**

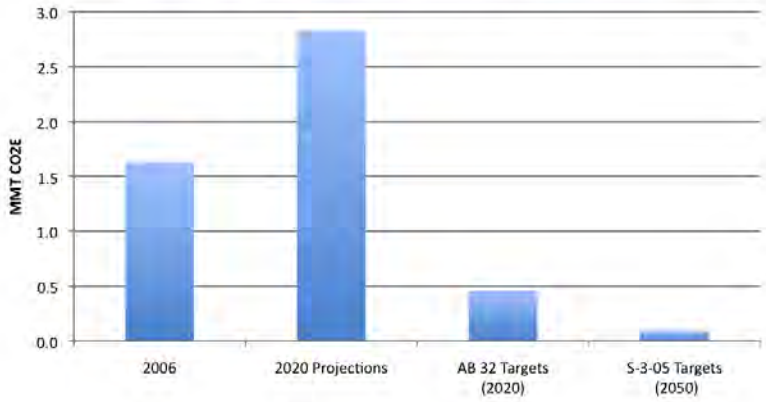



In 2006 Governor Arnold Schwarzenegger signed into law the Global Warming Solutions Act (AB 32), establishing statutory limits on GHG emissions in California. AB 32 seeks to reduce statewide GHG emissions to 1990 levels by the year 2020. Even though AB 32 does not specify reduction targets for specific sectors or jurisdictions, this study calculated theoretical reductions targets as if the statewide statutory emissions reductions targets were applied to San Diego County. To meet the targets established by AB 32 (1990 levels by 2020) the San Diego region would have to reduce its 2020 emissions from industrial processes and products by 2.4 MMT $CO_2E$ – an 84% reduction.

In 2005, Governor Schwarzenegger signed Executive Order S-3-05, which establishes long-term targets for GHG emissions reductions. It seeks to reduce emissions levels 80% below 1990 levels by 2050. While this reduction target is not law, it is generally accepted as the long-term target to which California regulations are aiming. Similar to AB 32, Executive Order S-3-05 is intended to be a statewide target, but if applied

hypothetically to San Diego County, total emissions from industrial processes and products would have to be reduced to 0.09 MMT $CO_2E$ –a reduction of 2.7 MMT $CO_2E$ (97%) below the 2020 business-as-usual projection. Figure 4 shows projected 2020 and actual 2006 emissions levels compared to the AB 32 and Executive Order S-3-05 targets.

**Figure 4. Hypothetical GHG Emissions Reduction Targets for Industrial Category (non-fuel), San Diego County**




## 3. Emissions Reduction Strategies

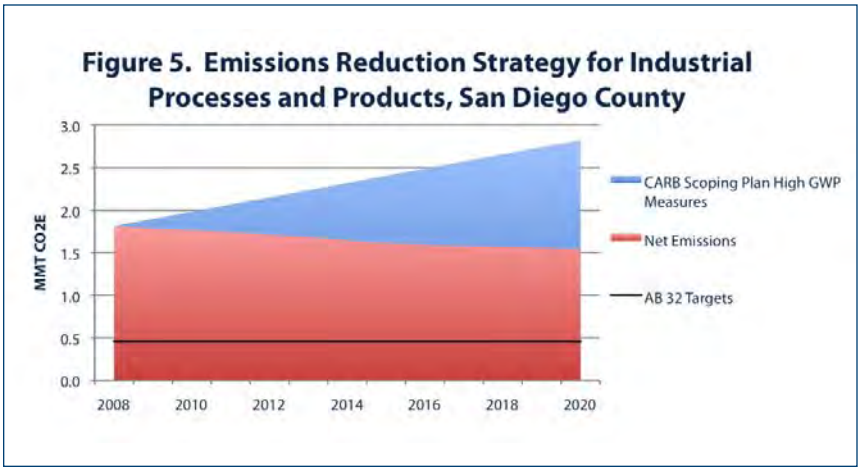
To reach emissions reductions targets set by AB 32, the industrial processes and products category will have to reduce emissions by approximately 2.4 MMT $CO_2E$ below the business as usual projection for 2020. To illustrate how the region could achieve the AB 32 targets and reduce emissions by this amount, the project team identified strategies and calculated the potential emissions reductions for each. The results were used to develop reduction "wedges," illustrated in Figure 4. This approach was adapted from the well-known study by Pacala and Socolow, demonstrating that global emissions could be reduced to levels that would stabilize climate change with existing technologies.[2] They took the total reductions needed to stabilize emissions and split that amount into equal parts or wedges, each wedge representing a certain amount of emissions reduction. The project team followed a similar approach to show how the San Diego region might reduce its GHG emissions to meet AB 32 targets.

