# Response to EPA's Stack Test Question 1

**<u>Frequency of stack testing (emission factor variability)</u>: The answers to these questions will help EPA to determine the appropriate frequency of stack testing.**

1. **Please provide the per-gas emission factors (EFs) and by-product emission factors (BEFs) across fabs (kg emissions/kg input) that you have collectively measured. Please provide each EF and BEF for each measurement campaign at each fab (i.e., not averages over multiple months or years). Please identify the fabs, line widths, product mixes, and dates from which the emission factors come. If Company D measured N2O emissions during the March and August runs, what were these emissions and emission factors?**

***<u>Response</u>:*** *Listed below are fab-wide emissions factors computed for the following:*

- *Company D Fab 1: March and August 2011*
- *Company D Fab 2: March and August 2011*
- *Company E: May 2011*
- *Company F: Fab 1, 2001 thru 2011*
- *Company F: Fab 2, 2011*

*Table 1-1 provides information for each fab requested by EPA.*

***Table 1-1. Description of Stack Test Fabs showing Test Dates, and Line Widths & Product Mixes***

| Facility | Wafer size (mm) | Tests | Production Technology |
|---|---|---|---|
| Company D Fab 1 | 300 | Mar & Aug 2011 | Primarily digital signal processors, 130 - 65 nm |
| Company D Fab 2 | 200 | Mar & Aug 2011 | Analog devices, 90 nm |
| Company E Fab | 200 | May 2011 | Logic for automotive and networking, 250 to 90nm |
| Company F Fab1 | 200/300 to 300 | Annually, 2003 - 2011 | Logic, 250 to 45 nm, over time |
| Company F Fab2 | 300 | Aug - Sept 2011 | Logic, 45 nm |

*As stated in Company G's test plan, Company G tested a subset of acid and base stacks at its 300mm fab. Data from Company G stack tests are being provided to EPA under separate cover. Because all greenhouse gas emitting stacks were not tested, Company G is unable to provide fab-wide emission factors.*

*Emission factors listed in subsequent tables were calculated using the following methods:*

- *If an fluorinated greenhouse gas (F-gas) is used in a fab, mass emissions are divided by the mass of that F-gas used;*
- *If an F-gas is not used but emissions are measured, the mass of emissions are divided by the total mass of all F-gases used.*

## *<u>Company D Emission Factors</u>*

*COMPANY D conducted stack emissions tests on Fabs 1, 2 and 3 in March and August of 2011. A comparison of the March and August emissions factors produced by the Fab 1 test is listed in*

*Table 1-2 and a comparison of the March and August emission factors produced by the Fab 2 test is listed in Table 1-3. In Fab 3, two of three process GHG emitting stacks were tested and limited gas usage data was collected; therefore, it was not possible to calculate fab-wide emission factors.*

*<u>COMPANY D Fab 1:</u>*

*Seven principal fluorinated gases, NF3, CF4, CHF3, SF6, CH2F2, C4F8, and C5F8 are used in Fab 1, and comprise over 95 % of the fab's F-gas emissions. As listed in Table 1-2, the emission factors that were determined for these gases from the March and August stack testing agree closely, with a maximum difference of 20.6 %.*

