SEMI S23-0708
GUIDE FOR CONSERVATION OF ENERGY, UTILITIES AND MATERIALS USED BY SEMICONDUCTOR MANUFACTURING EQUIPMENT

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1 Purpose

1.1 This guide addresses concepts related to energy, utilities and materials conservation on semiconductor manufacturing equipment.

1.2 This guide addresses measurements related to energy, utilities and materials usage on semiconductor manufacturing equipment.

1.3 This guide also addresses continuous improvement planning for energy, utilities and materials usage on semiconductor manufacturing equipment in order to promote energy, utilities and materials conservation.

1.4 This guide is a series of options and instructions intended to increase awareness of the reader to available techniques in the area of energy, utilities and materials conservation. A particular course of action is suggested for utilities and materials use measurement and conversion of use measurements into equivalent energy.

NOTE 1: Because this SEMI standard is a Guide, all criteria using "should" may be considered optional.

2 Scope

2.1 This guide is intended to be a tool that can be used to analyze energy, utilities and materials conservation on semiconductor manufacturing equipment.

2.2 This guide describes methods for reporting energy, utilities and material use rate, and the consumption reduction in semiconductor manufacturing equipment.

2.3 This guide also suggests use of energy equivalent values in order to facilitate quantification of overall energy consumption and conservation related to SME as well as easy planning of energy conservation.

2.4 This guide focuses only on the use stage of equipment life cycle and addresses a limited set of utilities and materials to be considered.

2.5 Additionally, this guide describes setting targets for, verifying and improving utilities and materials use rate and energy conservation.

2.6 This guide contains the following sections:

- Purpose
- Scope
- Limitations-
- Referenced Standards and Documents
- Terminology
- General Concepts
- Life Cycle Assessment (LCA) of Energy Usage
- Baseline Process(es)
- Utilities and Materials Use rate Measurement
- Conversion Factors for Equivalent Energy
- Target Setting and Improvement

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- Monitoring and Reporting
- Related Documents

NOTICE: This safety guideline does not purport to address all of the safety issues associated with its use. It is the responsibility of the users of this safety guideline to establish appropriate safety and health practices and determine the applicability of regulatory or other limitations prior to use.

3 Limitations

3.1 This guide is not intended to supersede the applicable codes and regulations of the region where the equipment is used.

3.2 This guide is not intended to provide definite targets for utilities and materials usage or energy conservation.

3.3 The information suggested in this guide may be provided by the equipment supplier to the user if that is the agreement between those parties.

4 Referenced Standards and Documents

4.1 *SEMI Standards*

SEMI E6 — Guide for Semiconductor Equipment Installation Documentation

SEMI S2 — Environment, Health and Safety Guideline for Semiconductor Manufacturing Equipment

NOTICE: Unless otherwise indicated, all documents cited shall be the latest published versions.

5 Terminology

5.1 *Abbreviations and Acronyms*

5.1.1 *DIW* — De-ionized Water

5.1.2 *ISMT* — International SEMATECH

5.1.3 *LCA* — Life Cycle Assessment

5.1.4 *UPW* — Ultra Pure Water

5.2 *Definitions*

5.2.1 Definitions defined in SEMI S2 and SEMI E6 is incorporated herein by reference unless a term is otherwise specified below.

5.2.2 *baseline* — for the purposes of this document, "baseline" refers to operating conditions, including process chemistry, for which the equipment was designed and manufactured, (refer to SEMI S2).

5.2.3 *energy impact* — positive and negative effects on the amount of energy required to produce or provide an item or material, or to execute a process or step.

5.2.4 *environmental impact* — positive and negative effects to the earth environment from a variety of sources including people and their activities, and the operation of semiconductor manufacturing equipment and facilities

5.2.5 *exhaust* — airflow moving from semiconductor manufacturing equipment to a location outside of a fab or laboratory area.

5.2.6 *heat load* — the sum of all heat energy transferred by conduction, convection, and radiation outside the envelop of the equipment.

5.2.7 *idle* — the condition where the equipment is energized and readied for processing (all systems ready and temperatures controlled) but is not actually performing any active function such as materials movement or processing, (refer to SEMI E6).

