



# Standard Guide for Characterizing Environmental Aspects of Manufacturing Processes<sup>1</sup>

This standard is issued under the fixed designation E3012; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

## 1. Scope

1.1 This guide provides manufacturers an approach to characterize any category of manufacturing process and to systematically capture and describe relevant environmental information.

1.2 This guide defines a Process Characterization Methodology that uses graphical and formal representations to support the construction of unit manufacturing process (UMP) information models for characterizing the environmental aspects of manufacturing processes.

1.3 This guide defines the graphical UMP information model as being comprised of four elements (input, output, product and process information, and resources) that supports manufacturers in systematically identifying, collecting, structuring, and visualizing manufacturing information.

1.4 This guide defines the formal representation of the UMP information model through the use of a modeling method and language that can effectively convey the meaning and intent of processes they characterize.

1.5 This guide provides the necessary structure and formality for identifying and capturing key information needs to assess manufacturing performance, yet provides no details about an actual assessment of the process performance.

1.6 This guide provides an approach to link individual UMP information models together to create a network or system of UMP models that extends the characterization of environmental aspects beyond an individual process to a production system or the product itself.

1.7 This guide may be used to complement other standards that address sustainability and the product life cycle. This guide most closely relates to the inventory component as discussed in the ISO 14040 series (ISO 14044) standards, and resource management as discussed in the ISO 55000 series (ISO 55001) standards.

1.8 *This guide does not purport to address all of the security issues and the risks associated with manufacturing information. It is the responsibility of the user of this standard to follow practices and establish appropriate information technology related security measures.*

1.9 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

## 2. Referenced Documents

### 2.1 ASTM Standards:<sup>2</sup>

**E2114** Terminology for Sustainability Relative to the Performance of Buildings

**E2986** Guide for Evaluation of Environmental Aspects of Sustainability of Manufacturing Processes

### 2.2 ISO Standards:<sup>3</sup>

**ISO 22400-1:2014** Automation systems and integration—Key Performance Indicators (KPIs) for manufacturing operations management; Part 1: Overview, concepts, and terminology

**ISO 14040** Environmental management—Life cycle assessment—Principles and framework

**ISO 14044** Environmental management—Life cycle assessment—Requirements and guidelines

**ISO 55000:2014** Asset management—Overview, principles and terminology

**ISO 55001:2014** Asset management—Management systems—Requirements

### 2.3 UL Standard:<sup>4</sup>

**ULE 880** Sustainability for Manufacturing Organizations

<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

<sup>3</sup> Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, <http://www.iso.org>.

<sup>4</sup> Available from Underwriters Laboratories (UL), 2600 N.W. Lake Rd., Camas, WA 98607-8542, <http://www.ul.com>.

<sup>1</sup> This guide is under the jurisdiction of ASTM Committee E60 on Sustainability and is the direct responsibility of Subcommittee E60.13 on Sustainable Manufacturing.

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2.4 World Wide Web Consortium (W3C):  
eXtensible Markup Language (XML) 1.0 Recommendation<sup>5</sup>  
W3C XML Schema Definition Language (XSD) 1.1<sup>6</sup>

### 3. Terminology

3.1 Definitions of terms shall be in accordance with Terminology E2114.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *composability, n*—the ability to link individual unit manufacturing processes together to create a network or system of UMPs that can characterize the environmental aspects of a production system or product.

3.2.2 *key performance indicator (KPI), n*—a quantifiable measure or a set of quantifiable measures that a company or industry uses to gauge or compare performance in terms of meeting their operational and strategic goals.

ISO 22400-1:2014

3.2.3 *unit manufacturing process (UMP), n*—the smallest element or sub-process in manufacturing that adds value through the modification or transformation of shape, structure, or property of input material or workpiece.

3.2.3.1 *Discussion*—The UMP is a clearly-scoped and well-defined manufacturing process that produces a component, assembly, or product.

### 4. Significance and Use

4.1 This guide provides manufacturers a systematic approach for characterizing the environmental aspects of manufacturing processes utilizing formal representations.

NOTE 1—A UMP is formally represented using languages such as eXtensible Markup Language (XML), Unified Modeling Language (UML), or Systems Modeling Language (SysML) to facilitate data exchange, computability, sharing, and communication with other manufacturing and analysis applications. These capabilities support manufacturers in evaluating, documenting, and improving performance.

4.2 This guide provides the required structure and formalism to ensure consistency in characterizing manufacturing processes in a computer-interpretable way enabling effective communication, computational analytics, and exchange of performance information.

NOTE 2—This guide will promote new tool development that can link manufacturing information and analytics for calculating the desired environmental performance measures.

