Comments of the
Semiconductor Industry Association (SIA)
On the Notice of Proposed Rulemaking:
"Revisions and Confidentiality Determinations for Data Elements Under the Greenhouse Gas Reporting Rule"
(87 FR 36920, June 21, 2022)
[EPA–HQ–OAR–2019–0424]
Submitted October 5, 2022

The Semiconductor Industry Association (SIA) appreciates the opportunity to submit the following comments on the Notice of Proposed Rulemaking on "Revisions and Confidentiality Determinations for Data Elements Under the Greenhouse Gas Reporting Rule" [87 Fed. Reg. 36920, June 21, 2022].

SIA is the trade association representing leading U.S. companies engaged in the design and manufacture of semiconductors. The U.S. is the global leader in the semiconductor industry, and continued U.S. leadership in semiconductor technology is essential to America's economic growth, technology leadership, and national security. More information about SIA and the semiconductor industry is available at www.semiconductors.org.

SIA supports efforts to improve the accuracy of reporting greenhouse gas (GHG) emissions in the semiconductor industry. As part of the World Semiconductor Council, the U.S. semiconductor industry has voluntarily reported its emissions of perfluorinated compounds since the mid-1990s, long before the adoption of the EPA's Mandatory Reporting Rule. SIA and the industry have worked to assist EPA in the development of Subpart I and subsequent revisions to the rule over the past 10 years. The industry and U.S. EPA invested significant effort to the multi-year refinement to 2006 IPCC Guidelines for National Greenhouse Gas Inventories (referred to as "2019 IPCC" in the following SIA comments). We support the continuous improvement of these reporting methods. SIA urges EPA to take into account the industry's longstanding voluntary efforts to reduce emissions and the overall context that emissions from the U.S. semiconductor industry constitute less than 0.1 percent of total U.S. greenhouse gas emissions.[1] Semiconductor products are also a key component in greenhouse gas reductions within other industries and services, such as energy, manufacturing, agriculture, land use, construction, and traffic management.[2] SIA supports some of the revisions proposed by EPA that would improve the reporting of GHG emissions, but are concerned that many of these changes add to the burden of reporting without substantially improving the overall accuracy of the methods.

While some of EPA's proposed changes are supported by SIA and will improve the accuracy of U.S. greenhouse gas (GHG) inventories, many elements of the proposed rule will not improve the accuracy and will impose significant costs on the industry. These requirements go beyond 2019 IPCC and risk placing the U.S. semiconductor industry at a competitive disadvantage. SIA wishes to specifically provide comment on thirteen elements of the proposed changes. A summary of those comments can be found in Table 1 with detailed comments following.

Table 1: Summary of SIA comments

EPA proposed change	SIA comment
1. Vacuum pump purge calibration requirement	SIA requests EPA remove proposed pump purge flow certification requirements because there is no impact on POU system performance and emissions estimate accuracy; moreover, the proposed changes would drive significant industry cost (in the tens of millions of dollars) as well as detrimental impacts to production tool uptime and go above and beyond 2019 IPCC.
2. Additions to abatement DRE certification requirements	SIA requests EPA tailor the emission control device operational requirements for default POU DREs to align with the following 2019 IPCC refinement language: "…obtain a certification by the emissions control system manufacturers that their emissions control systems are capable of removing a particular gas to at least the default DRE in the worst-case flow conditions, as defined by each reporting site." SIA requests EPA remove the requirement to provide supporting documentation for all abatement units using certified default or lower than default DREs. SIA also requests EPA clarify that reporters are not required to keep supporting documentation on abatement units for which a DRE is not being claimed. SIA requests that the worst-case flow definition align with the IPCC definition of highest total fluorinated compound or N_2O flows and highest total flow scenario. DREs measured at maximum flow conditions will be a worst case and should therefore be applied to all flows below maximum. SIA further requests EPA include language supporting full uptime for emission control devices interlocked with manufacturing tools or with abatement redundancy.
3. Revisions to stack testing method	SIA strongly requests that EPA clarify that testing is required for all operating stacks or stack systems <u>that have the potential to emit fluorinated greenhouse gases</u>. The proposed language requires a very large expansion in the testing scope and testing costs with no added emissions accuracy. SIA requests that EPA consider a stack testing methodology that can be simplified and used for both facility-level GHG abatement devices as well as POU abatement control. Uptime tracking for uncertified abatement devices is excessive, an expansion beyond the IPCC 2019 refinement requirements which puts U.S. fabs at a disadvantage in using a stack test method and does not improve the accuracy of emissions estimates. The current GHG stack test method is excessively onerous and, while simplifications are proposed, the stack test requirements remain onerous and more complex than criteria pollutant stack testing. The proposed F-GHG stack testing methodology is time, resource and cost prohibitive, thus, SIA requests the final rule include an option for facilities to simplify further to align with criteria emissions testing programs.
4. Frequency for submitting technology assessment reports	SIA urges EPA to proceed with finalizing the amendment to 98.96(y) before the March 31st 2023 due date for the next technology assessment report.

EPA proposed change	*SIA comment*
5. Requirement to use three methods to report results of emissions tests	The additional burden and complexity of calculating technology emission factors three different ways could be a disincentive to testing and will not improve overall emissions accuracy. Three sets of calculations result in the possibility that EPA will choose data that is not appropriate for the tested process. Due to the limitations of all proposed technology report emission factor calculation methodologies, SIA requests that emissions be calculated using the multi-gas method in which carbon-based F-GHG emissions are assigned across all carbon-based input F-GHG's. SIA believes the multi-gas method would appropriately assign emissions, especially for recipes running more than two gases at once. The multi-gas method will also eliminate concerns regarding emission factors that do not meet conservation of mass principles. SIA believes the multi-gas emission factor calculation methodology supports the intent of identifying changes to emissions characteristics due to developments within semiconductor technologies.
6. Addition of combustion emission factors	SIA requests EPA remove the requirement to calculate CF_4 emission byproduct from hydrocarbon-fuel-based emissions control systems that abate F_2 or remote plasma clean (RPC) NF_3. The data upon which these values are based are not peer reviewed, are based on assumptions, and appear to be based on emissions measurement values that did not use industry standards or the EPA DRE testing protocols.
7. Addition of hydrocarbon-fuel based emission control system definition	SIA strongly requests the removal of Equation I-9 and associated ABCF4,F2 and BF2,NF3 data elements. However, in the alternative, SIA requests changes to hydrocarbon-fuel-based combustion emissions control systems (HC fuel CECS) requirements to remove confusion and double counting of emissions. SIA requests the definition of hydrocarbon-fuel-based combustion emission control systems is tailored to specify hydrocarbon-fuel-based combustion emissions control systems (HC fuel CECS) connected to manufacturing tools. SIA also requests to include the following language: "…and have the potential to emit fluorinated greenhouse gases". SIA requests EPA specify that HC fuel CECS uptime during stack testing applies to NF_3 remote plasma clean or input F_2 processes only. SIA also requests that Equation I-9 is specifically exempted from the stack testing methodology to prevent inadvertent double counting of some CF_4 emissions. The additional complexity of apportioning F_2 and RPC NF_3 to both <0.1% certified and uncertified HC fuel CECS will require time and cost investments, which are not justified by data. Increased CF_4 emissions will result in a time series inconsistency for semiconductor industry greenhouse gas reporting, based on data that is not peer reviewed, are based on assumptions, and appear to be based on emissions measurement values that did not use industry standards or the EPA DRE testing protocols. SIA requests that within the default emission factor method, CF_4 emissions from the HC fuel CECS abatement of F_2, as calculated by Equation I-9, are applied instead of, not in addition to, default CF_4 BEF's for RPC NF_3.
8. Carbon-based emission byproducts from SF_6, NF_3, F_2, or other non-carbon input gases	SIA requests that the rule clarify that carbon-containing byproduct emission factors are zero when calculating emissions from non-carbon containing input gases (SF_6, NF_3, F_2 or other non-carbon input gases) and when the film being etched or cleaned does not contain carbon.
9. Updated input gas and byproduct emission factor values	SIA supports the update to input gas and BEF values based on conservative direct and byproduct emission pathways. SIA also supports the alignment of input gas and BEF values with 2019 IPCC values and requests the use of IPCC Fifth Assessment Report global warming potentials to continue to align with international and voluntary reporting standards.