***Table 1-2. COMPANY D Fab 1 Stack Emissions and Emission Factors for March and August 2011.***

| Fab 1 - March 2011 | | Fluorinated Gases Used in Fab 1 | | | | | | | Byproducts | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Gas** | **Units** | **NF3** | **CF4** | **CHF3** | **SF6** | **CH2F2** | **C4F8** | **C5F8** | **C2F6[a]** | **C3F8[a]** | **Total[b]** |
| EF | (kg emit / kg use) | 0.0673 | 0.8669 | 0.0591 | 0.3126 | 0.1108 | 0.0572 | 0.0247 | | | |
| bpEF | (kg emit / tot F use) | | | | | | | | 0.0069 | 0.0004 | |
| GWP | CO2e | 17,200 | 6,500 | 11,700 | 23,900 | 650 | 8,700 | 100 | 9,200 | 7,000 | |
| Emissions | Kg/hr | 0.2288 | 0.2776 | 0.0502 | 0.0059 | 0.0010 | 0.0008 | 0.0009 | 0.0322 | 0.0021 | 3.1024 |
| Emissions | (mTCO2e/mo) | 2,873 | 1,317 | 428 | 103 | 0 | 5 | 0 | 216 | 11 | 5,521 |
| Emissions | % of total CO2e | 52.03% | 23.86% | 7.76% | 1.87% | 0.01% | 0.10% | 0.00% | 3.92% | 0.19% | |
| **Fab 1 - August 2011** | | **Fluorinated Gases Used in Fab 1** | | | | | | | **Byproducts** | | |
| **Gas** | **Units** | **NF3** | **CF4** | **CHF3** | **SF6** | **CH2F2** | **C4F8** | **C5F8** | **C2F6[a]** | **C3F8[a]** | **Total[b]** |
| EF | Emissions/Usage | 0.0576 | 0.8321 | 0.0569 | 0.3768 | 0.1129 | 0.0676 | 0.0252 | | | |
| bpEF | (kg emit / tot F use) | | | | | | | | 0.0050 | 0.0039 | |
| GWP | CO2e | 17,200 | 6,500 | 11,700 | 23,900 | 650 | 8,700 | 100 | 9,200 | 7,000 | |
| Emissions | Kg/hr | 0.1453 | 0.2591 | 0.0426 | 0.0071 | 0.0009 | 0.0008 | 0.0008 | 0.0183 | 0.0142 | 4.9066 |
| Emissions | (mTCO2e/mo) | 1,824 | 1,229 | 364 | 125 | 0 | 5 | 0 | 123 | 73 | 4,743 |
| Emissions | % of total | 38.46% | 25.92% | 7.67% | 2.63% | 0.01% | 0.10% | 0.00% | 2.60% | 1.53% | |
| **EF Agreement** | % Mar - Aug EF∆ | **14.38%** | **4.01%** | **3.73%** | **-20.56%** | **-1.90%** | **-18.10%** | **-1.98%** | **27.55%** | | |

*a. C2F6 and C3F8 were not used by COMPANY D Fab 1, and are byproducts.*
*b. The totals include N2O.*

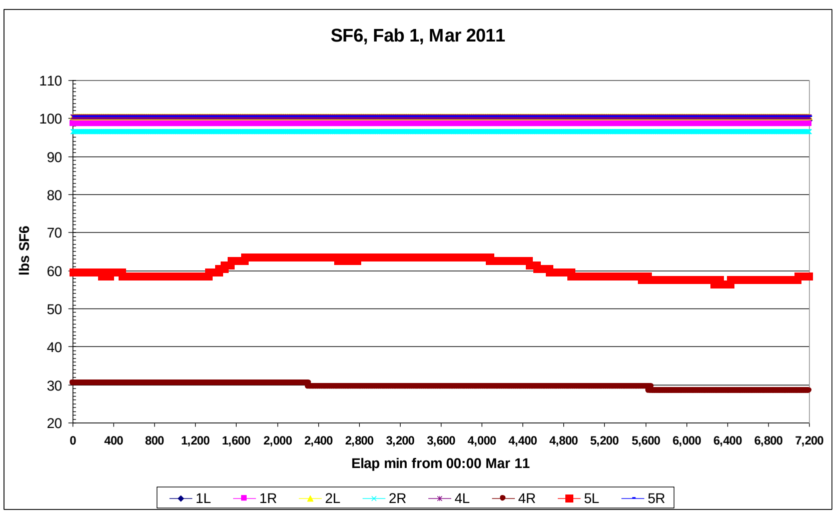
*Although we believe that the 20.6 % difference between the March and August emission factors for SF6 is quite good, we note that the relatively higher difference between the March and August tests for SF6 may likely be attributable to the resolution of the gas usage metrology that was available at the time of the test. Figure 1-1 shows the SF6 measurements data that is available from the time of the March test, and it can be seen that recorded weight from one of the gas cylinders experienced a small, but distinctly anomalous amount of drift. In order to correct for this drift, a regression analysis was performed over a one month period of SF6 data that bracketed the test period, and used to compute the emission factors.*