4.3 The guide supports the development of tools to improve decision support capabilities while facilitating the development and extension of standardized data and information bases such as Life Cycle Inventory (LCI) (ISO 14040 series).

NOTE 3—Data collected within manufacturing enterprises can be used to build enterprise-or-sector-specific databases that complement or extend LCI databases (ULE 880). This approach will improve the relevancy and completeness of the data while retaining key links to Life Cycle Assessment (LCA) methods.

### 5. Unit Manufacturing Process Representation

5.1 The UMP representation utilizes graphical and formal methods in constructing UMP information models for characterizing the environmental aspects of manufacturing processes. Formal methods for acquiring and exchanging information will lead to better consistency in these characterizations and help establish a consolidated database of environmental measurements. Consistency of the characterizations will ensure effective communication of computational analytics and sharing of sustainability data.

5.2 The graphical representation (Fig. 1) is comprised of four elements (inputs, outputs, product and process information, and resources) to systematically identify, collect, structure, and visualize manufacturing information. Structured information of manufacturing processes facilitates data exchange, sharing, and communication with other manufacturing applications such as modeling, simulation, and analysis tools. It can provide process specific information to LCI databases that will support a more detailed and accurate LCA.

5.3 To achieve formal representations of manufacturing processes, UMPs require the adoption of a formal modeling method or language to effectively convey the meaning and intent of processes they characterize. The complete XSD schema [XML Schema Definition Language] intended for an XML [XML 1.0] implementation of UMPs is presented in Appendix X1.

5.4 The basic building blocks of XML Schemas consists of elements and attributes. Elements can also contain other elements, that is, child elements. A data type defines the valid content that child elements and attributes contain.

5.5 Table 1 presents the basic elements used in creating a UMP. Fig. 1 presents the relationships between these basic elements. Besides the attributes, *name*, *description*, and *type* of the UMP, the remaining part of the graphical representation (Fig. 1) is captured in the schema as child elements and includes input (see 5.5.1), output (5.5.2), feedback (5.5.3), product and process information (5.5.4), resource information (5.5.5), and transformation (5.5.6 and 6.5). The UMP Name must be unique among the UMP child elements.

5.5.1 *Input*—Includes all inputs that enter the UMP such as material (for example, raw materials or work-in-progress), consumables (for example, lubrication or forced air), energy and external factors (such as temperature, humidity, particulates, vibration, and shocks) that occur during the manufacture of a product. In the schema, Inputs are described with attributes *name*, *type*, *description*, *category*, and *unit*. *Type* defines the material or energy used as input; it can also be “feedback” which implies that a feedback can be connected. *Description* is a free text explanation. *Category* classifies the input and can be Energy, Material, Consumables, or other external factors. *Unit* quantifies the input to enable conversions, for example, energy, material, or water use.

5.5.2 *Output*—Includes all outputs that exit the UMP model such as products, by-products, waste, and emissions. Output of one UMP model can be an input to another UMP model. In the schema, Outputs are described with attributes *name*, *type*, *category*, and *unit*. *Type* defines the output and its unit.

<sup>5</sup> <http://www.w3.org/TR/xml>.

<sup>6</sup> <http://www.w3.org/XML/Schema>.