EPA proposed change	SIA comment
10. EPA additional requests for comment	While capping an emission factor at 0.8 is likely an adequate assumption for maximum emissions, it remains somewhat arbitrary. SIA believes further N_2O stack testing investigation is necessary before commenting on potential accuracy. SIA is currently unaware of other testing methodologies that are accurate and feasible for the purposes of testing F_2 and CF_4 simultaneously at the semiconductor manufacturing tool and POU abatement device.
11. Revisions to default DRE's	SIA supports the proposals to assign default DREs to commonly used gases without distinguishing between process types and using the 96% NF_3 DRE as documented in EPA's technical support documentation (TSD) and August 25, 2022 docket memorandum update.
12. Subpart C additional device tracking	Tracking individual combustion units between 10 and 100 MMBtu/hr within the semiconductor industry would provide little value for the overall U.S. GHG emissions and would require an undue burden and cost to install individual unit natural gas meters. SIA requests an exemption from these requirements for Subpart I reporters.
13. Subpart OO additional gas use reports	SIA requests EPA clarify that chemical supply "end use" refers to industry category only, such as electronics or semiconductor use, and does not refer to more specific uses. The specific purchases and purposes of chemical use should be considered semiconductor industry confidential business information and therefore protected from public disclosure.

1.) Vacuum Pump Purge Calibration Requirement

In the Proposed Revisions to Improve the Quality of Data Collected for Subpart I, Revisions to calibration requirements for abatement systems, EPA requires:

> *"The site maintenance plan for abatement systems must include a defined preventative maintenance process and checklist. Preventative maintenance must include, but is not limited to, calibration of pump purge flow indicators. Pump purge flow indicators must be calibrated each time a vacuum pump is serviced or exchanged."*
> The preamble goes on to indicate this proposed change would: *"......require calibrations every 1 to 6 months, depending on the process.*

This proposal would have significant impacts to the U.S. semiconductor industry and will drive a major increase in pump replacement and tool downtime. Point-of-use (POU) abatement devices and their connected vacuum pumps are separate systems. While physically connected, POU maintenance activities and pump replacement schedules are independent of one another. Of particular importance, vacuum pumps are directly in-line with semiconductor processing tools and chambers and therefore must meet strict semiconductor manufacturing particle requirements for quality control to prevent product defects.

Based on discussions with pump manufacturers and SIA device manufacturers, pump purge flow calibration is technically and operationally infeasible for the device manufacturers to perform. Please note that the following statements represent standard practice as per SIA commenting members. The purge flow indicators are factory calibrated and are part of the pump installation and commissioning. If there is a flow indicator failure, the vacuum pump is replaced with a factory-calibrated pump. Pump maintenance and repair is not typically performed at the manufacturing tool and requires pump disconnection and physical removal, and therefore are often repaired off-site.

Pump manufacturers do not provide recommendations or specifications for re-calibration of these pumps because it is performed at the pump manufacturer's facility. There is no pump redundancy installed on a tool nor is it standard within the semiconductor industry. To check the calibration and potentially replace the flow transducer, the vacuum pump must be shut down to safely work on it. Any replacement of the pump would require a tool shutdown for safe pump replacement and therefore 12 to 48 hours of downtime for manufacturing requalification, as strict fab particle contamination requirements must be met upon restart of the pump. In many cases, the pump cannot be expected to immediately restart after reconnection to tool due to condensation of process byproduct.

Based on feedback from members of SIA via an August 2022 survey, semiconductor manufacturing sites can have 2,000+ POU abatement devices as well as 4,000+ vacuum pumps in a high-volume-manufacturing (HVM) site. Future semiconductor fabs will primarily be HVM sites and will also be impacted by these proposed changes. Pumps remain continually in service on the order of years, rather than months. Although EPA estimates pump purge calibrations every 1 to 6 months, pump vendors indicate that pumps can remain in service for many years without requiring calibration of the pump purge.

A pump change/refurbishment costs over $5000 per occurrence. Hiring trained personnel to perform these tasks would be operationally infeasible due to the sheer number of pumps. Process pump repair or calibration activities can require significant coordination with factory and site operations because equipment and technician resources are highly specialized. The number of staged pumps that would be required is prohibitive due to limited storage space.

SIA estimates that such increased pump downtime, process equipment tool downtime, and maintenance could cost the U.S. semiconductor industry annually **about *$40 million USD***[3] in labor and equipment costs and **significantly more cost in tool down time and other processing costs**, not including impact to revenue which will lead to even greater cost impacts.

SIA believes existing performance certification of POU emissions control devices based on high flow conditions are highly protective of POU system reliability. High flow POU certification is based on maximum device flows. For multi-chamber tools, this high flow certification includes all chambers running at once. Significant variations in pump purge flows are unlikely and the magnitude of these variations would be a small component of overall POU flow volumes. Therefore, pump purge flows are not necessary to calibrate after initial pump commissioning to ensure accurate POU performance.

SIA requests EPA remove proposed pump purge flow certification requirements because there is no impact on POU system performance and emissions estimate accuracy; moreover, the proposed changes would drive significant industry cost (in the tens of millions of dollars) as well as detrimental impacts to production tool uptime and go above and beyond 2019 IPCC.

2.) Additions to abatement DRE certification requirements

In the Proposed Revisions to Improve the Quality of Data Collected for Subpart I, Updates to default emission factors (EF's) and destruction or removal efficiencies (DREs) to improve the accuracy of emissions estimates, EPA states:

> *"…To use the default or lower manufacturer-verified destruction or removal efficiency values, operation of the abatement system must be within manufacturer's specifications, including but not limited to specifications on vacuum pumps' purges, fuel and oxidizer settings, supply and exhaust flows and pressures, and utilities to the emissions control equipment including fuel gas flow and pressure, calorific value, and water quality, flow and pressures."*
>
> EPA also states in the preamble: *"We are also proposing to modify the conditions in 40 CFR 98.94(f) under which the default DRE may be claimed to require that the reporter, in order to claim the default value for that abatement system and gas, must: (1) certify that the abatement device is able to achieve a value equal to or greater than the default DRE value under the worst-case flow conditions during which the facility is claiming that the system is operational; and (2) provide supporting documentation."*

SIA believes the proposed increase in certification and documentation requirements beyond existing POU operational requirements will dissuade semiconductor companies from accounting for DREs from installed POU, resulting in an over-estimate of emissions from the semiconductor industry. Based on an internal SIA survey, 85% of fabs indicated they are less likely to claim default DRE values based on the proposed POU certification and documentation language. Zero fabs indicated they already have the proposed expanded certification and documentation for all POU, whereas 100% of fabs indicate this will require additional time and resources from both semiconductor manufacturers and POU suppliers to collect and file additional POU information.

