



PRODUCT CATEGORY RULES (PCR)

For preparing an Environmental Product Declaration (EPD)
for the Product Category:

POWER INVERTER PRODUCTS

VERSION 1 (AUGUST 2017)

VALID THROUGH (AUGUST 2022)

Product Category Rules for Power Inverter Products, UL 10001

First Edition, Dated August 14, 2017

Summary of Topics

The first edition of the Product Category Rules for Power Inverter Products, UL 10001, has been issued.

Subject to these terms and conditions and those in any other agreements between you and UL Environment, Underwriters Laboratories Inc. (UL) and/or their representatives, you are hereby granted a limited, non-exclusive, non-transferable license to use the Product Category Rules (PCR) solely for your internal, non-commercial business purposes. The PCR is not being sold, and other than the limited license granted herein UL retains all rights, title and interest (including exclusive ownership) in the PCR and all copyright therein. UL reserves the right to regain possession of the PCR from you at any time. When no longer needed, you agree to destroy the PCR (if in hardcopy form) or delete and purge the PCR from your files (if in electronic form). No part of the PCR may be reproduced, modified, stored in a retrieval system, or transmitted in any form by any means, whether electronic, mechanical photocopying, recording, or otherwise without prior written permission of UL or UL Environment. You further agree not to create any derivative works from the PCR or remove or alter any copyright or other proprietary notices in the PCR. The limited license to use the standard shall automatically terminate upon your breach of any of the terms and conditions herein or any other agreement between you and UL, UL Environment and/or their representatives.

UL Environment provides this PCR “as is” without warranty of any kind, either expressed or implied, including but not limited to, the implied warranties of merchantability or fitness for any purpose.

In no event will UL Environment, UL or any of their affiliates be liable for any special, incidental, consequential, indirect or similar damages, including loss of profits, lost savings, loss of data, or any other damages arising out of the use of or the inability to use this PCR, even if UL Environment or UL or their authorized representative has been advised of the possibility of such damage. In no event shall UL Environment’s or UL’s liability for any damage ever exceed the price paid for the license to use this PCR, regardless of the form of the claim.

Users of the electronic versions of UL Environment’s Product Category Rules agree to defend, indemnify, and hold UL Environment, ULI, their affiliates and each of their respective trustees, officers, employees, agents and representatives harmless from and against any loss, expense, liability, damage, claim, or judgment (including reasonable attorney’s fees) resulting from any error or deviation introduced while purchaser is storing an electronic PCR on the purchaser’s computer system.

Contents

Contents.....	2
1. General Information	4
1.1. Committee Members.....	4
1.2. Identification of Power Inverter Product.....	4
1.1.1. Classification Codes.....	4
1.3. Geographic Coverage.....	5
1.4. Period of Validity.....	5
1.5. Public Comment.....	5
1.6. PCR Review Panel.....	5
1.7. Other Relevant Product Category Rules	5
1.8. LCA Study References	6
1.9. Definitions.....	6
2. Goal and Scope	10
2.1. System Function.....	11
2.2. Declared or Functional Unit.....	11
2.3. Product components.....	12
2.4. System boundaries.....	12
3. Requirements for the Underlying LCA	13
3.1. Product Stage (A1, A2, and A3).....	13
3.1.1. Raw material supply (A1)	14
3.1.2. Transport (A2)	14
3.1.3. Manufacturing (A3).....	14
3.2. Use Stage (B1 – B3) – Functional Unit Only	15
3.2.2. B1 Use of the installed product	15
3.2.3. B2 Maintenance of the installed product	16
3.2.4. B3 Replacement of the installed product	16
3.3. End-of-life Stage (C1, C2, C3, and C4)	16



3.3.1.	Removal (C1)	17
3.3.2.	Transport (C2)	17
3.3.3.	Waste processing (C3).....	17
3.3.4.	Disposal (C4).....	17
3.4.	Benefits and Loads Beyond the System Boundary (D) – Optional.....	17
3.5.	Cut-off rules	17
3.6.	Allocation rules	18
3.7.	Transportation	18
4.	Data Quality and Considerations	19
4.1.	Data sources.....	19
4.2.	Data Quality Requirements.....	20
4.3.	Period under consideration	20
4.4.	Electricity Grid.....	21
4.5.	Transport.....	21
4.6.	Recycled waste streams.....	21
4.7.	Renewable energy	22
4.8.	Impact and inventory results	22
4.8.1.	Parameters Describing Resource Use	24
4.8.2.	Other Environmental Information Describing Different Waste Categories and Output Flows.....	25
4.9.	Units	26
5.	Content of the EPD.....	26
5.1.	General information to be declared	26
5.2.	Declaration of environmental aspects.....	27
6.	References	29
7.	Appendix I – Project documentation/LCA report requirements	31
8.	Appendix III – Relevant product safety and efficiency standards.....	32
9.	Appendix IV – Hazardous Waste Classification by Region	33