*The F-gas with the next highest divergence between the March and August emission factors was c-C4F8 (18.1%). The March c-C4F8 usage rate is only <0.02 kg/hr., and the emissions only 0.0008 kg/hr., which is equivalent to 65 mTCO2e/yr. In the particular case of c-C4F8, all of the measured stack concentrations were less than the 0.8 ppbv field detection limit (FDL); therefore, the emission calculation is based upon an assigned concentration of ½ the FDL as per the standard practice used in this effort. Likewise, because of the very low gas usage rate, the measured gas usage for c-C4F8 is based upon the 5 day period bracketing the stack test period. Notably, the measured usage rate for this 5 day period was less than 0.3 % different than the average usage rate for the entire month of March.*

*There are a number of relatively straight forward options for increasing the resolution of gas usage measurements during future tests. For instance, under fab normal operation it is a common practice to gang several gas cylinders together as a means of minimizing the risk of the fab running out of a gas. For some fabs, one very simple means of increasing the gas usage measurement resolution is therefore to adjust the system so that only a single cylinder is used to supply gas over the duration of the stack test.*

*C2F6 and C3F8 are not used in Fab 1 but are generated as process byproducts. The byproduct emission factors (bpEF) for C2F6 as listed in Table 1-2 for March (0.0069) and August (0.0050) differ by 27.6%. Overall, the absolute C2F6 emissions are very small. The C3F8 byproduct emission factors for March (0.0004) and August (0.0039) did not agree well, but with less than 130 (mTCO2e/yr) emissions in March, the emissions are exceptionally low (approaching the resolution limits of the metrology) and of questionable relevance to the total GHG emissions statement for the fab. We note that, whereas the byproduct emission factors are calculated on the basis of the total F-gas usage, it seems likely that C2F6 and C3F8 byproducts would predominately be generated from higher fluorocarbon homologues; however, when we tried calculating bpEF for C2F6 and C3F8 solely on the basis of the COMPANY D Fab 1 usage of higher homologues, there was no significant change in the bpEF values for March and August.*

***Figure 1-1. SF6 weight scale measurements during the March 2011 Stack test at COMPANY D Fab 1.***




*COMPANY D Fab 2:*

*Two principal F-gases CHF3 and C2F6 were used in Fab 2 during the March and August stack testing periods. These 2 gases account for 97% of the total CO2e emissions. C4F8 and SF6 are used in small quantity in Fab 2; the usage rate is estimated to be less than 0.2 lb./day and is below the ability of the fab to measure with the metrology in use today. COMPANY D was thus not able to calculate emission factors. For low usage gases, the industry recommends estimating emissions using Tier 2a emission factors as discussed below. As listed in Table 1-3, the March and August emission factors for CF4 in Fab 2 agree within 17.7 %; whereas the emission factor for C2F6 agrees within 21 %. Although the agreement is not quite as good as obtained for the*

*Fab 1 gases, we believe that this data also represents an exceptionally good and robust demonstration of the utility of the SIA's proposed stack testing method for F-gas.*

