

Proposed Regulation to Reduce Greenhouse Gas Emissions from Semiconductor Operations

February 26, 2009



California Environmental Protection Agency

AIR RESOURCES BOARD

High GWP Gases Significant Sector in AB 32

- **High GWP Gases Include:**
 - Hydrofluorocarbons (HFC)
 - Perfluorocarbons (PFC)
 - Sulfur hexafluoride (SF6)
- **High GWP Emissions in California**
 - 1990 3 MMTCO₂e
 - 2004 15 MMTCO₂e
 - 2020 47 MMTCO₂e (BAU)

High GWP Measures in Scoping Plan Reduce GHG Emissions

- **~20 MMTCO₂e sector emission reductions by 2020**
- **High-GWP mitigation fee will provide economic incentive for further reductions**

Scoping Plan Measures Stationary Sources

- **Limit high-GWP use in consumer products (adopted 6/2008) ***
- **High-GWP gas reduction in semiconductor processing (today's regulation) ***
- **SF₆ in non-electricity and non-semiconductor manufacturing (later today) ***
- **Five additional measures**

* Discrete early action measure

Scoping Plan Measures Other Sources

- **Mobile Source Strategies**
 - **Small cans of HFC (adopted 1/2009)**
 - Refrigerant recovery at end of equipment/vehicle life (2009)
 - Pavley II: Improve system efficiency and use of low-GWP refrigerant alternatives
 - Vehicle AC system leak check and repair
- **Mitigation fee on high-GWP GHGs**

Semiconductor Operations and Emissions

- **85 operations in California**
- **Approximately 30,000 employees**
- **Sales exceed \$16 billion annually**
- **California represents 20% of U.S. market**
- **Total emissions are 0.32 MMTCO₂e**

Semiconductor Process

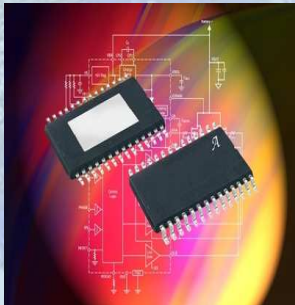
- **Two process steps: (1) CVD chamber cleaning and (2) etching**
- **High GWP gases are used in both processes**

High GWP Gases Used in Semiconductor Operations

<u>Gases</u>	<u>GWP</u>
Hexafluoroethane (C ₂ F ₆)	9,200
Octafluoropropane (C ₃ F ₈)	7,000
Tetrafluoromethane (CF ₄)	6,500
Trifluoromethane (CHF ₃)	11,700
Octafluorocyclobutane (c-C ₄ F ₈)	8,700
Sulfur Hexafluoride (SF ₆)	23,900
Nitrogen Trifluoride (NF ₃)	17,200

Semiconductors or “Chips”

- **High GWP gases are required to produce chips**
 - Fluorine atom removes deposits
 - Allows etching to submicron level
- **Chips are used in a variety of products**



Business As Usual Emissions

	2006 (MMTCO ₂ e)	2020 (MMTCO ₂ e)
Etching	0.17	0.13
CVD Chamber Cleaning	0.15	0.16
Total	0.32	0.29

National Voluntary Action

- **Three California operations participate in U.S. EPA voluntary program**
 - reduce emissions to 10% below 1995 level
 - two operations have exceeded the 10% goal
- **No mandatory GHG regulation**

Emission Reduction Strategies

- **Process Optimization:** reduce gas use in CVD chamber cleaning
- **Alternative Chemistries:** substitute one gas for another
- **Abatement Technology:**
 - thermal destruction
 - plasma destruction (alternative processing)

Proposed Regulation

- **Discrete Early Action Measure**
- **Includes performance standards, reporting, and recordkeeping**
- **Relies on existing reduction strategies**
- **Model for U.S. operations**

Performance Standards

- **Applies to 28 operations accounting for 94% of emissions**
- **Standards for large, medium, and small operations**
- **Stringency decreases with size of operation**
- **Reduce overall emissions by 56%**
- **Emission reductions = 0.18 MMT CO₂e**
- **12 of the 28 operations already comply**

Emission Reductions by Size of the Operation

Category	Number of Operations	Percent of Total Emissions	Percentage of Total Reduction
Large Operations	5	53	61
Medium Operations	11	25	17
Small Operations	12	16	22
Total	28	94	100

Compliance Schedule

January 1, 2012, except:

- January 1, 2014 for operations upgrading process tools
- 57 operations accounting for six percent of emissions are exempt from performance standards

Reporting and Recordkeeping

- **Reporting for all operations**
 - initial report due March 1, 2011
 - annual emissions report thereafter
- **Recordkeeping**
 - high GWP gas usage, three years
 - emission equipment malfunctions or failures, three years

Economic Impacts

- **Cost-effectiveness ranges from \$17-\$23 per metric ton CO₂e**
- **Average cost-effectiveness is \$21 per metric ton of CO₂e**
- **Annual cost is \$3.7 million**

Comments

- **Give credit for voluntary reductions**
- **Account for product complexity (layering)**
- **Extend compliance schedule**
- **Standards are not cost-effective**

Industry and Public Involvement

- **Industry Working Group**
- **District Working Group**
- **Survey**
 - gas use information
 - control equipment
- **Public Workshops**

Conclusions & Recommendation

- **Cost-effectively reduces GHG emissions by 0.18 MMTCO₂e**
- **Technically feasible with options to meet performance-based standards**
- **Meets all legal requirements**
- **Sets benchmark for national and international standards**

Staff recommends Board adoption