1. General Information

The intended application of this Product Category Rules (PCR) document is to 1) provide guidance for creating Environmental Product Declarations (EPDs) for commercial power inverter products and to 2) pinpoint the underlying requirements of the LCA pursuant to ISO standards that address appropriate environmental aspects of the power inverter life cycle. The user of this PCR will be electronics manufacturers and other interested parties and will enable EPDs that support comparable, informed, and objective sustainable purchasing of power inverters.

1.1. Committee Members

- Fuji Electric, LTD

1.2. Identification of Power Inverter Product

A power inverter product is an electronic device that controls the voltage and frequency supplied to a motor or other device that receives power input. In performing this function, the device effectively controls the speed of the motor and the input voltage to the system in which it has been placed. Key to its function is an ability to control voltage over a wide range, at user selected settings (rather than fixed point choices). Power inverters are classified by voltage rating as follows:

- Low voltage (<1 kV AC 50 Hz or 60 Hz and/or voltages up to and including 1.5 kV DC input side)
- Medium voltage (>1kV AC 50 or 60 Hz and/or voltages above and not exceeding 1.5kV- 35kV DC input side)

Other common names for power inverter products include variable frequency drives (VFDs), variable speed drives (VSDs), adjustable speed drives, adjustable frequency drive, AC drive, microdrive or inverter. The merits of using power inverters include, but are not limited to, product energy savings and enhanced process controls. Power inverters are subject to the standards or technical approvals shown under Section 8.

1.1.1. Classification Codes

The following codes cover the range of this rule:

- United National Standards Products and Services Code (UNSPSC): 39121006 – Power adapters or inverters
- Masterformat CSI Code: 16260 Static Power Converter - Variable Frequency Controllers

1.3. Geographic Coverage

This PCR is global in scope and was developed in English.

Markets of applicability include:

- Africa
- Asia
- Caribbean
- Central America
- Europe
- Middle East
- North America
- Oceania
- South America

1.4. Period of Validity

This document is effective for five years from latest date of publication. If relevant changes in LCA methodology for the product category occur, the document will be revised. This PCR will be reviewed annually to determine whether revisions are necessary.

1.5. Public Comment

In accordance with the UL Environment General Program Instructions, this PCR was published from 1-18-2017 through 2-20-2017 and open to all public comments.¹ No comments were received during the open consultation period.

1.6. PCR Review Panel

Gary Jakubcin
B&G Jakubcin &
Associates LLC
614-581-1344
gary.bgja@gmail.com

Lise Laurin
EarthShift Global LLC
lise@earthshiftglobal.com

Anoop Mathur
Terrafore Technologies LLC
Anoop.Mathur@terraforetechnologies.com

1.7. Other Relevant Product Category Rules

At the time of publication, the committee is not aware of any existing published PCRs for power inverters. The committee did review the PCR for preparing an EPD for Printed Circuit Boards. The committee considered the IEEE 112: IEEE Standard Test Procedure for Polyphase Induction Motors and Generators in the creation of this PCR, as well as the PEP ecopassport® program core PCR for electrical, electronic and HVAC-R products and the Product Specific Rule (PSR) for “Electrical switchgear and control gear Solutions”.

