Guidelines for International 300 mm Initiative (I300I) Environmental, Safety & Health (ESH) Equipment Specific Environmental Information and Environmental Impact

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Abstract: This document is a "white paper" on the distinctions between the requirements of a formal Environmental Impact Study and an Emissions Characterization Study.

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Authors: Craig Ottesen, David Carswell

Approvals: Craig Ottesen, ESH Program Manager/Author
David Carswell, DTM Program Manager/Author
Randy Goodall, Director of Productivity & Infrastructure
Laurie Modrey, Technical Information Transfer Team Leader

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1 EXECUTIVE SUMMARY

1.1 Environmental Impact Studies

The basic components of formal Environmental Impact Studies are distinguishable from an Emissions Characterization in one general particular. The complete scope of an Environmental Impact Study encompasses all effects over the entire lifetime of the equipment studied, in a total-effect style, and is supported with maximum acceptable values (generally with regulatory import) assigned to each of those effects. Impact studies are not limited to the site of operation, but begin with the selection of materials of construction and continue until the final disposition of the equipment as opposed to those effects related to emissions during operation, maintenance, and service. A number of items are associated with any Equipment Environmental Impact Study. These items fall under separate categories as follows:

1. Items associated with the manufacture and construction of the equipment.
2. Items associated with the preparation, packing, and shipping of the equipment.
3. Items associated with installation of the equipment.
4. Items associated with operation, maintenance, and service of the equipment.
5. Items associated with re-usability and recycling of equipment parts.
6. Items associated with decontamination of the equipment.
7. Items associated with the decommissioning of the equipment.
8. Items associated with the disposal of the equipment (product reusability).
9. Items associated with indirect effects such as generation of power and cooling or heat removal for the equipment.

1.2 Emissions Characterizations

The basic components of Emissions Characterizations are distinguishable from an Environmental Impact Study by the fact they are a direct result of all types of emissions resulting from the operation, maintenance, and service of the subject equipment under study.

In general, Emissions Characterizations provide the less formal data necessary to properly request permits for a facility where the subject will be installed and to evaluate Environmental, Safety & Health (ESH) procedures for operation and maintenance of such equipment. Emissions characterizations also indicate proper handling and disposal of the various wastes generated by the equipment during operation, maintenance, and service.

Characterization information should be used only for its intended purpose of managing the operation, maintenance, and service of equipment within the environmental and health arenas.

Emissions characterizations are generally limited to the immediate locality of the equipment in its operating environment.

Emissions characterizations constitute a sub-set of the total environmental impact of any equipment and include the following areas only:

4) Items associated with operation, maintenance, and service of the equipment

9) Items associated with indirect effects such as generation of power and cooling or heat removal for the equipment

These two line items include the following sub-set:

A. Process chemical emissions
B. Process water emissions
C. Process support system emissions
D. Process byproduct emissions
E. Support system byproduct emissions
F. Solid waste emissions
G. Maintenance waste emissions

The differences between the two types of environmental reports (Impact Study and Emissions Characterization) define the separation of information collected in each of the two types of studies. Evaluation of both information sets is required to identify properly the full scope of impact of any equipment subject on the environment. Neither type of report should be expected to stand completely alone when measuring the complete environmental effect of semiconductor process equipment, but they are each a necessary part of the information total required to manage the environmental impact of any given equipment subject through its lifetime.

2 CRITERIA SPECIFICS – IMPACT STUDIES: THE FULL SPECTRUM OF ENVIRONMENTAL AFFECTS

2.1 Environmental Impact Studies

2.1.1 General

The basic components of formal Environmental Impact Studies are distinguishable from an Emissions Characterization in one general particular. The complete scope of an Environmental Impact Study encompasses all effects of the subject of the study (e.g., the equipment studied) from conceptualization through final disposition, as opposed to those effects related to emissions while the equipment is operating. A number of items are associated with any subject of an Environmental Impact Study that are not related to operational emissions. These items fall under separate categories as follows:

1. **Items associated with the manufacture and construction of subject equipment**

   When considering the environmental impact of a piece of semiconductor process equipment, the required use of chemicals during the manufacture of the subject must be evaluated. If chemicals required for the manufacture have a negative impact on the environment (e.g., perfluorocarbons), such chemical should be considered for elimination, replacement, or reduction to mitigate the impact on the environment.