***Table 1-3. COMPANY D Fab 2 Stack Emissions and Emission Factors for March and August 2011.***

| Fab 2 - March 2011 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Gas** | **Units** | **NF3** | **CF4** | **CHF3** | **SF6** | **C2F6** | **C3F8** | **CH2F2** | **C4F8** | **C5F8** | **Total** |
| EF | (kg emit / kg use) | | 6.408 | | | 0.422 | | | | | |
| GWP | CO2e | 17,200 | 6,500 | 11,700 | 23,900 | 9,200 | 7,000 | 650 | 8,700 | | |
| Emissions | Kg/hr | 0.000 | 0.186 | 0.018 | 0.001 | 0.888 | 0.000 | 0.000 | 0.000 | 0.000 | |
| Emissions | MTCO2e/month | 0 | 884 | 157 | 17 | 5,965 | 0 | 0 | 0 | 0 | 7,023 |
| Emissions | % of total | 0.00% | 12.59% | 2.23% | 0.25% | 84.94% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| **Fab 2 - August 2011** | | | | | | | | | | | |
| **Gas** | **Units** | **NF3** | **CF4** | **CHF3** | **SF6** | **C2F6** | **C3F8** | **CH2F2** | **C4F8** | **C5F8** | **Total** |
| EF | Emissions/Usage | | 5.273 | | | 0.511 | | | | | |
| GWP | CO2e | 17,200 | 6,500 | 11,700 | 23,900 | 9,200 | 7,000 | 650 | 8,700 | | |
| Emissions | Kg/hr | 0.000 | 0.211 | 0.029 | 0.001 | 1.049 | 0.000 | 0.000 | 0.000 | 0.000 | |
| Emissions | MTCO2e/month | 0 | 1,003 | 252 | 11 | 7,044 | 0 | 0 | 0 | 0 | 8,310 |
| Emissions | % of total | 0.00% | 12.07% | 3.03% | 0.13% | 84.77% | 0.00% | 0.00% | 0.00% | 0.00% | 100.00% |
| **EF Agreement** | % Mar - Aug EF Δ | | **17.71%** | | | **-20.91%** | | | | | |

*<u>COMPANY D N2O Emissions:</u>*

*Table 1-4 lists the emissions for N2O as measured at both Fab 1 and Fab 2, during the March and August 2011 stack testing. The reported ambient atmospheric concentration of ~320 ppbv N2O was subtracted from the measured stack N2O concentration values in order to calculate emissions. Emission factors were determined using the March and August data for Fab 1, but not for Fab 2. The Fab 2 N2O gas usage rates could not be determined because data were missing from two of the N2O gas cylinder weight sensors. For Fab 1, the N2O emission factors for March (0.34) and August (0.66) differ by a factor of almost 2.  N2O is the only gas in the COMPANY D data for which a large difference in the March and August emission factors was determined, and we do not know the reason for the large difference. Accordingly we believe it is appropriate to structure a Subpart I reproposal such that N2O emissions are estimated by applying a default emission factor to usage as currently required by the rule instead of through stack monitoring.*

***Table 1-4. COMPANY D Fab 1 and 2 Stack Emissions and Emission Factors for N2O.***

| **March 2011** | | **Fab 1** | **Fab 2** |
|---|---|---|---|
| **Quantity** | **Units** | **Mar N2O** | **Mar N2O** |
| EF | (kg emit / kg use) | 0.3417 | NA |
| GWP | CO2e | 310 | 310 |
| Emissions | Kg/hr | 2.5029 | 1.6247 |
| Emissions | (mTCO2e/mo) | 566 | 368 |
| Emissions | % of total CO2e | 10.26% | 4.97% |
| **August 2011** | | **Fab 1** | **Fab 2** |
| **Quantity** | **Units** | **Aug N2O** | **Aug N2O** |
| EF | Emissions/Usage | 0.6558 | NA |
| GWP | CO2e | 310 | 310 |
| Emissions | Kg/hr | 4.4176 | 2.3878 |
| Emissions | (mTCO2e/mo) | 1,000 | 540 |
| Emissions | % of total | 21.08% | 6.11% |

***Company E Emission Factors***

*Company E conducted emissions testing at a 200mm fab in May 2011. FTIR sampling was conducted on the three exhaust headers through which GHG using processes are exhausted. The fab has primarily NF3-based CVD chamber cleans using remote plasma devices, but it does still have some CVD tools that run C2F6 and CF4 cleans – such that C2F6 and CF4 are the primary emissions overall. There are more than 100 tools using GHGs (F-gases and N2O) in the fab. The CVD and etch tools have up to four individual process chambers per tool. The fab uses 10 different process greenhouse gases: CF4, C2F6, C4F8, CHF3, NF3, SF6, N2O and very small amounts of C4F6, CH2F2, and CH3F.*