5.2.8 *Life Cycle Assessment* — a methodology used to evaluate the environmental impact of semiconductor manufacturing equipment throughout its life cycle, including raw material procurement, manufacturing, transportation, use and disposal.

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5.2.9 *process mode* — the condition where the equipment is energized and performing its intended function on target materials (such as implanting wafers, pumping gas, or inspecting photo-masks).

5.2.10 *roadmap* — a sequence for the incremental introduction or improvement of technology over time with month or year milestones and supporting information.

6 General Concepts

6.1 Energy is used to produce the various utilities and materials that go into the manufacturing, packaging, shipping, installing, use, decommissioning and disposing of a piece of semiconductor manufacturing equipment. Reducing the energy used in any of these life cycles will improve the environmental impact of the semiconductor manufacturing equipment.

NOTE 2: This guide focuses on only the use of the equipment life cycle stage.

6.2 Given the state of the industry with regard to energy conservation information and measurements, the use stage of the equipment life cycle appears to be the most effective stage to analyze for energy conservation opportunities. The energy used in the use stage is the best derived from the use rate of utilities and materials provided for the stage.

6.3 Various methods have been proposed for converting the use rate of specific utilities and materials into equivalent energy values. The energy used to produce any particular utility or material varies from location to location and from time to time. While any single set of energy conversion factors cannot be valid world wide, some parties find value in the conversion exercise, particularly in identifying a utility or material that has a greater energy impact than others.

6.4 The equipment suppliers should investigate the utilities and materials use rate of the equipment and identify and implement design or process changes that lessen the energy impact of the equipment. The expense of implementing these changes can be balanced against the potential energy impact improvement when developing an energy conservation plan.

NOTE 3: Changes in use rate can also affect the users cost of ownership for the equipment. This can also be considered in the cost-benefit analysis.

6.5 An equipment user can consider supplier-reported utilities and materials use rates, energy equivalent values, and planned improvements when making the purchasing decisions.

6.6 The use rate of utilities and materials for a piece of equipment depends on the particular control parameters used to achieve the desired effect on a wafer (i.e., it depends on the process recipe) as well as the particular hardware used in the equipment and the conditions under which the measurements are taken. It is important to record this and other particular information when use rate measurements are conducted.

6.7 Based on the above considerations, the equipment supplier should set targets for energy, utilities and materials conservation, and consider continuous improvement plans for energy, utilities and materials usage on semiconductor manufacturing equipment.

NOTE 4: The supplier may apply the concepts of this guide to the equipment model or models of their choice.

6.8 The characterization and quantification of energy, utilities and materials consumption should be based on a supplier baseline process.

7 Life Cycle Assessment (LCA) of Energy Usage

7.1 Analyzing energy use during various stages in the life cycle of semiconductor manufacturing equipment can yield valuable information for promoting energy conservation.

7.2 There are many ways the equipment life cycle can be conceptually divided into different stages.

7.3 This guide focuses only on the use (or use) stage of equipment life cycle.

7.4 Other life cycle stages may include:

- raw materials procurement,
- manufacturing,
- packaging,

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- transportation (shipment),
- decommissioning, and
- disposal.

7.5 The use stage can be further divided into processing, idling, maintenance and service. This guide only addresses processing and idling.

7.6 Using the model methods of this guide, the equipment supplier may also analyze maintenance and service.

NOTE 5: The SEAJ standard "SEAJ-E-003E — Guideline for conducting an LCA of Semiconductor Manufacturing Equipment – Energy Saving Perspective" may be referenced for an example of a more complete life cycle analysis.

8 Baseline Process(es)

8.1 The measurement, conservation monitoring, improvement, and reporting methods should be based on one or several supplier baseline process(es). The equipment supplier is encouraged to consider baseline process(es) which also meet the needs of the users.

8.2 Considering the range of use a supplier intends for the equipment, several baseline processes may be used when utilities and materials use rate measurements are conducted.

8.3 The use rate and energy impact of any particular baseline process recipe can vary depending on the equipment optional hardware that is installed, whether the optional hardware is participating in the process or not (it may consume utilities and materials even when idle). Therefore, when baseline process(es) are designed, the particular hardware configuration can be a significant parameter and should be considered.

NOTE 6: In the course of analysis, the supplier may discover that for two or more recipes which have the same desired effect, one recipe is more energy efficient than another.