The chemicals mentioned include all chemicals required for cleaning components for installation as well as for testing equipment assemblies (e.g., tracer gas analysis, process piping leak checks).

The selection of materials of construction for equipment should be studied carefully to determine if the materials negatively impact the environment during assembly, operation, decontamination, or disposal. Any material with an adverse environmental impact in any of these stages should be considered for elimination, replacement, or reduction.

The generation of contaminants during the manufacturing process (e.g., welding fumes from metals or plastics, cleaners, solders) should also be studied. These contaminants have an impact on the environment that must be measured to accurately engender a full appreciation of the total environmental impact.

Use of coatings with the least impact, while providing the best performance (such as powder coatings versus epoxy paints), should be researched, and the coating with the least impact, but retaining the necessary performance qualities, should be selected.

Energy efficiency for all phases of the manufacturing process should be evaluated during the design of the equipment and the most energy efficient components and methods of construction should be used in the factory to ensure the lowest environmental impact.

Part re-usability and recycling potential should also be a consideration in the component selection process. Parts that can potentially be remanufactured or recycled have a much lower impact than those that require disposal. Further, those parts that can be decontaminated provide for the ability to recover the materials of construction or even to re-use the material or component, instead of requiring destructive disposal or landfill.

2. Items associated with preparation, packing, and shipping of subject equipment

Items that are part of preparation, packing, and shipping include the cleaning materials used before packaging; crating materials, disposable packaging, and foam-in-place packaging as part of the overall impact. The use of recycled materials in any phase of preparation, packaging, or shipment can reduce the overall impact.

Wastes associated with the packing materials—for everything from the components of manufacture to the final assembly—also fall under this category. These include the parts packaging as received from the parts manufacturer or distributor as well as the packing of systems and sub-systems for delivery to the point of installation.

Wastes associated with the cleaning of materials, for everything from the components of manufacture to the final assembly, also fall under this category.

The fuel used to transport both the components and materials of construction and the equipment systems and sub-systems to their location of installation has an impact on the environment.

If the crating used to transport the equipment is reusable, then storage of such crates will usually have an impact on energy usage because of the climate controls necessary to maintain the cleanliness of the crating.

3. **Items associated with installation of subject equipment**

   This category includes such items as the need for cranes or other powered vehicles for installation, any disposable gear necessary for the installation (e.g., personal protective equipment [PPE]), any items that would be disposable as a function of the installation process (e.g., removable stoppers on chemical lines), and any chemicals required for acceptance tests.

4. **Items associated with operation, maintenance, and service of subject equipment**

   Items that are part of the periodic service of equipment include such things as lubricants, refrigerants, recirculating-water treatment chemicals, filter cartridges, and any other consumable or semi-consumable items required to keep the equipment in working order.

   Items that are part of the periodic cleaning of the processing components, such as chamber cleaning, optics cleaning, vacuum pump cleaning, etc., fall under this category. This includes wipes or disposable applicators as well as the chemicals and cleaners associated with the cleaning process.

   Items associated with parts cleaning include those required for periodically stripping built-up layers of semiconductor films as well for cleaning parts before shipment to re-builders or re-manufacturers.

   If parts cleaning or component exchange contract services are employed instead of in-house resources, these must also be included in a comprehensive impact study.

   Additional exhaust required during maintenance adds both energy and resource allotment factors to the environmental impact and may generate disposal requirements for filtered byproducts that are captured by the maintenance exhaust.

   The introduction of items that constitute hidden importation of products (such as packaged tubes of lubricants or maintenance materials) can have an impact on permitting, regulatory, and disposal requirements when the equipment is imported.