***Table 1-5. Emission Factors and Annual Emissions from Company E Fab***

| Gas | Emission Factor (kg emitted/kg used) | 2010 Emissions based upon stack EF (kg/yr) | GWP (kg CO2e/kg) | 2010 emissions (metTonCO2e/yr) | % CO2e emissions by gas |
|---|---|---|---|---|---|
| **CF4** | 0.851 | 2,669.6 | 6,500 | 19,728 | 42.44% |
| **NF3** | 0.014 | 178.8 | 17,200 | 3,075 | 40.07% |
| **SF6** | 0.155 | 32.2 | 23,900 | 733 | 7.52% |
| **C2F6** | 0.724 | 1,780.8 | 9,200 | 21,726 | 4.48% |
| **CHF3** | 0.377 | 156.4 | 11,700 | 2,314 | 3.61% |
| **C4F8** | 0.321 | 169.7 | 8,700 | 1,748 | 1.88% |

*Six process greenhouse gases were measured in the exhaust and emission factors are listed in Table 1-5. C4F6, CH2F2 and CH3F emissions were not detected. As previously discussed, emissions of these low use gases can be estimated using Tier 2a emission factors. N2O emissions were only detected in a single header which is the lowest using zone; concentrations were below measurement sensitivities. Detection limits for N2O were high during this testing (several ppm), because the enhanced FTIR system is optimized for F-gas detection. N2O is not included in this analysis. It is recommended that N2O emissions be estimated using default factors separate from F-gas emissions.*

***Company F Emission Factors***

*This section describes the emission factors that have been determined at two Company F Fabs: one in Fab 1 and the other in Fab 2.*

*Fab 1:*

*Company F has conducted annual stack level emissions testing at their Fab 1 since 2003, and the results from this testing, as presented in Table 1-6 , present an excellent record for the evaluation of stack testing, and stack testing emission factors. Following is a discussion of several key aspects of the Fab 1 stack testing data that are important to consider in addressing this data.*

- *There are 3 times over the 9 year sequence of data at which the change in gas mix would have signaled a need to retest the stacks and determine new emission factors. Recall from our November 2011 presentation to EPA in Washington DC, as well as from our prior letters that we believe that a change in the proportion of gases used at a Fab serves as a direct indicator of when production conditions have changed significantly,* *and stack retesting is warranted. The bottom row in Table 1-6 indicates that retesting would have been warranted in 2007, 2008, and 2009.*

- *The fraction of the Company F Fab plasma tool fleet which has POU abatement installed has evolved over the nine year period. Since the presence of POU abatement influences the emissions from a stack, we have configured Table 1-6 to show the pre-POU abatement EF for NF3, CF4 and SF6. These gases were all partially abated at this fab in recent years, with the % mix abated changing year by year. The listing of both a pre-abated EFs as well as the measured abated EF serves to factor out the difference caused by the changing abatement mix. Thus, for instance the measured EF for CF4 in 2010 and 2011 were 1.03 and 0.93 as listed in the first row of Table 1-6; however, factoring out the influence of the change in abatement, the effective emissions factors were 1.05 and 1.07, as listed in the second row of the table. The net effect is that there is a 9.7 % difference between the raw CF4 emission factors for 2010 and 2011; but only a 1.9% difference when the influence of the change in abatement is factored out. Likewise, by factoring out the influence of the changing mix in abatement the difference between the 2010 and 2011 EF for SF6 reduces from a 28.4 % to a 7.1 % difference; and the NF3 reduces from a 41.2 % to a 21.1 % difference. As we had noted previously for the period to period comparisons of the Company D emission factors, the Company F data likewise shows an exceptional degree of agreement that is highly supportive of our stack emission factor proposal. The influence of abatement affects NF3 from 2008-'11, and SF6 & CF4 in 2010 and '11. NF3 had no abatement prior to 2008 and SF6 and CF4 had none prior to 2010.*
- *C2F6 was not used at the fab after 2007. Although C2F6 is a known byproduct of some other F-gases, it has never been detected in the exhaust stacks in Fab 1 since it ceased being used as a process gas after 2007; therefore, no conclusions can be reached about byproduct C2F6 emission factors from this data.*
- *The CHF3 emission factors are listed as ranges because the concentrations were typically quite low, and influenced by the manner in which values below the limit of detection were treated. The lower value listed in the table was obtained by treating non-detects as if they were equal to zero, and the higher value is based upon treating the non-detects as if they were equal to the detection limit.*
- *CH2F2 was never detected in the Fab 1 stack tests although it is used at that facility. Because its use is small, it would still have been non-detectable even if all use had been emitted. Accordingly, we have listed the EF for CH2F2 as 1.0. This simply signifies that due to the low usage rate, and corresponding low emission rate, no conclusions about CH2F2 emission rates could be reached from this data. As discussed in the section below, SIA recommends that emissions of low use F-gases be estimated using Tier 2a emission factors.*

