



*NSF International Standard /
American National Standard*

NSF/ANSI 457 - 2017

Sustainability Leadership Standard for Photovoltaic Modules



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Chair, Joint Committee on Sustainability Leadership Standard for Photovoltaic Modules
c/o NSF International
789 North Dixboro Road, P.O. Box 130140
Ann Arbor, Michigan 48113-0140 USA
Phone: (734) 769-8010 Telex: 753215 NSF INTL
FAX: (734) 769-0109
E-mail: info@nsf.org
Web: <http://www.nsf.org>

Prepared by
The NSF Joint Committee on Sustainability Leadership Standard for Photovoltaic Modules

Recommended for Adoption by
The NSF Council of Public Health Consultants

Adopted by
NSF International
October 2017

Published by

NSF International
PO Box 130140, Ann Arbor, Michigan 48113-0140, USA

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“NSF/ANSI 457 – 2017.”

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Foreword²

This American National Standard, NSF/ANSI 457 Sustainability Leadership Standard for Photovoltaic Modules, has been developed as part of the ongoing efforts of a number of interested parties to document and improve the sustainability performance profile of photovoltaic modules using established and advanced scientific principles, practices, materials, and standards.

The purpose of this Standard for Photovoltaic modules is to establish product sustainability performance criteria and corporate performance metrics that exemplify sustainability leadership in the market. These performance criteria are intended to form the basis of conformity assessment programs, such as third-party certification or registration.

Suggestions for improvement of this Standard are welcome. This Standard is maintained on a Continuous Maintenance schedule and can be opened for comment at any time. Comments should be sent to Chair, Joint Committee on Sustainability Leadership Standard for Photovoltaic Modules at standards@nsf.org, or NSF International, Standards Department, P.O. Box 130140, Ann Arbor, Michigan 48113-0140, USA.

² The information contained in this Foreword is not part of this American National Standard (ANS) and has not been processed in accordance with ANSI's requirements for an ANS. As such, this Foreword may contain material that has not been subjected to public review or a consensus process. In addition, it does not contain requirements necessary for conformance to the Standard.

NSF/ANSI Standard for Sustainability—

Sustainability Leadership Standard for Photovoltaic Modules

1 General

1.1 Purpose

The purpose of this Standard for Photovoltaic (PV) modules is to establish product sustainability performance criteria and corporate performance metrics that exemplify sustainability leadership in the market.

The Standard provides a framework and standardized set of performance objectives for manufacturers and the supply chain in the design and manufacture of PV module components. For purchasers, this Standard provides a consensus-based definition of key sustainability attributes and performance metrics, alleviating individual purchasers from the arduous and complex task of defining sustainability performance for PV modules. This Standard can be used within an established system for the identification of sustainability/environmentally preferable products by purchasers and to provide market recognition for conforming products and brand manufacturers.

This Standard was developed based on the principle that only sustainability leadership products, those in the top third of the market, are expected to qualify to the Standard at the Bronze level at the date of publication of the Standard. Only a few products are expected to meet the highest performance level (Gold) at the date of publication of the Standard.

This Standard will be continually maintained and periodically reviewed to ensure that the definition of sustainability leadership, as reflected in the performance criteria, progresses with the evolution of technology and services and sustainability/environmental improvements in the product sector.

1.2 Scope

This is a sustainability leadership Standard for PV modules. The scope of this Standard includes PV modules for installation on, or integral with buildings, or to be primarily used as components of free-standing power-generation systems, including but not necessarily limited to:

- photovoltaic cells that generate electric power using solar energy
- interconnects (materials that conduct electricity between cells)
- encapsulant (insulating material enclosing the cells and cell interconnects)
- superstrate (material forming primary light-facing outer surface) and substrate (material forming back outer surface) (e.g., glass, plastic films)
- wires used to interconnect photovoltaic modules and connect junction boxes to the balance of system equipment
- frame or integrated mounting mechanism, if present

The following are not included:

- balance of system equipment, such as cabling and mounting structures, equipment intended to accept the electrical output from the array, such as power conditioning units (inverters) and batteries, unless they are contained in the photovoltaic module
- a photovoltaic cell that is a part of another device for which it produces the electricity, such as consumer or industrial electronic products (e.g. calculators, lights, textile) where the photovoltaic cell primarily provides the energy needed to make the electronic product function
- mobile photovoltaic cell where the inverter is so integrated with the photovoltaic cell that the solar cell requires disassembly before recovery

This Standard establishes measurable criteria for multiple levels of sustainability/environmental leadership achievement and performance throughout the lifecycle of the product. This Standard addresses multiple attributes and environmental performance categories including management of substances, preferable materials use, life cycle assessments, energy efficiency and water use, responsible end-of-life management and design for recycling, product packaging, and corporate responsibility.