**Table 2. Emissions Reduction Measures for High GWP Gases in CARB Draft Scoping Plan**

| |
|---|
| Motor Vehicle Air Conditioning Systems: Reduction of Refrigerant Emissions from Non-Professional Servicing (Discrete Early Action) |
| SF6 Limits in Non-Utility and Non-Semiconductor Applications (Discrete Early Action) |
| High GWP Reduction in Semiconductor Manufacturing (Discrete Early Action) |
| Limit High GWP Use in Consumer Products (Discrete Early Action) |
| High GWP Reductions from Mobile Sources<br>· Low GWP Refrigerants for New Motor Vehicle Air Conditioning Systems<br>· Air Conditioner Refrigerant Leak Test During Vehicle Smog Check<br>· Refrigerant Recovery from Decommissioned Refrigerated Shipping Containers<br>· Enforcement of Federal Ban on Refrigerant Release during Servicing or Dismantling of Motor Vehicle Air Conditioning Systems |
| High GWP Reductions from Stationary Sources<br>· High GWP Recycling and Deposit Program<br>· Specifications for Commercial and Industrial Refrigeration<br>· Foam Recovery and Destruction Program<br>· SF6 Leak Reduction and Recycling in Electrical Applications<br>· Alternative Suppressants in Fire Protection Systems<br>· Residential Refrigeration Early Retirement Program |

To develop an emissions reduction wedge for non-fuel industrial emissions, the project team used statewide reduction strategies developed by CARB. In its Climate Change Draft Scoping Plan of June 2008, CARB identified preliminary strategies to reduce emissions from high global warming potential gases (Table 2).[3] These comprehensive measures are expected to result in a 16 MMT $CO_2E$ statewide reduction in emissions by 2020.

If scaled down to San Diego County using ratios of industrial activity, these measures would reduce GHG emissions by 1 MMT $CO_2E$ by 2020 (Figure 5).




While it is clear that overall reduction targets of AB32 (1990 levels by 2020) will not be applied directly to individual sectors of the economy, we are using it as a benchmark within each sector to evaluate whether the sector may be able to contribute meaningful reductions at the regional level. Savings expected from the HFC reductions included in the CARB Scoping Plan would not achieve the reductions necessary for the industrial processes and product use category to reduce its emissions to 1990 levels by 2020; however, the AB 32 goal could be fully accomplished within the category by phasing out HFC refrigerants in favor of low-GWP alternatives such as hydrocarbon refrigerants, which are currently legal in the U.S. only in industrial process refrigeration due to flammability concerns. Several alternatives to HFCs have already been commercialized, however. If HFCs are not phased out, reductions in other sectors would be required to compensate for reduced but continued HFC use in 2020.

To reach the goals included in Executive Order S-3-05 – 80% below 1990 by 2050 – within this category, HFC refrigerants will need to be phased out in favor of systems using gases that have negligible GWPs. In addition, further reductions in all of the other top 11 categories (e.g. $SF_6$ emissions from electricity generation and halogenated gas emissions from electronics manufacturing) would be required. The replacement of $SF_6$ with other insulators is considered technically feasible, and would result in a 90% reduction in $SF_6$ released to the atmosphere.[4]

# 4. Methodology

In general, the project team used the categories contained the CARB Greenhouse Gas Emissions Inventory and either calculated emission directly from primary data or scaled down statewide emissions based on a ratio of industrial activity in San Diego County and the state as a whole. Emissions from the following IPCC categories as used in the CARB GHG inventory were set to zero because Economic Census data from 1997 and 2002 from the US Census Bureau indicated no economic activity in San Diego County:

- 2A1: Manufacturing : Stone, Clay, Glass & Cement : Cement > Clinker production > $CO_2$
- 2A2: Manufacturing : Stone, Clay, Glass & Cement : Lime > Lime production > $CO_2$
- 2B2: Manufacturing : Chemicals & Allied Products : Nitric Acid > Nitric acid production > $N_2O$
- 2H3: Petroleum Refining : Transformation > Fuel consumption

Emissions from the following categories were set to zero because the California state greenhouse gas inventory (CARB, 2007) indicated no emissions statewide over the period 1990 – 2004:

- 2D2 Paraffin wax use: Not Specified Industrial > Fuel consumption - Waxes > $CO_2$
- 2D4: Not Specified Industrial > Fuel consumption - Asphalt > $CO_2$

Emissions from the following categories were calculated using the same methods as in the California state greenhouse gas inventory (CARB, 2007):