***Table 1-6. F-Gas Emission Factors for Years 2003 -2011 at Company F's Fab 1 Site***

| | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 |
|---|---|---|---|---|---|---|---|---|---|
| CF4 | 0.84 | 0.70 | 0.82 | 0.66 | 0.78 | 1.39 | 0.86 | 1.03 | .93 |
| Pre-abated EF | | | | | | | | 1.05 | 1.07 |
| SF6 | 0.79 | 0.53 | 0.64 | 0.59 | 0.39 | 0.69 | 0.51 | 0.67 | 0.48 |
| Pre-abated EF | | | | | | | | 0.70 | 0.65 |
| CHF3 | .33 - .96 | ≤1 | 0.58 - 1 | .63 - .83 | 0.52 - 1 | ≤1 | 0.13 - 1 | 0.54 - 1 | .35 - .98 |
| NF3 | 0.05 | 0.05 | 0.12 | 0.06 | 0.11 | 0.125 | 0.093 | 0.085 | 0.050 |
| Pre-abated EF | | | | | | 0.14 | 0.23 | 0.19 | 0.23 |
| C4F8 | No data | No data | No data | No data | No data | No data | No data | No data | ≤1 |
| CH2F2 | ≤1 | ≤1 | ≤1 | ≤1 | ≤1 | ≤1 | ≤1 | ≤1 | ≤1 |
| C2F6 | 0.58 | 0.60 | 0.48 | 0.37 | 0.38 | Not used | Not used | Not used | Not used |
| C4F6 | No data | No data | No data | No data | No data | No data | No data | No data | No data |
| product | microprocessors, flash memory | | | | | microprocessors | | | |
| linewidth | 90 - 180nm | 90 - 180nm | 90 ,180nm | 90 ,180nm | 90 ,180nm | 90nm | 45nm | 45, 32nm | 32nm |
| Retesting required?[1] | | | | | yes | yes | yes | | |

*The N2O emissions factors for Company F's Fab 1 site are listed in Table 1-7. Ambient atmospheric concentrations of N2O are reported to be on the order of 320 ppb and, therefore, this value was subtracted from the measured stack value of N20 to develop the N2O emission factors. As indicated previously, the N2O emission factors represent an anomaly relative to the predictable and consistent behavior that has been observed in the F-gases. It is recommended that N2O emissions be estimated using default factors.*

***Table 1-7. N2O Emission Factors for Years 2003 -2011 at Company F's Fab 1 Site***

| | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** |
|---|---|---|---|---|---|---|---|---|---|
| N2O | 0.51 | 0.52 | 4.18 | 0.87 | 1.7 | 1.89 | 0.77 | 1.15 | 0.54 |
| **Retesting required** | | | | | Yes | Yes | Yes | | |

*Averages of the emissions factors from 2009 -2011 were applied to estimated 2011 chemical use for the Fab 1 site to determine the emissions that would have been calculated using this data. The results are shown in Table 1-8. Current emission factors would only be based on 2009 and later data under the SIA stack re-testing proposal; earlier emission factors would have been updated under the SIA proposal due to changes in the F-gas usage mix. As Table 1-8 shows, when we apply these emission factors to 2011 usage, only 4 gases make significant contributions to annual F-gas emissions.*