2 References

2.1 Normative references

The following referenced documents are required for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments or corrigenda) applies. European Union Directives, which contain the adoption date in their title, shall not be treated as “dated standards or regulations”. Unless explicitly indicated otherwise, when a European Union Directive is referenced in this Standard, a new or updated European Union Directive shall apply as the referenced Directive upon its enforcement date.

ANSI/AIHA/ASSE Z10, Occupational Health and Safety Management System³

ANSI 50021 – Superior Energy Performance®— Additional Requirements for Energy Management Systems

ANSI 50028 - Superior Energy Performance® – Requirements for verification bodies for use in accreditation or other forms of recognition

California Safer Products Alternatives Analysis –CA Code of Regulations Title 22, Division 4.5, Chapter 55, Article 5, Sections 69505.5-69505.7⁴

Candidate List of Substances of Very High Concern (SVHC)⁵

Conflict Free Sourcing Initiative (CFSI)⁶

DIN 6120-1 - Marking of packaging and packaging materials for recycling purposes - Plastics packaging and packaging materials - Part 1: Graphical symbols⁷

³ ASSE International Office, 901 Canterbury, Suite A, Westlake, OH 44145 <www.asse.org>

⁴ DTSC Headquarters 1001 I Street Sacramento, CA 95814-2828 <www.dtsc.ca.gov>

⁵ European Chemicals Agency P.O.Box 400 00121 Helsinki, Finland <www.echa.europa.eu>

⁶ CFSI 1737 King Street Suite 330 Alexandria, VA 22314 <www.conflictreesourcing.org>

⁷European Standards Krimicka 134 318 13 Pilsen < Czech Republic VAT: CZ7908212026 <www.en-standard.eu>

Ecospold v.2⁸

Electronic Industry Citizenship Coalition (EICC) Code of Conduct⁹

European Chemicals Agency database⁵

European Chemicals Agency “Guidance on requirements for substances in articles” and Judgement C-106/14 of the European Court of Justice.⁵

European Commission Joint Research Centre, International reference Life Cycle Data System (ILCD) Handbook¹⁰

European Union, Eco-Management and Audit Scheme (EMAS)¹¹

EU Product Environmental Footprint Category Rules (PEFCR) Pilots, 24 April 2016 – v.2.0 ¹²

EU Product Environmental Footprint Category Rules for Photovoltaic Electricity Generation (V. 1.3 or more current) ¹²

European Union, European Commission Directive 94/62/EC of the European Parliament and of the Council on Packaging and Packaging Waste¹³

European Union Product Environmental Footprint Guide¹²

European Union Regulation (EC) No. 1907/2006, Registration, Evaluation, Authorization and Restriction of Chemicals (REACH)¹¹

GRI Sustainability Reporting Standards¹⁴

International Energy Agency (IEA) Photovoltaic Power Systems (PVPS) Methodology Guidelines on Life Cycle Assessment of Photovoltaic Electricity Task¹⁵

IEC 62321-3-1, Determination of certain substances in electrotechnical products - Part 3-1: Screening - Lead, mercury, cadmium, total chromium and total bromine using X-ray fluorescence spectrometry¹⁶

IEC 62321-3-2, Determination of certain substances in electrotechnical products - 3-2: Screening - Total bromine in polymers and electronics by Combustion - Ion Chromatography¹⁶

IEC 62474, Material declaration for products of and for the electrotechnical industry¹⁶

Intergovernmental Panel on Climate Change's Fifth Assessment Report¹⁶

⁸ Ecoinvent Technoparkstrasse 1 8005 Zurich, Switzerland <www.ecoinvent.org>

⁹ Electronic Industry Citizenship Coalition Suite 330 Alexandria, VA 22314

¹⁰ European Commission Joint Research Centre JRC Directorate D – Sustainable Resources D1 Bio-Economy Via E. Fermi 2749 I-21027 Ispra (VA) Italy <<http://eplca.jrc.ec.europa.eu/>>