Often, POU suppliers provide high-level certifications specifying the parameters for which POU are considered certified to abate GHG's. Some POU devices have been in place for over 20 years and may no longer have the original supplier documentation with the additional data requirements. The existing 40 CFR Part 98 Subpart I rule language states that to use default DRE values in emissions calculations, required documentation is limited to the site maintenance plan, which shall include "manufacturer's recommendations and specifications for installation, operation, and maintenance…" SIA believes the existing language in Subpart I is sufficient to ensure proper POU device performance while being consistent with IPCC 2019. The requirement to provide supporting documentation of manufacturer certified POU DREs, including testing method, is burdensome and may be unachievable, especially for older abatement units.

SIA members comply with the manufacturer-specified performance requirements to ensure certified POU DREs are achieved. Adding operational elements of fuel and oxidizer settings, fuel gas flows and pressures, fuel calorific values, and water quality, flow and pressures to the POU DRE requirements are outside the manufacturer-specified requirements for emissions control. Additionally, many of these proposed expanded parameter tracking elements are not necessary to ensure accurate POU DREs. These and other POU default DRE certification and documentation requirements go above and beyond the 2019 IPCC and will make it more difficult for U.S. reporters to take credit for installed and future emissions control devices, resulting in a less accurate, overestimated U.S. GHG emissions inventory.

The inclusion of a low flow certification boundary is unduly restrictive and should not be considered within default DRE requirements. The measurement methodology drives a minimum field detection limit (FDL) and DREs can only be measured with accuracy if the concentration is above FDL's. The methods do not address destruction of low levels of GHG. This does not mean there is no destruction of the GHG but only that it cannot be measured accurately at levels below an instrument detection level. DREs measured at maximum flow conditions will be a worst case and should therefore be applied to all flows below maximum. SIA requests the use of maximum flow certified manufacturers' DREs without restricting application of DRE below detection limits; otherwise, DRE tracking and calculation complexity would significantly increase, and emissions accuracy would decrease. 2019 IPCC refers to the worst-case flow conditions as "…the highest total FC [fluorinated compound] or N2O flows through each model of emissions control systems (gas by gas and process type by process type across the facility) <u>and</u> highest total flow scenarios …" with no mention of low-flow or additional control parameters.

Additionally, SIA supports 2019 IPCC language that: "Inventory compilers should also note that UT [uptime] may be set to one (1) if suitable backup emissions control equipment or interlocking with the process tool is implemented for each emissions control system. Thus, using interlocked process tools or backup emissions control systems reduces uncertainty by eliminating the need to estimate UT for the reporting facility." SIA believes such language will drive further use of manufacturing tool interlocks or emission control system redundancy while having the added benefit of simplifying uptime tracking of individual POU.

SIA requests EPA tailor the emission control device operational requirements for default POU DREs to align with the following 2019 IPCC refinement language: "…obtain a certification by the emissions control system manufacturers that their emissions control systems are capable of removing a particular gas to at least the default DRE in the worst-case flow conditions, as defined by each reporting site."

SIA requests EPA remove the requirement to provide supporting documentation for all abatement units using certified default or lower than default DREs. SIA also requests EPA clarify that reporters are not required to maintain supporting documentation on abatement units for which a DRE is not being claimed.

SIA requests that the worst-case flow definition align with the IPCC definition of highest total fluorinated compound or N_2O flows <u>and</u> highest total flow scenario. DREs measured at maximum flow conditions will be a worst case and should therefore be applied to all flows below maximum.

SIA further requests EPA include language supporting full uptime for emission control devices interlocked with manufacturing tools or with abatement redundancy.

3.) Revisions to stack testing method

In the Proposed Revisions to Improve the Quality of Data Collected for Subpart I, Revisions to improve the calculation methodology for stack testing, EPA requires:

> *"For each stack system in the fab, measure the emissions of each fluorinated GHG from the stack system by conducting an emission test. In addition, measure the fab-specific consumption of each fluorinated GHG by the tools that are vented to the stack systems tested."*
>
> The preamble: *"propos[es] to add new Equations I-24C and I-24D and a table of default weighting….[and] proposing to revise Equations I-24A and I-24B… [and]… proposing at 40 CFR 98.93(i)(3) to require that all stacks be tested if the stack test method is used….[and]… proposing to replace Equation I-19 with a set of equations (i.e., Equations I-19A, I-19B, and I-19C) that will more accurately account for emissions when pre-control emissions of an F-GHG come close to or exceed the consumption of that F-GHG during the stack testing period."*

Since its inception in 2014, EPA data indicate that no U.S. semiconductor facilities have used the stack testing method as a basis for reporting. SIA appreciates EPA's efforts to revise the stack testing method portion of Subpart I to simplify the method and reduce the burden on reporting facilities. However, the proposed revision to the stack testing method remains very complex. SIA does not expect member companies to use this method, as proposed, due to its complexity and marked difference to stack criteria air pollutant compliance calculations.

SIA first requests that EPA continue to use the "stack system" nomenclature for stack testing, consistent with previous mandatory reporting rule publications as well as 2019 IPCC. The proposed changes within the preamble use the term "all stacks" and SIA requests that language in the rule should retain the term "stack systems".

EPA proposes that all stacks be tested based on the erroneous assumption that "… the number of stacks at each fab is expected to be small (e.g., 1-2)…" Based on an August 2022 survey of nine SIA member companies, responding member companies counted over 250 stacks that would require testing under the existing stack testing methodology for the 33 fabs surveyed, as well as more than 170 additional process stacks that do not contain fluorinated GHG's (for example: general fab exhaust). Based on physical stack or stack system testing as well as the subsequent data processing and analysis, stack test costs are estimated at about $10,000 USD per sampling location plus an approximate $20,000 mobilization fee per testing event plus an average of $10,000 of infrastructure preparation (scaffolding, duct drilling, provision of electricity for testing equipment, etc.). Assume 12 stack systems require testing, the cost of one stack testing event per fab can average approximately $150,000 per site. For difficult or large testing events, the cost can be as much as $700,000 USD to test all GHG-containing process stack systems. Adding stacks that do not have the potential to emit fluorinated greenhouse gases to stack testing scope would add an additional $60,000 to $200,000 per testing event and as much as $400,000 for large sites.

SIA strongly requests EPA clarify that the testing is required for all operating stacks or stack systems *that have the potential to emit fluorinated greenhouse gases*. The proposed

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language requires a very large expansion in the testing scope and testing costs with no added emissions accuracy.

SIA supports the removal of the preliminary stack testing calculation process within 40 CFR 98.93(i). SIA suggests alignment with stack testing methods that various regulatory agencies require for criteria air pollutant annual reporting that are in current air permits. These stack testing methods for criteria pollutants require the testing of operating stack systems that have the potential to emit the pollutant being measured. The tested emissions from all operating stacks or stack systems are then summed into a tested mass emission rate. The production rate during the testing is also tracked. Emissions are then calculated using the stack testing emission rate and multiplying by a production scalar (for example, monthly or annual production divided by production rate at time of testing). These stack testing events are repeated on an ongoing basis ranging from annual to once every 5 years. This criteria pollutant stack testing methodology supports both POU as well as facility-level GHG abatement control strategies.