¹ Publication URLs include <http://industries.ul.com/environment/transparency/product-category-rules-pcrs> and <https://csds.ul.com/cwa/cwa.aspx?cid=19452>

1.8. LCA Study References

In developing this PCR, the committee reviewed several LCA studies of power inverters considered to be the most robust power inverter LCAs conducted at the time of PCR publication:

1. Boyd, S. "Life-cycle Assessment of Semiconductors", PhD diss., University of California, Berkley, 2009.
2. Cortes, M. A., Patiño, M.L., Ruiz, N.L., and Vaca, L.E.M., "Importance of Life Cycle Analysis of the Printed Circuit Board Computer", Open Journal of Applied Sciences, 2016, 6, 1-6
3. Fernando F J T E., Fong, J A C., and de Almeida, A T. "Ecoanalysis of Variable-Speed Drives for Flow Regulation in Pumping Systems." IEEE Transactions on Industrial Electronics, 2011, 58(6): 2117-2125
Andrada, P., Blanqué, B., Martínez, E., Perat, JI., Sánchez, J.A., and Torrent, M. "Environmental and life cycle cost analysis of one switched reluctance motor drive and two inverter-fed induction motor drives". IE Electric Power Applications, 2012, 6(7): 390-398
4. FUJITSU, "Contributing to the Environment when Investing in ICT" (white paper), Retrieved July 14, 2017 from <http://www.fujitsu.com/global/products/computing/servers/>
5. Supurmaniam, A, "Life Cycle Assessment in Electronics", PhD diss, University of Southern Queensland, 2004.

1.9. Definitions

For the purposes of this document, the following definitions apply:

CDM (Complete Drive Module)

Complete Drive Module is another name for a power inverter. The CDM consists of the drive and any of the other auxiliary equipment connected to the drive, like a braking chopper or electromagnetic compatibility (EMC) filter.

DU (Declared Unit)

Quantity of a product for use as a reference unit in an EPD, based on a LCA, for the expression of environmental information based on one or more information modules.

Example: mass (kg); volume (m3) [modified from ISO 21930]

Feedstock Energy

Heat of combustion of a raw material input that is not used as an energy source to a product system, expressed in terms of higher heating value or lower heating value [ISO 14044].

FU (Functional Unit)

The quantified performance of a product system for use as a reference unit in an EPD, based on a LCA [ISO 14044].

Information Module

Compilation of data to be used as a basis for a Type III Environmental Declaration, covering a unit process or a combination of unit processes that are part of the life cycle of a product [ISO 21930].

ISO (International Standards Organization)

International Organization for Standardization

Inverter Duty Motors

Motors specifically designed for operation with power inverters, typically having better insulation systems to overcome the loss of cooling resulting from operation of the motor at low speeds and high loads.

LCA (Life Cycle Assessment)

Calculation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle [ISO 14040].

LCI (Life Cycle Inventory)

Phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle [ISO 14040]

LCIA (Life Cycle Impact Assessment)

Phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product [ISO 14040]

LHV (Lower Heating Value)

The amount of heat released by combusting a specified quantity of fuel (initially at 25°C or another reference state) and returning the temperature of the combustion products to 150°C. The lower heating value (LHV) (net calorific value (NCV) or lower calorific value (LCV)) is determined by subtracting the heat of vaporization of the water vapor from the higher heating value. This treats any H₂O formed as a vapor. The energy required to vaporize the water therefore is not released as heat.

LHV calculations assume that the water component of a combustion process is in vapor state at the end of combustion, as opposed to the higher heating value (HHV) which assumes that all of the water in a combustion process is in a liquid state after a combustion process.

Load Characteristic or Load Profile

Load applies to all systems designed to set a mobile object or fluid in motion. The movement of a mobile object involves changing its speed or position, which implies applying a torque to overcome its

resistance to movement so as to accelerate the inertia of the load. The load placed on a motor system can typically be classified as follows:

- Constant Torque Load (torque is constant regardless of speed, e.g. conveyors, screws and reciprocating compressors),
- Constant Power Load (as the torque increases, the speed must decrease to have a constant horsepower load, e.g. machine tools)
- Variable Torque Load or Quadratic Torque Load where torque varies directly with speed squared, and power varies directly with speed cubed (e.g. fans, pumps). Power inverters used for pumps, blowers and fans typically fall into the third category. The advantage to power inverters used in a variable torque load system is that the total energy is reduced at lower loads compared with other methods that may use a valve to throttle flow.

Motor Efficiency

The full load efficiency of electric motors, which is the ratio of Power Output (mechanical energy) to Power Input (electrical energy).

Motor Slip

For an inverter motor, slip is defined as the difference between its synchronous speed and its speed at full load.

PDS (Power Drive System)

A Power Drive System (PDS) is the combination of a power inverter and motor.