¹¹ European Commission Environment DG B - 1049 Brussels Belgium <<http://ec.europa.eu/environment/emas>>

¹² European Union Product Environmental Footprint Guide < <http://eur-lex.europa.eu>>

¹³ European Union Directives are available at <<http://europa.eu>>

¹⁴ Global Reporting Initiative PO Box 10039 1001 EA Amsterdam, The Netherlands <www.globalreporting.org>

¹⁵ International Energy Agency Waldweg, 8 CH 1717 St. Ursen, Switzerland <<http://iea-pvps.org>>

¹⁶ International Electrotechnical Commission 3, rue de Varembe, 1st floor P.O. Box 131 CH - 1211 Geneva 20 - Switzerland <<http://www.iec.ch/>>

International Accreditation Forum (IAF)¹⁷

Interstate Chemicals Clearinghouse (IC2) Alternatives Assessment Guide, Hybrid or Sequential Frameworks¹⁸

Interstate Chemicals Clearinghouse Database¹⁸

IPCC Guidelines for National Greenhouse Gas Inventories, 2006¹⁹

ISO 9001, Quality management systems - Requirements²⁰

ISO 14001, Environmental management systems—Requirements with guidance for use²⁰

ISO 14021, Environmental Labels & Declarations—Self-declared environmental claims (Type II environmental labelling)²⁰

ISO 14025, Environmental labels and declarations—Type III environmental declarations—Principles and procedures²⁰

ISO 14040, Environmental management—Life cycle assessment—Principles and framework²⁰

ISO 14044, Environmental management—Life cycle assessment—Requirements and guidelines²⁰

ISO 50001 - Energy management systems — Requirements with guidance for use²⁰

ISO 50003 - Energy management systems — Requirements for bodies providing audit and certification of energy management systems²⁰

LCA Society of Japan, Life-cycle Impact Assessment Method based on Endpoint modeling²¹

Model Toxics in Packaging Legislation [compilation was developed by CONEG and is administered by the Toxics in Packaging Clearinghouse (TPCH)]²²

National Academies of Science, Design and Evaluation of Safer Chemical Substitutions – A Framework to Inform Government and Industry Decisions²³

OHSAS 18001, Occupational Health and Safety Management²⁴

Superior Energy Performance (SEP) Certification Protocol²⁵

¹⁷International Accreditation Forum <<http://www.iaf.nu/>>

¹⁸ Interstate Chemicals Clearinghouse 89 South Street, Suite 600 Boston, MA 02111-2651 < <http://www.theic2.org/>>

¹⁹ Intergovernmental Panel on Climate Change 7bis Avenue de la Paix C.P. 2300 CH- 1211 Geneva 2, Switzerland
<http://www.ipcc.ch/>

²⁰ International Organization for Standardization Chemin de Blandonnet 8 CP 401 - 1214 Vernier, Geneva, Switzerland <<http://www.iso.org/>>

²¹ LCA Society of Japan LCA Development Office, 2-1, Kajicho 2-chome, Chiyoda-ku, Tokyo, 101-0044
<http://lca-forum.org/english/>

²² Model Toxics in Packaging Legislation c/o NERC, 139 Main ST., Suite 401, Brattleboro, VT 05301
< <http://www.toxicsinpackaging.org/>>

²³ National Academies of Science 500 Fifth St. N.W. | Washington, D.C. 20001 <<http://www.nap.edu>>

²⁴ OHSAS 18001, BSI Group <<http://www.bsigroup.com>>

²⁵ U.S. Department of Energy <www.energy.gov/eere/amo/SEP-equivalency>

Superior Energy Performance (SEP) Measurement and Verification (M&V) Protocol²⁵

Superior Energy Performance (SEP) Industrial Facility Best Practice Scorecard²⁵

Social Accountability (SA) 8000²⁶

Solar Energy Industries Association (SEIA), Solar Industry Environmental & Social Responsibility Commitment²⁷

Substitution Support Portal (SUBSPORT)²⁸

Sustainability Accounting Standards Board (SASB) Solar Energy Sustainability Accounting Standard²⁹

University of Leiden Institute of Environmental Sciences (CML), Handbook on LCA³⁰