Table 2 (located at the end of this document) provides a comparison of an example criteria air pollutant stack testing calculation methodology as compared to the stack testing methodology for F-GHG's. The less complicated criteria air pollutant stack testing methodologies are widely accepted for compliance demonstration. ***SIA requests that EPA consider a stack testing methodology that can be simplified and used for both facility-level GHG abatement devices as well as POU abatement control.***

Additionally, SIA requests that, for emissions close to maximum field detection limits (FDL's) or intermittently below FDL's, default emission factor methods can be used instead of detection limits or one-half detection limits. In a representative calculation, one semiconductor fab quoted an annual flow of 1.25 million dry standard cubic feet (dscf) per year of exhaust through which fluorinated greenhouse gases are emitted. Based on flows and stack concentrations of one-half detection limit, an example CH_2F_2 stack testing result is 15 times that of the default emission factor method. Due to high flow and low concentration of emissions from a semiconductor fab, individual gas emissions close to or below FDL's may be represented more accurately with the default emission factor method than with stack testing. ***As such, SIA requests that the rule specifically allow a hybrid approach where stack testing of individual F-GHGs can be used in conjunction with the default emission factor method for other F-GHGs.*** This hybrid method could also be used to estimate process N_2O emissions.

The Agency further explains in the preamble their intent to "…require that the uptime… during stack testing period average at least 90% for uncertified hydrocarbon-fueled emissions control system." ***Uptime tracking for uncertified abatement devices is excessive, an expansion beyond the IPCC 2019 refinement requirements which puts U.S. fabs at a disadvantage in using a stack test method and does not improve the accuracy of emissions estimates.***

The current GHG stack test method is excessively onerous and, while simplifications are proposed, the stack test requirements remain onerous and more complex than criteria pollutant stack testing. The proposed F-GHG stack testing methodology is time, resource and cost prohibitive, thus, SIA requests the final rule include an option for facilities to simplify further to align with criteria emissions testing programs.

4) Frequency for submitting technology assessment reports

SIA supports EPA's proposal to amend 98.96(y) to decrease the frequency of submission of technology assessment reports from every three years to every five years. As stated in the preamble:

> *"Under the current rule, semiconductor manufacturing facilities are required to submit their next technology assessment report by March 31st, 2023 (concurrent with their RY2022 annual report). This proposed revision would affect the due date for that technology assessment, moving the due date from March 31, 2023, to March 31, 2025."*

We urge EPA to proceed with finalizing the amendment to 98.96(y) before the March 31st 2023 due date for the next technology assessment report.

5.) Requirement to use three methods to report results of emissions tests

In the Proposed Revisions to Improve the Quality of Data Collected for Subpart I, Revisions to clarify and revise calculation methodologies and required data elements for data submitted in the technology assessment report, EPA proposes within the preamble to

> *"…submit three sets of emission factors for each test…" and EPA indicates they "do not anticipate would significantly increase burden."*

Plasma etching and wafer cleaning are critical process steps in the manufacture of semiconductors and these steps use various F-GHG's applied individually or as a mixture of two or more F-GHG gases. In plasma etching, a dynamic solution of ions, electrons, and neutral species is generated to react and change the surface of semiconductor products. This highly energetic and reactive ion cloud is used to complete three basic steps in the overall etching manufacturing process: adsorption, product formation, and product desorption. The range of surface changes completed via plasma etching process can be as minute as the formation of nanometer unique 3D channels to larger removal of entire surface layers. As a result, the plasma etching processes used in manufacturing must be optimized across many variables including, for example: ion selectivity, etch rate, surface material type(s), potential for surrounding damage, and repeatability. To meet the requirements for successful manufacturing of advanced semiconductor products, many of the modern manufacturing plasma etch process recipes contain multiple GHG gases.

EPA has identified three specific goals for the implementation of emission factors "in order to ensure that emission factors are developed in a consistent manner across facilities and over time and to allow the EPA to compare emission factors across the industry and track trends in industry emission rates." These goals include:

> 1 – Calculating the same way as the emission factors already in the EPA's database to track technology changes and eliminate differences attributable to calculation methods,
>
> 2 – Be robust and broadly applicable to reflect physical reality as much as possible and to not be impacted by changing proportions of input gases, and

3 – Consistently calculating across facilities and processes to ensure that resulting defaults are not biased by "cherry-picking" of methods.

EPA proposes the semiconductor industry provide three sets of calculation data for each emissions test, tripling the reporting burden for technology emission factor data. In addition to the increased scope of data collection and integration, each of EPA's proposed methods fail to meet the three goals stated above, but for different reasons.

The "Dominant Input Gas" calculation method violates the physical reality of conservation of mass for multi-gas plasma etch / wafer cleaning processes and may lead to emission factors (1-U) greater than 1. Additionally, this method does not clearly define what gas would be dominant in situations where gases of equal or near-equal mass are used. The increased use of recipes using multiple gases also increases the probability of generating emission factors greater than 1 when characterizing process emissions and highlights the need for alternative emission factor integration methodology(s). To address this possibility, EPA sets a "cap" on the dominant input gas emission factor of 0.8. The use of a "cap" value does not meet the goal of calculating the same way as the emission factors already in EPA's database as well as it may amplify or obfuscate technology changes by setting an artificial maximum emission value.

The "All Input Gas" calculation method does not select a dominant gas, but rather calculates emission factors based on all input gases. While potentially decreasing the possibility of an emission factor greater than one as compared to the "Dominant Input Gas" calculation methodology, this method also violates the physical reality of conservation of mass for plasma etch / wafer cleaning processes when using multiple gases and may lead to byproduct emission factors (BEF) greater than 1. Capping the 'max (1-U)' value at 0.8 for individual testing does not align with the maximum seen within historical test data submitted by industry but is instead aligned with the maximum average EF across all gases. Again, by using an assumed emission factor within the calculation methodology, this method does not meet the goal of calculating the same way as the emission factors data existing in EPA's database and it may amplify or obfuscate technology changes by setting an artificial maximum emission value.

The "Reference Emission Factor" calculation method, as proposed, ties tested emission factors to historical or past submitted data. It is unclear how this method would be implemented and whether (1-U) or BEFs would be held constant. The method, as a whole, increases the difficulty in comparing individual tests depending on what is held constant. In addition, if new gases or byproducts are used or measured, the methodology will not have a reference emission basis to apply. Again, this method does not meet the goals listed by EPA in collecting emission factors consistently over time.