   Exhaust and control of items such as heating, cooling, humidity, and noise can also require materials and energy that have an impact on the environment. For every item installed (sound dampening, insulation, etc.), each of them must be recycled, reclaimed, or disposed during equipment removal. The methods of installation should facilitate removal and reuse of these items to eliminate their disposal.

   Heat elimination or contamination control can alternatively require energy expenditure that affects the overall impact of the equipment. Eliminating the need for these types of controls is most desirable, but using the most energy-efficient systems and methods is the alternative preferred design.

   The use of chemicals or materials in point-of-use abatement systems to pre-treat emissions is also included in this category.

   The inclusion of components traditionally described as “items” in the equipment (such as vapor lamps, lithium batteries, or mercury switches) create a potential for hazardous material disposal that can be poorly received, or even improperly performed, if not adequately identified in the characterization.

5. Items associated with re-usability and recycling of parts of subject equipment

Every option that reduces the generation of waste (especially landfill) must be documented, and all options reported.

The chemicals necessary to prepare parts for recycling also fall under this category.

Part and product reclaim services should be documented, if available, so that they are included in the total impact calculation.

Recycle-ability of component parts reduces the environmental impact.

6. Items associated with decontamination of the subject equipment

Neutralization supplies, cleaning supplies, personal protective equipment (PPE), contaminated water, and contaminated solids involved in the decontamination of the equipment for removal or disposal should be reported in the appropriate waste category.

Evaluating decontamination effects requires inclusion of all materials to decontaminate the equipment and its sub-systems, any materials to decontaminate effluent handling materials (piping or ducts) or equipment (abatement devices), and materials to decontaminate the facility equipment installation site and surrounds.

7. Items associated with the decommissioning of the subject equipment

Installation pedestals, custom-cut flooring, chemically contaminated structural items, spill containment, used piping and tubing, used electrical components, used ducting, and other components associated with the subject installation that are not directly re-usable must be captured in the impact study. They should also be evaluated for reclamation or recycling and their re-usability reported.

Chemicals such as solvents required to remove components of installation (such as floor covering adhesives) are a part of the overall impact.

8. Items associated with the disposal of the subject equipment (product reusability)

Sale of equipment for re-use could significantly reduce the environmental impact since full decontamination of equipment would not be required and fewer parts must be disposed of as contaminated waste. Redirection of the equipment, as an assembled whole, to another user, a research institution, or other location for use as originally intended has been known to double the life expectancy of equipment. This practice could potentially halve the amount of equipment that must be produced.

Disposal of the main components of the equipment along with the reclamation or disposal of any related sub-systems and their associated wastes (such as refrigerants) is a necessary part of the disposal impact. Crating materials and other items associated with the transport of the subject to its final disposal are included.

Recycle-ability or re-usability of the equipment as a partially assembled whole (such as re-manufacture or upgrade), for use by another business needing similar equipment can extend the life expectancy of the equipment and reduce its overall environmental impact.

Eventual recycling or reclamation of the equipment materials of construction reduces the final impact of the equipment to the lowest possible effect.

9. **Items associated with indirect environmental effects from equipment**

   This category includes such things as generated power and cooling or heat removal

   These items, traditionally, have not been captured in impact studies, but they are an ever-larger percentage of the total environmental impact of the subject equipment.

   Waste of energy, either for process effects or for handling or elimination of heat, can significantly affect the subject equipment's impact on the environment.

3 CRITERIA SPECIFICS – CHARACTERIZATIONS: A SUBSET OF THE TOTAL AFFECTS

3.1 Emissions Characterizations

3.1.1 General

The basic components of Emissions Characterizations are distinguishable from an Environmental Impact Study by the fact they are the subset of environmental impact items that are a direct result of the operation and maintenance of the equipment under study. However, Emissions Characterizations do not capture the entire environmental cost or effect of any equipment subject.