U.S. Department of Energy (DOE) Superior Energy Performance (SEP) program³¹

U.S. EPA ENERGY STAR Guidelines for Energy Management³²

U.S. EPA GHG Reporting Rule, Subpart I³³

U.S. EPA Protocol for Measuring Destruction or Removal Efficiency (DRE) of Fluorinated Greenhouse Gas Abatement Equipment in Electronics Manufacturing (U.S. EPA DRE Protocol)³³

U.S. EPA Tool for the Reduction and Assessment of Chemical and other Environmental Impacts (TRACI) 2.1³³

U.S. Securities Exchange Act of 1934, Rule 13p-1³⁴

2.2 Informational references

Conflict Free Tin Initiative³⁵

GEMI Local Water Tool³⁶

²⁶ Social Accountability International 15 West 44th Street, 6th Floor New York, NY 10036 <<http://www.sa-intl.org/>>

²⁷ Solar Energy Industries Association <<https://www.seia.org/>>

²⁸ Substitution Support Portal Kooperationsstelle Hamburg IFE GmbH Harburger Schlossstrasse 6-12 D-21079 Hamburg Germany <<http://www.subsport.eu>>

²⁹ Sustainability Accounting Standards Board <<https://www.sasb.org/>>

³⁰ Universiteit Leiden Institute of Environmental Sciences Rapenburg 70, 2311 EZ Leiden, Netherlands <<http://cml.leiden.edu>>

³¹ U.S. Department of Energy 1000 Independence Ave. SW Washington DC 20585 <www.energy.gov>

³² Energy Star <https://www.energystar.gov/>

³³ U.S. Environmental Protection Agency 1200 Pennsylvania Avenue, N.W. Washington, DC 20460 <<https://www.epa.gov/>>

³⁴ U.S. Securities and Exchange Commission 100 F Street, NE Washington, DC 20549 <<https://www.sec.gov>>

³⁵ Conflict Free Tin Initiative <http://solutions-network.org/>

³⁶ GEMI 1155 Fifteenth Street, NW, Suite 500 Washington, DC 20005 <<http://gemi.org/localwatertool/>>

Public Private Alliance for Responsible Mineral Trade³⁷

Solutions for Hope³⁸

OECD, Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas³⁹

World Business Council for Sustainable Development (WBCSD) Global Water Tool⁴⁰

World Resource Institute's Aqueduct Global Water Risk Mapping Tool⁴¹

WWF-DEG Water Risk Filter⁴²

3 Definitions and acronyms

3.1 Definitions

3.1.1 Conflict free: A product that does not contain conflict minerals, necessary to the functionality or production of that product, that directly or indirectly finance or benefit armed groups in the Democratic Republic of the Congo (DRC) or an adjoining country. Conflict minerals that a manufacturer or its supplier(s) obtains from recycled or scrap sources, are considered conflict free.

NOTE — The term “armed group”⁴³ means an armed group that is identified as perpetrators of serious human rights abuses in the annual Country Reports on Human Rights Practices under sections 116(d) and 502B(b) of the Foreign Assistance Act of 1961 (22 U.S.C. 2151n(d) and 2304(b)) relating to the Democratic Republic of the Congo or an adjoining country.

3.1.2 Conflict minerals⁴³:

- columbite-tantalite (coltan), cassiterite, gold, wolframite, or their derivatives, which are limited to tantalum, tin, and tungsten; and
- any other mineral or its derivatives determined by the U.S. Secretary of State to be financing conflict in the Democratic Republic of the Congo or an adjoining country.

3.1.3 Declaration: Information made publicly available:

- by the manufacturer on a publicly available registry; or
- on the manufacturer's or certifying organization's website in the form of a certification report, or equivalent, issued by the certifying organization; or
- on the manufacturer's website, if the product is self-declared to conform to the Standard.