To encourage additional tool level testing of existing and emerging technologies, we encourage EPA to add a single, multi-gas calculation methodology to the rule. In the "Multi-Gas" calculation method, all non-carbon-containing GHG's, such as SF_6 and NF_3, are attributed to the input of these non-carbon-containing GHG's. SF_6 emissions are divided by the input of SF_6 only and NF_3 emissions are divided by the input of NF_3 only. Carbon-containing emissions are attributed to all carbon containing input gases. Therefore, the emissions of input chemicals include byproduct formation from other source gases. This method ensures the conservation of mass, meeting EPA's goal of reflecting physical reality. Due to the relative unpredictability of plasma reactions depending on amount or concentration of input gases as well as plasma and manufacturing tool variables, any carbon-based byproduct could be generated by any carbon-based input gas. This relative unpredictability drives variability across single-gas emission factors, most falling anywhere between 0.1 to 0.9. High variability in emission factors is based on many factors, not just varying input gas proportions, as seen in the spread of emission factors within single gas data. For this reason, SIA suggests using the "Multi-Gas" method for simple, consistent, and robust emissions calculations. The "Multi-Gas" method generates emission factors consistent and within the range of the existing emission factor data. The "Multi-Gas" method is currently and will remain robust through future technology changes. This method accommodates new gases, changes in technology, and does not violate the physical reality of conservation of mass. And this method does not use past or assumed data to calculate emission factors or byproduct emission factors, which supports EPA's goal to trace technology changes and not obfuscate with previous data.

EPA proposes that emission factors be calculated using three different methods and that results be submitted for all three methods. ***The additional burden and complexity of calculating technology emission factors three different ways could be a disincentive to testing and will not improve overall emissions accuracy. Three sets of calculations result in the possibility that EPA will choose data that is not appropriate for the tested process.***

Due to the limitations of all proposed technology report emission factor calculation methodologies, SIA requests that emissions be calculated using the multi-gas method in which carbon-based F-GHG emissions are assigned across all carbon-based input F-GHG's. SIA believes the multi-gas method would appropriately assign emissions, especially for recipes running more than two gases at once. The multi-gas method will also eliminate concerns regarding emission factors that do not meet conservation of mass principles. SIA believes the multi-gas emission factor calculation methodology supports the intent of identifying changes to emissions characteristics due to developments within semiconductor technologies.

6.) Addition of combustion emission factors

In the Proposed Revisions to Improve the Quality of Data Collected for Subpart I, Calculation of byproducts produced in hydrocarbon fueled abatement systems to improve the accuracy of emissions estimates, EPA proposes to establish the following:

> *"If your fab employs hydrocarbon-fuel-based emissions control systems (including, but not limited to, abatement systems as defined at § 98.98) to control emissions from tools that use either NF3 in remote plasma cleaning processes or F2 as an input gas in any process type or sub-type, you must calculate the amount CF4 produced within and emitted from such systems using Equation I–9 using default utilization and by-product formation rates as shown in Table I–3 or I–4 of this subpart. A hydrocarbon-fuel-based emissions control system is assumed not to form CF4 from F2 if the electronics manufacturer can certify that the rate of conversion from F2 to CF4 is <0.1% for that hydrocarbon-fuel-based emissions control system…*
>
> $AB_{CF4,F2}$ *= Mass fraction of F2 in process exhaust gas that is converted into* CF_4 *by direct reaction with hydrocarbon fuel in a combustion abatement system. The default value of* $AB_{CF4,F2}$*=0.116.*
>
> $B_{F2,NF3}$ *= Byproduct formation rate of F2 created as a by-product per amount of NF3 (kg) consumed in remote plasma cleaning processes (kg).* $B_{F2,NF3}$ *= 0.5"*

The data upon which CF_4 byproduct emissions from hydrocarbon-fuel-based emissions control system abatement of F_2 gas (from etch or remote plasma chamber cleaning processes) is based on limited and unverified data. The values documented within 2019 IPCC and referenced within EPA's rule proposal are ultimately based on a single, confidential data set from one abatement supplier. SIA is concerned that developing regulatory language around this single, unverified data set does not accurately represent the CF_4 byproduct emissions from the uses or generation of F_2 and may deliver an advantage to the single emissions control system supplier that provided the data.

SIA has a number of concerns with the information provided within the 2019 IPCC and EPA proposed rule supporting documentation upon which the CF_4 byproduct ($AB_{CF4,F2}$ and $B_{F2,NF3}$) is based.

- The F_2 emission values presented in *"Influence of CH_4-F_2 mixing on CF_4 byproduct formation in the combustive abatement of F_2"* by Gray & Banu (2018) are based on testing conducted in a lab under conditions that are not found in actual semiconductor abatement installations. Test methods do not appear to adhere to those specified in industry standard test methods or the EPA DRE Protocol. F_2 results are measured from a device, the MST Satellite XT, designed to provide "nominal" F_2 concentrations meant for health and safety risk management and not for environmental emissions measurement.
- "FTIR spectrometers measure scrubber abatement efficiencies" by Li, et. al. (2002) and "Thermochemical and Chemical Kinetic Data for Fluorinated Hydrocarbons" by Burgess, et. al. (1996) provide anecdotal and hypothetical emission pathways for the combustion of fluorinated gases, but do not confirm reliable and peer reviewed CF_4 emission results from current semiconductor manufacturing use or generation of F_2.
- Finally, EPA references a single, confidential data set from Edwards, Ltd (2018) upon which numerical $AB_{CF4,F2}$ and $B_{F2,NF3}$ values are based. This single data set of 15 measurements refers to an RPC NF_3 to F_2 emission value based on mass balance. SIA does not support using the data provided by Edwards confidentially without the ability to review the underlying data and experimental procedure of the 15 measurements upon which the RPC NF_3 to F_2 emission factor was based. Mass balance has shown to be a highly conservative method in estimating emission factors and this confidential data set lacks visibility into repeatability, experimental design, and semiconductor process applicability.

Because $AB_{CF4,F2}$ and $B_{F2,NF3}$ are based on a single set of supplier data, SIA is concerned this single supplier will have a marked advantage in demonstrating compliance with proposed requirements.

SIA requests EPA remove the requirement to calculate CF_4 emission byproduct from hydrocarbon-fuel-based emissions control systems that abate F_2 or remote plasma clean (RPC) NF_3. The data upon which these values are based are not peer reviewed, are based on assumptions, and appear to be based on emissions measurement values that did not use industry standards or the EPA DRE testing protocols.

7.) Addition of hydrocarbon-fuel based emission control system definition

In the Proposed Revisions to Improve the Quality of Data Collected for Subpart I, Calculation of byproducts produced in hydrocarbon fueled abatement systems to improve the accuracy of emissions estimates, EPA proposes to establish the following definition:

> *"Hydrocarbon-fuel based emission control systems means a hydrocarbon fuel based combustion device or equipment that is designed to destroy or remove gas emissions in exhaust streams via combustion from one or more electronics manufacturing production processes, and includes both emissions control systems that are and are not designed to destroy or remove fluorinated GHGs or N2O."*

SIA strongly requests the removal of Equation I-9 and associated $AB_{CF4,F2}$ and $B_{F2,NF3}$ data elements. An alternative approach would be to modify in the following respects:

A. General Comments:

SIA supports using the term "hydrocarbon-fuel-based combustion emissions control systems" (HC fuel CECS) which aligns with the nomenclature within 2019 IPCC rather than the less used "hydrocarbon-fueled abatement systems" or other terms. SIA requests that all emissions control systems language is updated to be consistent.

SIA believes the broad definition of HC fuel CECS may be interpreted to include all hydrocarbon-based fuel control systems, not just tool-level POU abatement. Semiconductor facilities widely implement large, facility-level volatile organic compound abatement devices to eliminate and control criteria volatile and non-volatile organic compounds, with no expectation of fluorinated greenhouse gas emissions. Additionally, although not currently implemented, future facility-level F-GHG abatement systems could be incorrectly included in the scope of Equation I-9 as it is written.