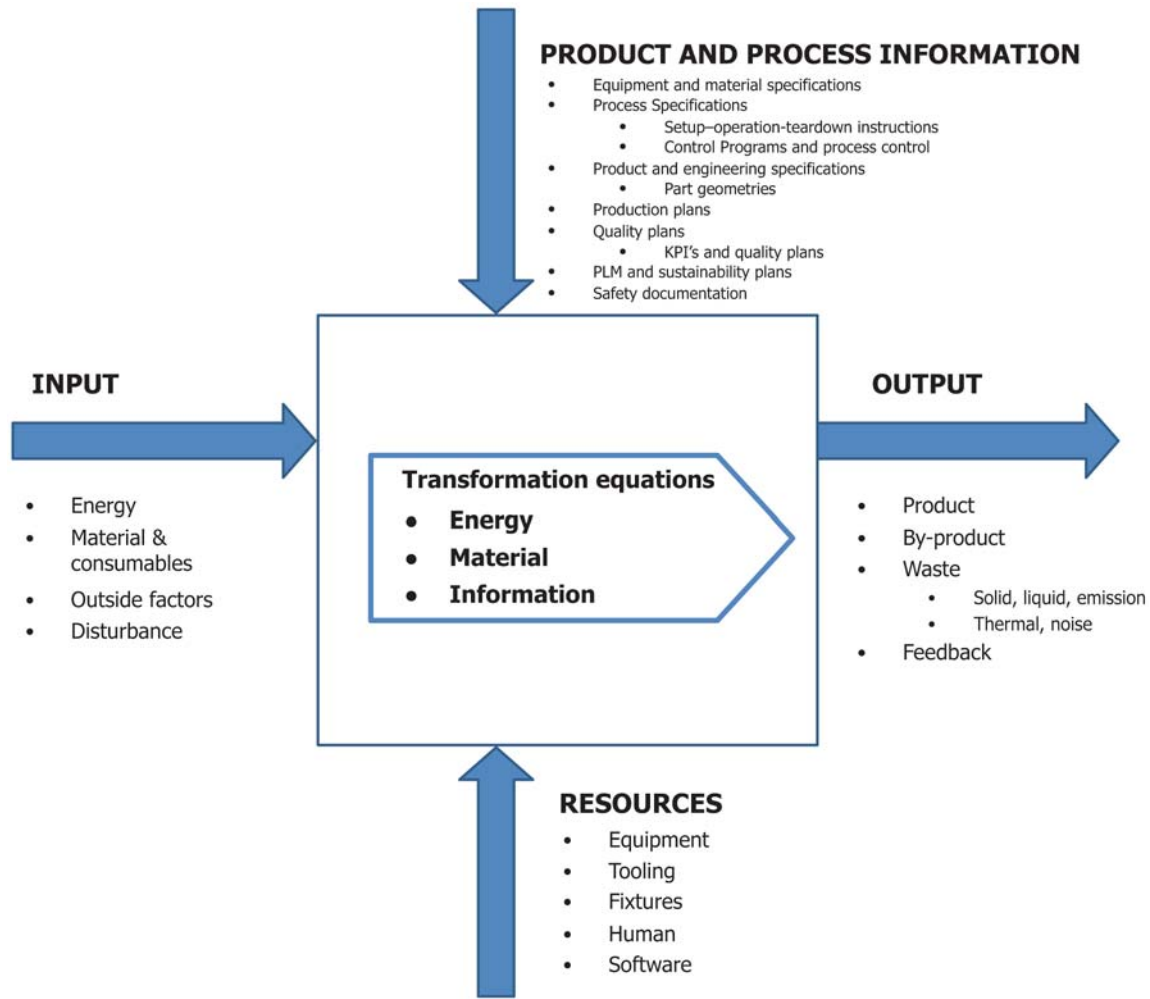


FIG. 1 Graphical Representation of UMP Information

TABLE 1 Element Description for UMP

| Attribute                 | Datatype | Description                                                   |
|---------------------------|----------|---------------------------------------------------------------|
| name                      | String   | A unique name to identify the UMP                             |
| description               | String   | A freetext description of the UMP                             |
| type                      | String   | A specific UMP type, for example, machining, casting, molding |
| Child Elements            |          |                                                               |
| Input                     | Element  | See Table 2                                                   |
| Output                    | Element  | See Table 3                                                   |
| Feedback                  | Element  | See Table 4                                                   |
| ProductProcessInformation | Element  | See Table 5                                                   |
| ResourceInformation       | Element  | See Table 6                                                   |
| Transformation            | Element  | See Table 7                                                   |

TABLE 2 Element Description for Input

| Attribute   | Datatype | Description                                                                |
|-------------|----------|----------------------------------------------------------------------------|
| name        | String   | A unique name to identify the Child within the UMP model                   |
| description | String   | A freetext description of the Input                                        |
| type        | String   | The type of Input, for example, electricity, steelbar, oxygen, or feedback |
| category    | String   | Energy, Material, Consumables, or Disturbances                             |
| value       | Decimal  | Numeric value                                                              |
| unit        | String   | The unit of Input                                                          |

energy. *Category* classifies the output and can be Product, By-product, Waste, or Emission. *Unit* quantifies the output to enable conversions, for example, energy, material, or water use.

**5.5.3 Feedback**—A feedback is a specific Output of the current process status. Feedback can be used as input back to the current UMP, to another UMP, or to other sets of UMPs models. The element is defined using a *name* and a unit. *Unit* quantifies the value to enable conversions, for example, energy, material, or water use.

**5.5.4 Product and Process Information**—Includes relevant information to enable the transformation (5.5.6) calculations of material, energy, and information. This includes items such as part geometry, material properties, control programs, and process plans. The schema element ProductProcessInformation describes attributes *name*, *category*, *description*, *value*, and *unit*. *Category* classifies the Product and Process Information and is user defined. *Value* defines a number. *Unit* quantifies the value unit to enable conversions.

**5.5.5 Manufacturing Resource**—Includes process resources such as equipment, fixtures, tooling, and inspection gauges. The schema element ResourceInformation describes attributes