³⁷ Public-Private Alliance for Responsible Minerals Trade <<http://www.resolv.org/site-ppa/>>

³⁸ Solutions for Hope <<http://solutions-network.org/site-solutionsforhope/>>

³⁹ OECD 2, rue Andre Pascal 75775 Paris Cedex 16, France <<https://mneguidelines.oecd.org/mining.htm>>

⁴⁰ World Business Council for Sustainable Development MAISON DE LA PAIX Chemin Eugène-Rigot, 2B Case Postale 2075CH-1211, Geneva 1 <<http://www.wbcd.org/>>

⁴¹ Aqueduct 10 G Street NE Suite 800, Washington, DC 20002 <<http://www.wri.org/our-work/project/aqueduct>>

⁴² World Wildlife Federation Gland, Switzerland <<http://waterfilter.panda.org/>>

⁴³ U.S Securities and Exchange Commission 100 F Street, NE Washington, DC 20549 <<https://www.sec.gov/>>

3.1.4 Disclosure: Information made available to the audience specified in criterion (e.g. purchasers, public, etc.).

3.1.5 Documentation: Information to be provided at time of verification or certification.

3.1.6 End-of-life (EOL): Life-cycle stage of a product when it is no longer intended for use and are destined, or intended to be destined for, dismantling, material recovery, recycling or disposal.

3.1.7 Energy recovery: An operation where the material is used principally as a fuel or to generate energy.

3.1.8 Environmental management system (EMS)²⁰ Part of the management system used to manage environmental aspects, fulfil compliance obligations, and address risks and opportunities.

NOTE 1 — Management system: set of interrelated or interacting elements of an organization to establish policies and objectives and processes to achieve those objectives. A management system can address a single discipline or several disciplines (e.g. quality, environment, occupational health and safety, energy, financial management). The system elements include the organization's structure, roles and responsibilities, planning and operation, performance evaluation and improvement. The scope of a management system can include the whole of the organization, specific and identified functions of the organization, specific and identified sections of the organization, or one or more functions across a group of organizations.

NOTE 2 — Environmental aspects: element of an organization's activities or products or services that interacts or can interact with the environment.

3.1.9 Feedstock: Raw material used in a manufacturing process.

3.1.10 Fiber-based: Cellulose material derived from trees and other plants.

3.1.11 Greenhouse gas (GHG) inventory: Identification and quantification of emissions and removals of greenhouse gases from manufacturing processes.

3.1.12 Impact assessment categories⁴⁴: Classifications of human health and environmental effects caused by a product throughout its life cycle.

3.1.13 Initial service providers: Company that performs recycling and/or refurbishment services for product/equipment/components; and that contracts directly with the manufacturer, or indirectly through a manufacturer's agent, and is the first party to provide one or more initial take-back services.

3.1.14 Inventory data⁴⁴: The identification and quantification of energy, resource usage, and environmental emissions for a particular product, process, or activity.

3.1.15 Life cycle assessment (LCA): A framework for the compilation and evaluation of the inputs, outputs, and the potential environmental impacts of a product system throughout its life cycle, from the extraction of resources and the production of raw materials, to product manufacturing, transportation/distribution, use and re-use, maintenance, and recycling and/or disposal.

3.1.16 Manufacturer: The legal entity that is the owner or the licensee of the brand or trademark under which the product in the scope of this Standard is placed on the market, and:

- manufactures a product; and, or
- has a product designed or manufactured; and, or
- acquires a product for sale under their brand or trademark.

3.1.17 Packaging: All materials of any nature to be used for the containment, protection, handling, delivery and presentation of products from the manufacturer to the user or the customer.

⁴⁴ U.S. EPA, Life Cycle Assessment: Editor 2006, U.S. EPA: Cincinnati, OH <<https://www.epa.gov/>>

NOTE — for the purposes of this Standard, unless otherwise noted, the term “packaging” only applies to sales packaging or primary packaging, i.e. packaging that contains and protects and is designed to deliver a product unit to the final user or customer, and does not include pallets.

3.1.18 Packaging component²²: Any individual assembled part of packaging such as, but not limited to, any interior or exterior blocking, bracing, cushioning, weatherproofing, exterior strapping, coatings, closures, inks, and labels.