SIA requests the definition of hydrocarbon-fuel-based combustion emission control systems is tailored to specify hydrocarbon-fuel-based combustion emissions control systems (HC fuel CECS) connected to manufacturing tools. SIA also requests to include the following language: "…and have the potential to emit fluorinated greenhouse gases"

B. Stack Testing Requirements:

EPA is proposing to require within stack testing that all HC fuel CECS "that are not certified not to form CF_4 must operate with at least 90% uptime during the test." SIA requests language to limit this requirement to "at least 90% uptime of NF_3 remote plasma clean HC fuel CECS devices that are not certified to not form CF_4 during the test."

Also, it is unclear if Equation I-9 applies in addition to stack testing requirements. SIA requests that CF_4 emissions from the HC fuel CECS abatement of F_2, as calculated by Equation I-9, is specifically exempted from the stack testing method as it would double count CF_4 emissions.

SIA requests EPA specify that HC fuel CECS uptime during stack testing applies to NF_3 remote plasma clean or input F_2 processes only. SIA also requests that Equation I-9 is specifically exempted from the stack testing methodology to prevent inadvertent double counting of some CF_4 emissions.

C. Default Emission Factor Requirements:

As proposed, EPA requires the addition of calculated CF_4 emissions from HC fuel CECS abatement of F_2 based on Equation I-9 if the HC fuel CECS is not certified to not convert F_2 at less than 0.1%. This requirement appears to apply to all relevant HC fuel CECS regardless of whether a default or measured DRE is claimed for the abatement device. SIA member companies have installed HC fuel CECS for which they choose to not claim DRE under the current rule. The additional complexity of apportioning RPC NF_3 and F_2 to both <0.1% certified and uncertified HC fuel CECS will require time and cost investments, which are not justified by data.

If HC fuel CECS abatement suppliers and device manufacturers are not able to provide the required certification to exempt systems from this added emission, for every kilogram of RPC NF_3 used, CO_2e emissions out of the HC fuel CECS will increase more than 600% for 200mm and more than 400% for 300mm. This jump in CF_4 emissions will result in a time series inconsistency for semiconductor industry greenhouse gas reporting, based on data that is not peer reviewed, are based on assumptions, and appear to be based on emissions measurement values that did not use industry standards or the EPA DRE testing protocols.

Additionally, if EPA maintains this requirement, it is unclear if Equation I-9 applies in addition to or in place of existing CF_4 byproduct emission factors. SIA requests CF_4 emissions from the HC fuel CECS abatement of F_2, as calculated by Equation I-9, are applied instead of, not in addition to, default CF_4 BEF's for RPC NF_3.

SIA strongly requests the removal of Equation I-9 and associated $AB_{CF4,F2}$ and $B_{F2,NF3}$ data elements. However, in the alternative, SIA requests changes to hydrocarbon-fuel-based combustion emissions control systems (HC fuel CECS) requirements to remove confusion and double counting of emissions.

SIA requests the definition of hydrocarbon-fuel-based combustion emission control systems is tailored to include POU HC fuel CECS only and include the following language: "…and have the potential to emit fluorinated greenhouse gases"

SIA requests EPA specify that HC fuel CECS uptime during stack testing is "representative of the emissions stream." SIA also requests that Equation I-9 is specifically exempted from the stack testing methodology to prevent inadvertent double counting of some CF_4 emissions.

The additional complexity of apportioning RPC NF_3 and F2 to both <0.1% certified and uncertified HC fuel CECS will require time and cost investments, which are not justified by data. Increased CF_4 emissions will result in a time series inconsistency for semiconductor industry greenhouse gas reporting, based on data that is not peer reviewed, are based on assumptions, and appear to be based on emissions measurement values that did not use industry standards or the EPA DRE testing protocols. SIA requests that within the default emission factor method, CF_4 emissions from the HC fuel CECS abatement of F_2, as calculated by Equation I-9, are applied instead of, not in addition to, default CF_4 BEF's for RPC NF_3.

8.) Carbon-based emission byproducts from SF_6, NF_3, F_2, or other non-carbon input gases

In the Proposed Revisions to Improve the Quality of Data Collected for Subpart I, Updates to default emission factors and destruction or removal efficiencies to improve the accuracy of emissions estimates, EPA proposes in the preamble to

> *"…remove BEFs from tables I-3 and I-4 where there is … a low BEF and a low GWP…removing BEFs for C_4F_6 and C_5F_8 for all input gases used in [etch]…not adding COF_2 and C_2F_4…"*

SIA supports proposed language regarding the removal of BEFs for C_4F_6, C_5F_8, COF_2 and C_2F_4. Byproduct emissions from the four chemicals identified are estimated to account for << 0.001% of overall GHG emissions from semiconductor manufacturing operations.

SIA requests that the rule clarify that carbon-containing byproduct emission factors are zero when calculating emissions from non-carbon containing input gases (SF_6, NF_3, F_2 or other non-carbon input gases) and when the film being etched or cleaned does not contain carbon. This language would align the EPA final rule with IPCC 2019.

9.) Updated input gas and byproduct emission factor values

In the Proposed Revisions to Improve the Quality of Data Collected for Subpart I, Updates to default emission factors and destruction or removal efficiencies to improve the accuracy of emissions estimates, EPA proposes in the preamble to

> *"…revise the input gas and BEF values assigned to gas/process combinations where no default input gas emission factor is available… input gas EF (1-U) equal to 0.8… BEFs of 0.15 for CF4 and 0.05 for C2F6…" EPA also proposes to "…update Table I-8 to include distinct utilization rates for N2O… and by process type."*

SIA supports the alignment of uncharacterized input gas and BEF default emission factors with 2019 IPCC values of 0.8, 0.15, and 0.5 for input gases, CF_4 and C_2F_6 respectively.

The proposed revisions to the Mandatory Greenhouse Gas Reporting Rule included various updates to Table A-1, Global Warming Potentials. However, as proposed, Table A-1 will continue to require the use of AR4 GWP values (from the IPCC Fourth Assessment Report) for all CO_2e calculations. Reporting under various voluntary standards and frameworks, both in the U.S. and internationally, refer to the use AR5 (from the IPCC Fifth Assessment Report) GWP values. As such, SIA members are often required to maintain multiple sets of GHG calculations for compliance and voluntary reporting. By updating the factors in Table A-1 to AR5, the agency will not only be using the most up-to-date factors but also will provide consistency among reporting entities' various public disclosures.

SIA supports the update to input gas and BEF values based on conservative direct and byproduct emission pathways. SIA also supports the alignment of input gas and BEF values with 2019 IPCC values and requests the use of IPCC Fifth Assessment Report global warming potentials to continue to align with international and voluntary reporting standards.

SIA SEMICONDUCTOR INDUSTRY ASSOCIATION

10.) EPA additional requests for comment

In addition to the previous comments, SIA would also like to provide brief comment in response to EPA's request within the preamble for feedback:

> *"The EPA requests comment on whether the gain in robustness achieved by capping 1-U values at 0.8 justifies the accompanying loss in comparability to previously submitted data, particularly given that we are proposing to require submission of results using both the historically used methods and the new, likely more robust, reference emission factor method…. In addition, the EPA requests comment on the use of 0.8 as the maximum 1-U value in the modified dominant-gas and all-input gas methods."*

As per Comment 5 above, SIA believes there are limitations in all proposed emission factor calculation methodologies. While capping an emission factor at 0.8 is likely an adequate assumption for maximum emissions, it remains somewhat arbitrary. SIA suggests using an emissions calculation methodology that divides all emissions across all input gases. Input gas emissions are calculated as kilograms of input gas emitted divided by kilograms of all input gases used. Byproduct emissions are calculated as kilograms of byproduct emissions divided by kilograms of all input gases used.