- 2E: Manufacturing : Electric & Electronic Equip. : Semiconductors & Related Products > Semiconductor manufacture > Halogenated gases (in $CO_2E$.). These emissions were taken from the EPA's national inventory, May 2008 version (http://www.epa.gov/climatechange/emissions/usinventoryreport.html) and ratioed to the value of semiconductor shipments. Semiconductor shipment data is available by county for 1997 and 2002 in economic census data from the US Census Bureau. Ratios were assumed constant before 1997 and after 2002 and extrapolated linearly between 1997 and 2002.
- 2F: Not Specified Not Specified > Use of substitutes for ozone depleting substances > $CF_4$, HFC-125, HFC-134a, HFC-143a, HFC-23, HFC-236fa, HFC-32, and other ODS substitutes. These emissions were taken from the most recent California state inventory (CARB, November 2007) and ratioed to population. State emissions for 2005 and 2006 were estimated using a linear fit to 1996 – 2004 data. Annual population data is from the US Census Bureau.
- 2G4: Not Specified Industrial > Soda ash consumption > $CO_2$. These emissions were taken from estimates of national soda ash consumption (http://minerals.usgs.gov/ds/2005/140/sodaash.pdf, 1990 - 2004), ratioed to population (annual data from the US Census Bureau), and multiplied by a MMT-soda-ash-to-MMT-$CO_2$ conversion factor of 0.415. National soda ash consumption in 2005 and 2006 was estimated using a linear fit to 1996 – 2004 data.

Emissions from the following categories were not performed using the same methods as the California state inventory (CARB 2007) because data on industrial production and consumption of resources is not available at the county level with sufficient detail. Instead, emissions were estimated from California state emissions (CARB, 2007) using ratios of industrial (or vehicular) activity in San Diego County and California, as described below. In all cases, state emissions for 2005 and 2006 were estimated using a linear fit to 1996 – 2004 data. Economic data was taken from 1997 and 2002 economic census data (US Census Bureau), the only two years with county data available. Ratios of county-to-state manufacturing activity were assumed constant before 1997 and after 2002, and linearly interpolated between 1997 and 2002 since no other data was available.

- 2B: Manufacturing : Chemicals & Allied Products > Fuel consumption. These emissions were ratioed from the California state inventory (CARB, 2007) based on the total value of chemical manufacturing shipments.
- 2D1: Not Specified Industrial > Fuel consumption - Lubricants > $CO_2$
- 2D4: Not Specified Industrial > Fuel consumption - Naphtha > $CO_2$
- 2D4: Not Specified Industrial > Fuel consumption - Other Petroleum Products > $CO_2$

- 2G4: Not Specified Industrial > $CO_2$ Consumption > $CO_2$

- 2G4: Not Specified Industrial > Limestone and dolomite consumption > $CO_2$. The emissions from these categories were ratioed from the California state inventory (CARB, 2007) based on the total value of all manufacturing shipments.

- 2D1: Not Specified Transportation > Fuel consumption - Lubricants > $CO_2$. These emissions were ratioed from the California state inventory (CARB, 2007) based on the total annual vehicle miles traveled in 1990, 1995, 2000, 2005, and 2006 as estimated by the California Department of Transportation (http://www.dot.ca.gov/hq/tsip/smb/documents/ mvstaff/mvstaff60.pdf). Ratios in intervening years were linearly extrapolated.

- 2G1b - Use of Electrical Equipment: Imported Electricity : Not Specified > $SF_6$ use > $SF_6$

- 2G1b - Use of Electrical Equipment: In-State Generation: Not Specified > $SF_6$ use > $SF_6$. These emissions were ratioed from the California state inventory (CARB, 2007) based on the total electricity generated by and imported to the state and county (http://www.sdreo.org/uploads/Regional_Energy_Strategy_Final_07_16_03.pdf (1990 - 2002, p15), http://www.energy.ca.gov/electricity/electricity_by_county_2005.html, linear extrapolation for 2003 and 2004.). The percentage of county electricity consumed that is imported from outside the county is estimated in this work (see electricity report).

The potential reduction wedges provided in section 3 were calculated based on measures either approved or being discussed now at the state level. The Discrete Early Action Measure already approved for adoption under AB 32 targets only HFC 134a and is expected to lead to a reduction of an average 1 MMT $CO_2E$ statewide. This reduction is a part of the total expected statewide 16 MMT to be achieved through the proposed measures to reduce emissions of all high Global Warming Potential gases (see End Note 2). This reduction was converted to a county level by multiplying by the projected population ratio of San Diego County to California in 2020.

## 4.1. Limitations

This analysis could be improved by the addition of data on the industrial consumption of the following raw materials at the county level.

Consumption by manufacturers of chemicals and allied products of:

- Liquefied petroleum gas (LPG)

- Natural gas

- Petroleum feedstocks

- Consumption by lubricants in transportation.

Industrial consumption of:

- Lubricants
- Naphtha
- Other petroleum products
- Carbon dioxide
- Limestone and dolomite

## End Notes


1. Data from the United Nations Framework Convention on Climate Change, 1995, accessed at http://unfccc.int/ghg_data/items/3825.php on May 15, 2008.
2. S. Pacala and R. Socolow, Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies. Science, 13 August 2004, Vol 305, pp. 968-972.
3. These potential measures are described in the Draft AB32 Scoping Plan Document is available at http://www.arb.ca.gov/cc/scopingplan/document/draftscopingplan.htm, page 26.
4. Maiss, M. and Brenninkmeijer, C. A. M. Atmospheric SF6: Trends, Sources, and Prospects. Environ. Sci. Technol. 32 (20) 3077-3086 (1998)