3.1.19 Photovoltaic module: A photovoltaic module for installation on, or integral with buildings, or to be primarily used as components of free-standing power-generation systems, including but not necessarily limited to:

- photovoltaic cells that generate electric power using solar energy
- interconnects (materials that conduct electricity between cells)
- encapsulant (insulating material enclosing the cells and cell interconnects)
- superstrate (material forming primary light-facing outer surface) and substrate (material forming back outer surface) (e.g., glass, plastic films)
- wires used to interconnect photovoltaic modules and connect junction boxes to the balance of system equipment
- frame or integrated mounting mechanism, if present

The following are not included:

- balance of system equipment, such as cabling and mounting structures, equipment intended to accept the electrical output from the array, such as power conditioning units (inverters) and batteries, unless they are contained in the photovoltaic module
- a photovoltaic cell that is a part of another device for which it produces the electricity, such as consumer or industrial electronic products (e.g. calculators, lights, textile) where the photovoltaic cell primarily provides the energy needed to make the electronic product function
- mobile photovoltaic cell where the inverter is so integrated with the photovoltaic cell that the solar cell requires disassembly before recovery

3.1.20 Postconsumer recycled material²²: Material generated by households or by commercial, industrial and institutional facilities in their role as end-users which can no longer be used for its intended purpose. This includes returns of material from the distribution chain.

NOTE — This definition applies to materials such as plastic, fiber, metal, etc.

3.1.21 Pre-consumer material²²: Material diverted from the waste stream during a manufacturing process. Excluded is reutilization of materials such as rework, regrind or scrap generated in a process and capable of being reclaimed within the same process that generated it.

3.1.22 Prepared for reuse: Equipment and components that have been checked, tested, cleaned, repaired, and determined to be safe and fully functional, to be placed back on the market in their original use or in their upgraded state, without further processing.

3.1.24 Processed chlorine free (PCF): Packaging material produced with pulp from virgin and/or recycled content that has been bleached without any type of chlorine, or that has not been bleached at all. Recycled content may have originally been bleached with chlorine or chlorine derivatives.

3.1.25 Product: A marketing model of a photovoltaic module.

NOTE — See definition for *photovoltaic module*.

3.1.26 Publicly available: Obtainable to the public without restriction of access; for example, cannot require member only access. A requirement to provide a name and, or organization to obtain access is not considered a “restriction of access”.

3.1.27 Recovery: Operations that are part of a process to recapture elements, compounds, or materials and transform them into commodities.

3.1.28 Recycled content²⁰: Proportion, by mass, of recycled material in a product or packaging. Only pre-consumer and post-consumer materials shall be considered as recycled content.

NOTE — Recycled materials derived from any source, including but not limited to, pre-consumer and post-consumer photovoltaic products, qualify as recycled content.

3.1.29 Recycling: Operations by which products, components, materials, or waste are processed and converted into raw materials for use in the production of new products or in processes, not including energy recovery or disposal.

3.1.30 Refurbishment: Functional or aesthetic maintenance or repair of a product to restore to original or upgraded state.

3.1.31 Reporting boundary: The area of operations and impact upon which the Global Reporting Initiative (GRI) disclosure is based. The boundary may be “within the organization” or it may include some part of the organization’s supply chain.

3.1.32 Reuse: Using again, equipment or components for the originally intended purpose, a similar purpose, or in an upgraded state, possibly after refurbishment, repair or hardware upgrading.

3.1.33 Semiconductor material¹⁶: Substance, the conductivity of which, due to charge carriers of both signs, is normally in the range between that of conductors and insulating media, and in which the density of its charge carriers can be changed by external means.

NOTE 1 — The term “semiconductor” generally applies where the charge carriers are electrons or holes.

NOTE 2 — In order to increase the conductivity, the energy supplied must be greater than the band gap energy. See also “band gap energy”, 3.1.6.

NOTE 3 — Certain semiconductors, such as silicon, gallium arsenide, cadmium telluride and copper indium diselenide compounds, to name a number of materials currently available, are well suited to the PV conversion process.

3.1.34 Substance⁴⁵: Matter of constant composition best characterized by the entities (molecules, formula units, atoms) it is composed of. Physical properties such as density, refractive index, electric conductivity, melting point etc. characterize the chemical substance.

3.1.35 Supplier: Entity that provides goods or services.

3.1.36 Tier 1 suppliers: Companies that provide the manufacturer with materials, components, subassemblies, manufacturing services, or product assembly services, and with which the manufacturer has a contractual relationship.

3.1.37 Total water withdrawal: The sum of all water drawn into the boundaries of the organization from all sources for any use over the course of the reporting period.

⁴⁵ IUPAC, PO BOX 13757 Research Triangle Park, NC 27709-3757, USA <<https://iupac.org/>>