> *"The EPA requests comment on the extent to which the sources of N2O formation from electronics manufacturing have been identified. We are also requesting comment on the expected variability of the estimated N2O emission factor from stack testing if using the current or revised methods for estimating emissions using stack testing and whether new data are available."*

N_2O emissions are generated from the use of N_2O as an input gas in thin films, diffusion, and other process operations. Additionally, N_2O can be generated from the combustion of hydrocarbon-based fuels in the presence of nitrogen and oxygen. This combustion N_2O is already accounted for in the emissions calculated from the combustion of natural gas and other fuel burning equipment inside and in support of the process fab. SIA believes further N_2O stack testing investigation is necessary before commenting on potential accuracy.

> *"…required to measure the rate of conversion from F2 to CF4 using a scientifically sound, industry-accepted method that accounts for dilution through the abatement device, such as the EPA DRE Protocol, adjusted to calculate the rate of conversion from F2 to CF4 rather than the DRE. The EPA requests comment on whether there are other measurement methods that should be cited as examples or listed as options for this measurement... The EPA requests comment on this and any other issues that may arise in adapting the EPA DRE Protocol to measure the rate of conversion from F2 to CF4 in hydrocarbon-fuel-based emissions control systems. These issues and means of handling them could then be specifically addressed in the final rule"*

SIA is currently unaware of other testing methodologies that are accurate and feasible for the purposes of testing F_2 and CF_4 simultaneously at the semiconductor manufacturing tool and POU abatement device.

11.) Revisions to default DRE's

In the Proposed Revisions to Improve the Quality of Data Collected for Subpart I, Updates to default emission factors and destruction or removal efficiencies to improve the accuracy of emissions estimates, EPA is

> *"…proposing to update the default DREs in Table I-16 to… assign chemical-specific DREs to all commonly used F-GHGs… without distinguishing between process types [and]"…proposing to revise default DREs in Table I-16 … new data… proposing to remove the distinction by process type…"*

SIA supports the removal of process type from default DRE categories and supports the alignment of default DREs with 2019 IPCC. While most individual chemical DRE values generally align with 2019 IPCC, NF_3 DRE is a distinct outlier. 2019 IPCC sets NF_3 DRE at 95% with significant data submissions from U.S. EPA. EPA's current rule language proposal of 88% NF_3 DRE does not align with 2019 IPCC data and does not align with the technical support documentation provided by EPA.

SIA supports the proposals to assign default DREs to commonly used gases without distinguishing between process types and using the 96% NF3 DRE as documented in EPA's technical support documentation (TSD) and August 25, 2022 docket memorandum update.

12.) Subpart C additional device tracking

In the Proposed Revisions to Improve the Quality of Data Collected for Subpart C, Proposed Revisions to Improve the Quality of Data Collected for Subpart C, EPA requires the following information:

> *"(ii) For each unit in the group greater than or equal to 10 mmBtu/hr, the unit type, maximum rated heat input capacity, and an estimate of the total annual heat input (expressed as a decimal fraction). To determine the total annual heat input decimal fraction for a unit, divide the actual heat input for that unit (all fuels) by the sum of the actual heat input for all units (all fuels), including units less than 10 mmBtu/hr. Estimates of the actual heat inputs may be based on company records. If all units in this configuration are less than 10 (mmBtu/hr), this requirement does not apply."*

SIA understands EPA's desire to collect data on an additional category of greenhouse gas emissions (fuel burning equipment with heat inputs equal to or greater than 10 MMBtu/hr and less than 100 MMBtU/hr). This change would include an increase in individual reporting scope of various pieces of fuel-burning equipment from SIA member companies (for example, smaller facility-level boilers). Some of these fuel-burning equipment do not have individual natural gas meters to measure the individual unit's fuel use. These fuel-burning equipment are just a small subset of the semiconductor industry's overall reported GHG emissions, which are a very small subset of the entire U.S. GHG emissions. Estimates show semiconductor equipment between 10 MMBtU/hr to 100 MMBtU/hr represent less than 0.005% of overall U.S. GHG emissions.

Tracking individual combustion units between 10 and 100 MMBtu/hr within the semiconductor industry would provide little value for the overall U.S. GHG emissions and

would require an undue burden and cost to install individual unit natural gas meters. SIA requests an exemption from these requirements for Subpart I reporters.

13.) Subpart OO additional gas use reports

In EPA's proposals related to Subpart OO—Suppliers of Industrial Greenhouse Gases, EPA proposes to require

> *"…suppliers of N_2O, saturated PFCs, and SF6 identify the end uses for which the N_2O, SF_6, or PFC is used and the aggregated annual quantities of N_2O, SF_6, or each PFC transferred to each end use, if known. "*

SIA believes the Subpart OO increased chemical supply tracking by "each end use, if known" may constitute a potential risk to semiconductor industry and individual company confidential business information. Chemical suppliers or distributors do not typically have visibility to end use, particularly specific end use categories.

SIA requests EPA clarify that chemical supply "end use" refers to industry category only, such as electronics or semiconductor use, and does not refer to more specific uses. The specific purchases and purposes of chemical use should be considered semiconductor industry confidential business information and therefore protected from public disclosure.

SIA and its member companies appreciate the opportunity to provide comments on the proposed revisions to the Mandatory Greenhouse Gas Reporting Rule. SIA urges EPA to proceed with finalizing the amendment to 98.96(y) before the March 31st 2023 due date for the next technology assessment report, regardless of possible delays in additional rule updates.

If you have any questions regarding this letter or require additional information, please feel free to contact me.

Table 2: Comparison of typical semiconductor stack testing methodologies for criteria pollutants and GHG's

	MRR F-GHG stack testing – semiconductor	Example criteria pollutant process stack testing - semiconductor
Method(s)	EPA Test Methods 320 or ASTM D6348-12 or alternate method approved through EPA waiver Method 1 or 1A (sampling port location) Method 2, 2A, 2C, 2D, 2F, or 2G (gas velocity) Method 3, 3A, or 3B (gas molecular weight) Method 4 (moisture content)	EPA Test Methods 320 or ASTM D6348-12 and Other test methods depending on emission species Method 1 or 1A Method 2, 2A, 2C, 2D, 2F, or 2G Method 3, 3A, or 3B Method 4
Scope	NF_3, SF_6, and fluorinated carbon compounds only N_2O is outside of current GHG stack testing scope	Depends on methodology
Frequency	Annually or Every approximately 5 years: after 3 stack tests (at least 2 months apart), if < 20% standard deviation requirements are met, can use the average of the three stack tests for the next 4 annual tests - unless fab operations change in a way that triggers re-test. Retest required if wafer size changes, stack system adds F-GHG's to exhaust for first time, consumption changes by 10%, new gases, decrease > 10% of abated fraction of tools	Start up of new abatement device (requirements can vary) and Annually to every five years
Location(s)	Proposed rule update preamble language: "*require that all stacks be tested if the stack test method is used*"	All stack systems (non-concurrently) or representative stack samples adjusted based on a ratio of total design flows to tested exhaust design flows
Required length	8 hours or more per stack system	Typically 2 to more than 8 hours per stack measurement
Production data required	None	# of wafers (or other applicable production metric) during testing # of wafers (or other applicable production metric) monthly, annually, or other calculation timeframe
Preliminary emission estimates	Proposed language removes this provision	None