Power Inverter

An electronic device that controls voltage and frequency being supplied to a motor. In performing this function, the device effectively controls the speed of the motor, and therefore its input to the system in which it has been placed.

Primary Data

Specific unit process data related to the company pursuing an EPD, either measured directly or sampled. Primary data is typically site specific, and collected from the producers of goods and operators of processes and services via interviews, questionnaires, surveys, data collection tools and/or on-site measurements (e.g., electricity invoices, monthly monitoring data, supplier sources, etc).

Process Energy

Energy input required for operating the process or equipment within a unit process, excluding energy inputs for production and delivery of the energy itself [ISO 14044].

Product Category

Group of products that can fulfill equivalent functions [ISO 14025].

Pulse Width Modulation (PWM)

A technique by which inverters vary the voltage and frequency of current provided to an induction

motor to match the load conditions. This technique requires a semi-conductor called an insulated-gate bipolar transistor (IGBT) which converts fixed frequency AC current input fed to the inverter to a variable frequency, variable voltage AC current.

RSL (Reference Service Life)

Service life of a product which is known to be expected under a particular set, i.e. a reference set, of in-use conditions and which may form the basis of estimating the service life under other in-use conditions.

Secondary data

Aggregated or modified data from a reputable source, e.g. descriptions of the local electric grid derived by the local utility company, published peer review articles, etc.

Specific data

Data representative of a product, product group or construction service, provided by one supplier.

Switching Frequency

The inverter output current waveform can be made up of many narrow pulses (fast switching with shorter “on” duration) or fewer wide pulses (slower switching with longer “on” duration). The frequency at which these devices are switched “on” and “off” is referred to as the switching frequency or the carrier frequency, and it is this frequency which can have an effect on acoustic noise generated by the driven motor.

Technosphere Data

Technosphere data, as opposed to ecosphere data, are intermediate flow data associated with financial transactions, such as energy and materials use and solid waste disposal. Ecosphere or biosphere data estimate the use of resources from and emissions to the natural earth and are not purchased.

Type III Environmental Declaration, Environmental Product Declaration (EPD)

Providing quantified environmental data using predetermined parameters and, where relevant, additional environmental information [ISO 14025].

Unit Process

Smallest portion of a product system for which data are collected when performing a LCA.

VA (Volt Ampere)

The unit used for the apparent power in an electrical circuit, equal to the product of root-mean-square (RMS) voltage and RMS current. In direct current (DC) circuits, this product is equal to the real power (active power) in watts.

VFD (Variable Frequency Drive)

A variable frequency drive (VFD) refers to alternating current (AC) drives. VFDs vary the speed of an AC motor by varying the frequency to the motor.

VSD (Variable Speed Drive)

A variable speed drive (VSD) refers to either AC Drives or direct current (DC) Drives. VSDs referring to DC motors vary the speed by varying the voltage to the motor.

2. Goal and Scope

The intended application of this Product Category Rules (PCR) document is to 1) give guidance for conducting Environmental Product Declarations (EPD) for power inverters and 2) to pinpoint the underlying Life Cycle Assessment (LCA) requirements that address appropriate environmental aspects of these products. The users of this PCR will be manufacturers of electrical devices and other interested parties.

This PCR addresses the environmental impacts of power inverters and conforms with ISO 14025, Environmental labeling and declarations – Type III environmental declarations – Principles and procedures.

EPDs prepared under this PCR will specify the EPD type and present data that has been aggregated over the life cycle stages presented in Table 1.

Production, maintenance, and disposal of capital equipment such as manufacturing machinery is excluded, as well as personnel impacts. However, operation of capital equipment is included. Additional information as shown under Section 5 is permitted.

Table 1. Power inverter product EPD type

EPD type	Unit	Life Cycle Stages and modules	Reference Service Life (RSL)	Primary audience
Cradle to gate with options (end of life)	Declared unit	Product stage (including raw material supply, transport and manufacturing), End of life stage	Optional	Business to business (B to B)
Cradle to grave	Functional unit	Product stage (including raw material supply, transport and manufacturing), Use, Maintenance and Repair stages, End of life stage	Required	Business to business (B to B)

Comparability of EPDs of power inverter products will be in accordance with the requirements for comparability as described in ISO 14025, Sections 4, 5.6, and 6.7.2.