***Table 1-8. 2011 Emissions for the Fab 1 Site Based on 2011 Gas Usage and 2009-2011 Average Emission Factors***

| | GWP | Avg. EF | Avg. Emissions (MTCO2e/yr) | % of total |
|---|---|---|---|---|
| CF4 | 6500 | 0.94 | 36,029 | 26.3% |
| SF6 | 23900 | 0.55 | 26,831 | 19.6% |
| CHF3 | 11700 | 0.67 | 17,779 | 13.0% |
| NF3 | 17200 | 0.08(1) | 56,174 | 41.0% |
| C4F8 | 8700 | | Not Detected | 0.0% |
| CH2F2 | 650 | 1 | 132 | 0.1% |
| C2F6 | 9200 | | Not Detected | 0.0% |
| Total F-gases | | | 136,945 | |
| N2O | 310 | 0.88 | 1,856 | |
| Total GHGs | | | 138,801 | |

*Fab 2:*

*Table 1-9 lists the emission factors for Company F's Fab 2 site. The 2011 testing at the Fab 2 facility was specifically targeted at measuring F-gases and was able to achieve lower limits of detection for those materials than the previous testing at the Fab 1 facility. As a result, the errors introduced by non-detect values are considerably less. The table illustrates the uncertainty introduced by non-detect readings for each compound. It does this by showing total emissions calculated as if all non-detect readings were equal to zero, then recalculates the totals setting non-detect readings equal to the detection limit, and one half the detection limit. In this case, the total error introduced by non-detect readings across all gases is about 4,000 MTCO2e/yr. Whereas the gases that are emitted at higher levels are not strongly influenced by the MDL, the gases that are emitted at lower concentrations, and therefore which have measured values that are closer to the MDL, are in fact influenced by the choice of how the MDL is handled.*

***Table 1-9. Emission Factors for Company F's Fab 2 Site based on 2011 Testing and Different Non-Detect (ND) Value Assumptions***

| | Emissions (MTCO2e/yr) | | | EF | | % tot CO2e |
|---|---|---|---|---|---|---|
| | ND=0 | 1/2 MDL | ND = MDL | ND=0 | ND=1/2MDL | @ 1/2 MDL |
| CF4 | 25,488 | 25,490 | 25,492 | 0.825 | 0.825 | 31.88% |
| CHF3 | 11,692 | 11,732 | 11,772 | 0.648 | 0.650 | 14.67% |
| CH2F2 | 0 | 65 | 130 | 0.000 | 1.000 | 0.08% |
| C2F6* | 7291 | 7837 | 8382 | 0.021 | 0.023 | 9.80% |
| C4F8 | 4,801 | 5,789 | 6,778 | 0.446 | 0.538 | 7.24% |
| C4F6 | 0 | | no GWP | 0.000 | 0.791 | 0.00% |
| NF3 | 5,049 | 5,264 | 5,479 | 0.011 | 0.011 | 6.58% |
| SF6 | 10,282 | 10,414 | 10,548 | 0.360 | 0.365 | 13.02% |
| N2O | 13,372 | 13,372 | 13,371 | 1.760 | 1.760 | 16.72% |
| Total | 77,975 | 79,963 | 81,952 | | | 100.00% |
| F-Gases | 64,603 | 66,591 | 68,581 | | | |

* C2F6 is not used in this fab; the EF calculation uses total F-gas used in the denominator.

*SIA Proposal for Estimating Emissions of Low Use Gases:*

*The ability to develop an accurate emission factor is highly dependent on the ability to monitor gas usage during the test period. For low usage gases, it is difficult to accurately measure gas usage over a brief period of time with currently available pressure or weight based monitoring. In the document "EPA Etch Question Responses 02032012", SIA provided justification for our proposal that Tier 2a be used as the basis for calculating annual manufacturing capacity and determining whether reporting is required. Under the Stack Test Alternative, SIA recommends that Tier 2a be used as a screening tool to determine what gases must be addressed via stack testing. If estimated emissions of an F-gas exceed a minimum threshold (to be determined) or if estimated emissions for that gas are greater than 15% of total F-gas emissions, SIA recommends that stacks be monitored for emissions of that gas and that a fab specific emission factor be developed. If emissions are less than the threshold or 15% of total estimated F-gas emissions, SIA recommends estimating emissions using Tier 2a emission factors.*