	MRR F-GHG stack testing – semiconductor	Example criteria pollutant process stack testing - semiconductor
Chemical data required	Amount of each F-GHG consumed during testing $Activity_{if}$ = Consumption of fluorinated GHG input gas i, for fab f, in the tools vented to the stack systems being tested, during the sampling period Amount of each F-GHG consumed annually = $I_{Bi} – I_{Ei} + A_i – D_i$ I_{Bi} & I_{Ei} = Inventory of input gas I stored in containers at the beginning and end of the reporting year, including heels, on a fab basis A_i = Acquisitions of input gas I during the year through purchases or other transactions, including heels D_i = Disbursements of input gas I through sales or other transactions during the year, including heels in containers returned and exceptional circumstance disbursements	None
Abatement device uptime	UT_f = The total uptime of all abatement systems for fab f, during the sampling period = $\Sigma_p Td_{pf} / \Sigma_p UT_{pf}$ Td_{pf} = The total time, in minutes, that abatement system p, connected to process tool(s) in fab f, is not in operational mode UT_{pf} = Total time, in minutes per year, in which the tool(s) connected at any point during the year to abatement system p, in fab f could be in operation. For tools that were installed or uninstalled during the year, you must prorate the operating time to account for the days in which the tool was not installed.	Abatement systems have uptime requirements Excess emissions are calculated if criteria pollutants are emitted without abatement. Excess emissions are based on system inlet testing or engineering models

	MRR F-GHG stack testing – semiconductor	Example criteria pollutant process stack testing - semiconductor
Abatement device removal efficiencies	a_f = Fraction of input gas i emitted from tools with abatement systems in fab f (expressed as a decimal fraction), as calculated in equation I-24C = $a_{i,f}$ = $(\Sigma_p \gamma_{i,p} \bullet n_{i,p,a} + m_{i,q,a}) / (\Sigma_p \gamma_{i,p} \bullet n_{i,p} + m_{i,q})$ d_{if} = The average weighted fraction of f-GHG input gas i destroyed or removed when fed into abatement systems by process tools in fab f = $\{ \Sigma_p (\gamma_{i,p} \bullet \Sigma_{DREy} n_{i,p,DREy} \bullet DRE_y) + \Sigma_{DREz} DRE_z \bullet m_{i,q,DREz} \} / (\Sigma_p \gamma_{i,p} \bullet n_{i,p,a} + m_{i,q,a})$ [equations for input gases and similar equation for byproducts] $\gamma_{i,p}$ = Default factor reflecting the ratio of uncontrolled emissions per tool of input gas i from tools running process type p process to uncontrolled emission per tool of input gas i from process tools running process type q processes $n_{i,p}$ = Total number of tools using gas i and running chamber process sub-type p $n_{i,p,a}$ = Number of tools that use gas i, that run chamber cleaning process sub-type p, and that are equipped with abatement systems for gas i $m_{i,q}$ = Total number of tools using gas i and running etch and / or wafer cleaning processes $m_{i,q,a}$ = Total number of tools using gas i and running etch and/or wafer cleaning processes DRE_y = Default or alternative certified DRE for gas i for abatement system connected to CVD tool DRE_z = Default or alternative certified DRE for gas i for abatement system connected to etching and/or wafer cleaning tool $n_{i,p,DREy}$ = Number of tools that use gas i, that run chamber cleaning process p, and that are equipped with abatement systems for gas i that have the DRE DRE_y $m_{i,q,DREz}$ = Number of tools that use gas i, that run etch and/or wafer cleaning processes, and that are equipped with abatement systems for gas i that have the DRE DRE_z	Typically based on simultaneous inlet and outlet testing at start up and periodically thereafter (not always annually)

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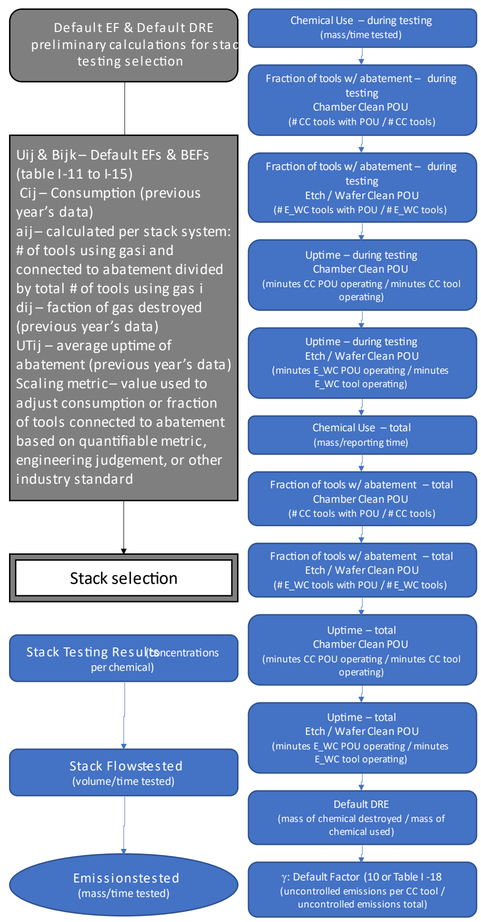
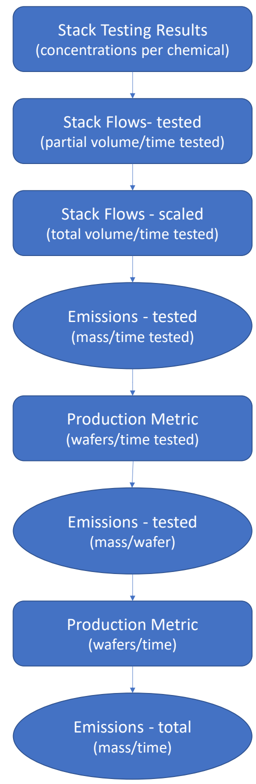
<tr><td>Calculation Elements</td><td>
</td><td>
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Endnotes:

[1] *From U.S. EPA Inventory of U.S. Greenhouse Gas Emissions and Sinks, 2020*
2020 U.S. Greenhouse gas net emissions 5222.4 MMT CO_2 eq.
2020 U.S. Greenhouse gas electronics industry processes and product use emissions 4.74 MMT CO_2 eq.
US EPA Flight tool (R.148) 1.2 MMT CO_2 eq. from electronics industry combustion sources
(4.74 + 1.2) MMT CO_2 eq. from electronics industry ÷ 5222.4 net U.S. GHG emissions = 0.1%

[2] *From Digital technology can cut global emissions by 15%. Here's how, World Economic Forum, 2019*
https://www.weforum.org/agenda/2019/01/why-digitalization-is-the-key-to-exponential-climate-action/

[3] *The cost of pump change-out is approximately $5000 per pump (according to feedback from one pump vendor). The number of additional pump change outs required for the U.S. industry per year is more than 8000 (based on SIA survey of members August 2022, the value is closer to 12000).*
$5000 per pump x 8000 additional pump change outs per year = $ 40 million per year.