NOTE 7: For users to make effective cost of ownership or energy impact comparisons between equipment, it is useful to have supplier data derived from the same baseline process (i.e., achieving the same desired effect on a substrate or other material). It is recommended that suppliers discuss this with the users and gather data that will facilitate effective comparisons.

9 Utilities and Materials Use Rate Measurement

9.1 A first step in determining the energy impact of a particular piece of equipment during any life cycle stage is to measure the use rate of utilities and materials in that stage.

9.2 Table 1 contains the recommended minimum set of utility and material parameters to measure while the equipment is performing its intended material processing function (according to a particular recipe) and while it is idling.

NOTE 8: Related Information 1 contains additional use rate information that may be useful.

NOTE 9: Many different chemicals may be used in the processing step. Process chemicals are not included in Table 1 because equivalent energy conversion factors are generally not available for them. The equipment supplier may, however, wish to measure and record their use rate anyway.

9.3 The units used in Table 1 are those used in SEMI E6, "Guide for Semiconductor Equipment Installation Documentation" which contains criteria for documenting all utility requirements for every connection point on a piece of equipment. If the measurement equipment used to gather data does not report values in the indicated units, appropriate conversion factors should be used.

9.4 For the processing measurements, the average value of each parameter over the course of several processing cycles should be recorded as well as the length of the cycle.

9.5 For the idling measurements, the average value of each parameter over a period of idling should be recorded as well as the length of the period.

NOTE 10: See Related Information 1 for additional recommendations.

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Table 1 Recommended Minimum Set of Utility and Material Parameters

Utility or Material	*Basic Use rate Metrics and Units*	*Related SEMI E6 Sections (0303 Version)*
Exhaust	Pressure (Pa) Flow (m^3/hr.) Inlet Temp (°C) Outlet Temp (°C)	§ 18
Vacuum	Pressure (Pa) Flow (m^3/hr.)	§ 17
Clean Dry Air High Pressure Clean Dry Air, and Nitrogen (N2)	Inlet Pressure (Pa) Flow (m^3/hr.) Inlet Temp (°C)	§ 16
Refrigerated Cooling Water or Tower-cooled Cooling Water	Inlet Pressure (kPa) Outlet Pressure (kPa) Flow (m^3/hr.) Inlet Temp (°C) Outlet Temp (°C)	§ 13
Ultra Pure Water (UPW) or De-Ionized Water	Purity Requirements Inlet Temp (°C) Flow (m^3/hr.)	§ 13
Electricity (Electrical Energy = Electrical Power Measurement Period)	Real Power[#1] (Watts) For single phase circuits, Real Power[#1] = $V_{RMS} \times I_{RMS} \times PF$ For three phase circuits, Real Power[#1] = $V_{RMS} \times I_{RMS} \times PF \times 1.73$ Alternately, the average Real Power as indicated by a power meter may be used.	§ 12

#1 "Real Power" is sometimes known as "True Power" or "Effective Power."

10 Conversion Factors for Equivalent Energy

10.1 Conversion factors can be used to convert the utility and material use rate data gathered for a particular baseline process recipe into equivalent energy consumption data.

10.2 The actual electrical energy required to provide a particular utility or material will, of course, vary among the locations where the equipment will be installed. Therefore, the output of the conversion calculation will not be correct for any particular location. However, if a reasonable set of conversion factors are used, the output of the conversion can be used to identify those utilities and materials which, generally speaking, have a higher environmental impact.

NOTE 11: The use of a standard set of conversion factors also allows comparison of results from tests of various equipment.

10.3 It is recommended that equivalent energy be reported on a per year basis.

10.4 In Table 1, the use rate metrics have a per-hour basis. Therefore, the number of hours the equipment spends processing and idling must be estimated to calculate per-year data.

10.5 Table 2 contains a recommended set of conversion factors. Comparison of different equipment based on the use of the conversion factors may be useful, even though the total calculated energy is correct only for the hypothetical facility for which the conversion factors are correct.

NOTE 12: Related Information 1 contains additional conversion factor information that may be useful.

10.6 The output units of all conversions are estimated kJ [kWh/(3.6 × 10^3)] (kJ: kilojoule, kWh: kilowatt hours). This can be understood as the energy impact of the particular utility or material used.

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