Proposed Regulation to Reduce Greenhouse Gas Emissions from Semiconductor Operations

February 26, 2009
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 MMTCO$_2$e
  – 2004 15 MMTCO$_2$e
  – 2020 47 MMTCO$_2$e (BAU)
High GWP Measures in Scoping Plan
Reduce GHG Emissions

• ~20 MMTCO$_2$e 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**
85 operations in California
Approximately 30,000 employees
Sales exceed $16 billion annually
California represents 20% of U.S. market
Total emissions are 0.32 MMTCO$_2$e
Semiconductor Process

- Two process steps: (1) CVD chamber cleaning and (2) etching
- High GWP gases are used in both processes
<table>
<thead>
<tr>
<th>Gases</th>
<th>GWP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hexafluoroethane (C\textsubscript{2}F\textsubscript{6})</td>
<td>9,200</td>
</tr>
<tr>
<td>Octafluoropropane (C\textsubscript{3}F\textsubscript{8})</td>
<td>7,000</td>
</tr>
<tr>
<td>Tetrafluoromethane (CF\textsubscript{4})</td>
<td>6,500</td>
</tr>
<tr>
<td>Trifluoromethane (CHF\textsubscript{3})</td>
<td>11,700</td>
</tr>
<tr>
<td>Octafluorocyclobutane (c-C\textsubscript{4}F\textsubscript{8})</td>
<td>8,700</td>
</tr>
<tr>
<td>Sulfur Hexafluoride (SF\textsubscript{6})</td>
<td>23,900</td>
</tr>
<tr>
<td>Nitrogen Trifluoride (NF\textsubscript{3})</td>
<td>17,200</td>
</tr>
</tbody>
</table>
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

<table>
<thead>
<tr>
<th></th>
<th>2006 (MMTCO$_2$e)</th>
<th>2020 (MMTCO$_2$e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Etching</td>
<td>0.17</td>
<td>0.13</td>
</tr>
<tr>
<td>CVD Chamber</td>
<td>0.15</td>
<td>0.16</td>
</tr>
<tr>
<td>Cleaning</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>0.32</strong></td>
<td><strong>0.29</strong></td>
</tr>
</tbody>
</table>
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 CO$_2$e
- 12 of the 28 operations already comply
## Emission Reductions by Size of the Operation

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of Operations</th>
<th>Percent of Total Emissions</th>
<th>Percentage of Total Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Operations</td>
<td>5</td>
<td>53</td>
<td>61</td>
</tr>
<tr>
<td>Medium Operations</td>
<td>11</td>
<td>25</td>
<td>17</td>
</tr>
<tr>
<td>Small Operations</td>
<td>12</td>
<td>16</td>
<td>22</td>
</tr>
<tr>
<td>Total</td>
<td>28</td>
<td>94</td>
<td>100</td>
</tr>
</tbody>
</table>
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-$23 per metric ton CO$_2$e

• Average cost-effectiveness is $21 per metric ton of CO$_2$e

• 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 MMTCO$_2$e
- Technically feasible with options to meet performance-based standards
- Meets all legal requirements
- Sets benchmark for national and international standards

Staff recommends Board adoption