These characterizations, more and more frequently, include all aspects of operations and maintenance. Previously they only included process emissions.

They should definitely include the full scope of categories as listed below.

A) Process Chemical Emissions

These emissions result from the chemistry of the process. They include such items as the natural vaporization of open baths, the discharge of vacuum-system process exhausts, the fugitive emissions that are a part of the normal handling of process chemicals, and the routing to drain of spent chemicals.

Process chemical emissions include gaseous, vapor, mist, and liquid waste products and products that are diverted to reclaim processes.

B) Process Water Emissions

The total picture of water emissions can be difficult to capture unless ***all*** sources are evaluated. From the water used in the dilution of chemicals through the discharge of water that has been used for rinsing and all the way to the disposal of water that leaks from (or must be disposed from) recirculation systems, water can be an overlooked item in the emissions picture.

Water that is pH-adjusted, concentrated for reprocessing, condensed, or vaporized must all be included.

The total water picture is best captured by performing a mass-balance calculation and test that determines the route by which all the water that enters the equipment leaves the equipment.

C) Process Support System Emissions

The potential for emissions from such items as gaseous generating systems through the potential for emission of refrigerants or cryogenics from sub-systems must all be considered.

D) Process By-Product Emissions

The vast array of potential emissions from process chambers or baths is the group of items traditionally called emissions. Full characterization of potential byproducts, from process chambers or baths, usually requires sophisticated monitoring and specialized analysis equipment to determine the exact chemical constituents.

This single portion of the Emissions Characterization usually has the most impact on the availability of air permits that allow our factories to operate under various world regulations. Without the ability to predict the potential emissions from subject equipment, the regulatory agencies could refuse to allow operations.

E) Support System Byproduct Emissions

This subset includes byproduct emissions from sub-systems such as point-of-use abatement system generated vapors that were not original byproducts, but were generated by the treatment of the discharge, and the transformed solid from adsorptive media used for purification of re-treatment of waste.

F) Solid Waste Emissions

While not as critical to the permitting process as process byproduct emissions, the ability to plan for adequate and legal disposal of potential hazardous solid wastes can have a profound impact on the cost of operations. The aggregate cost of disposing of highly hazardous wastes (such as lithium batteries, mercury lamps, etc.) can be detrimental to profits. In addition, if solid wastes are not characterized in advance, the risk to operations of a factory could be catastrophic if a highly hazardous solid waste were routinely disposed into standard disposal locations.

G) Maintenance Waste Emissions

The little remembered category of maintenance waste has long been a contributor to problems in waste disposal. The understanding of the waste generated during maintenance can provide the ability to manage all waste disposal effectively or can create a nightmare of waste disposal problems. The possible generation of flammable solid waste from cleaning with a flammable solvent is only one such problem. Additionally the disposal of mercury contaminated collection components, lubricants that require special disposal, sludges and byproducts of waste containers as well as disposal of contaminated PPE and components are just a few.

In addition, disposal of packing materials from parts as well as disposable components from the subject equipment requires careful study to determine if they present hazards from a waste disposal perspective.

4 CONCLUSIONS

4.1 Summary

Distinctions between the requirements of a formal Environmental Impact Study and an Emissions Characterization Study are easily separable, but have long been misunderstood.

These two types of environmental reports each have their own place in the environmental evaluation of any subject equipment, but the effects of their individual results can create almost the same impression on the public.

The responsible use of Emissions Characterization can generate confidence from the public that both the user and the equipment designer have a positive attitude toward environmentally safe design and engage in the purchase of environmentally safe equipment.

The complete adoption of formal Environmental Impact Studies can further enhance public opinion. The certainty that all of the parties involved in the subject equipment have considered the full effect of the subject equipment on the environment—from design and manufacture through use and final disposal—will confirm to the public that the semiconductor industry is a true partner in the environment.

SEMATECH Technology Transfer
2706 Montopolis Drive
Austin, TX 78741

http://www.sematech.org
e-mail: info@sematech.org