Designation: E3096 – 18

Standard Guide for Definition, Selection, and Organization of Key Performance Indicators for Environmental Aspects of Manufacturing Processes[1]

This standard is issued under the fixed designation E3096; 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 (ε) indicates an editorial change since the last revision or reapproval.

1. Scope*

1.1 This guide addresses Key Performance Indicators (KPIs) for environmental aspects of manufacturing processes.

1.2 This guide provides a procedure for identifying candidate KPIs from existing sources for environmental aspects of manufacturing processes.

1.3 This guide provides a procedure for defining new candidate KPIs that are not available from existing sources for environmental aspects of manufacturing processes.

1.4 This guide defines a methodology for selecting effective KPIs from a list of candidate KPIs based on KPI criteria selected from Appendix X3 or defined by users.

1.5 This guide provides a procedure for normalizing KPIs, assigning weights to those KPIs, and aligning them to environmental objectives.

1.6 KPIs of Manufacturing Operation Management activities as defined in IEC 62264-1 are out of the scope since they are specifically addressed in ISO 22400-2.

1.7 How to evaluate environmental impacts is out of the scope since it is addressed in Guide E2986.

1.8 This guide can be used to complement other standards that address environmental aspects of manufacturing processes, for example, Guide E2986, Terminology E2987/E2987M, and Guide E3012.

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

1.10 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.11 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E2114 Terminology for Sustainability Relative to the Performance of Buildings

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

E2987/E2987M Terminology for Sustainable Manufacturing

E3012 Guide for Characterizing Environmental Aspects of Manufacturing Processes

2.2 *IEC Standard:*[3]

IEC 62264-1 Enterprise-control system integration–Part 1: Models and terminology

2.3 *ISO Standards:*[4]

ISO 14001 Environmental management–Requirements with guidance for use

ISO 14044 Environmental management–Life cycle assessment–Requirements and guidelines

ISO 20140-1 Automation systems and integration–Evaluating energy efficiency and other factors of manufacturing systems that influence the environment–Part 1: Overview and general principles

[1] 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] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from International Electrotechnical Commission (IEC), 3, rue de Varembé, 1st Floor, P.O. Box 131, CH-1211, Geneva 20, Switzerland, http://www.iec.ch.

[4] 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.

***A Summary of Changes section appears at the end of this standard**

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

ISO 22400-2 Automation systems and integration–Key Performance Indicators (KPIs) for manufacturing operations management–Part 2: Environmental performance evaluation process

2.4 *NSF Standard:*[5]

NSF/GCI/ANSI 355 Greener Chemicals and Processes Information

3. Terminology

3.1 *Definitions*—Definitions of terms shall be in accordance with terminology in Terminology E2114, Guide E2986, Terminology E2987/E2987M, Guide E3012, ISO 20140, and ISO 22400.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *KPI criterion, n*—a norm or characteristic of a KPI that is used to determine whether the KPI is capable of assessing an environmental aspect of manufacturing processes.

3.2.2 *KPI effectiveness, n*—a measure of how well a KPI evaluates the impact of an environmental aspect of a manufacturing process on the environment.

3.2.3 *KPI normalization, n*—a procedure to adjust KPIs on different scales to a common scale.

4. Significance and Use

4.1 This guide provides methods for developing environmental sustainability KPIs at the manufacturing process level.

4.2 This guide provides standard approaches for systematically identifying, defining, selecting, and organizing KPIs for determining the impact of manufacturing processes on the environment.

4.3 This guide is intended for those who need effective KPIs to assess manufacturing process performance, raise understanding, inform decision-makers, and establish objectives for improvement.

4.4 If the number of stakeholders is small and the manufacturing processes are simple, KPI developers can follow the first two steps (5.2 Establishing KPI Objectives and 5.3 Defining needed KPIs) of this guide. The steps that follow include KPI selection, normalization and weighting, and KPI organization. They can be applied to larger groups of stakeholders and more complex manufacturing processes. Users of this guide can determine the number of steps they will follow because the decision is highly dependent upon the products that they make and the processes that they use.

4.5 The guide enables the development of tools for KPI management and performance evaluation that will support decision-making capabilities in a manufacturing facility, including the development and extension of standardized data, performance information, and environmental knowledge.

[5] Available from NSF International, P.O. Box 130140, 789 N. Dixboro Rd., Ann Arbor, MI 48105, http://www.nsf.org.

4.6 Procedures outlined in this guide are intended for environmental KPIs, and they also can be applied to broader sustainability KPIs as in Guide E2986.

4.7 A quick guide on how to use this guide can be found in Appendix X7.

5. Procedure for KPI Definition, Selection, and Organization

5.1 This section provides a procedure to establish objectives, identify/define candidate KPIs, select effective KPIs, and organize them into a set. Fig. 1 shows a workflow chart describing the procedure to develop KPIs. The following subsections describe the activities represented in each box in Fig. 1.

5.2 *Establish KPI Environmental Objectives*—A KPI objective is a threshold of achievement to improve certain environmental aspects of manufacturing processes. An objective should (*1*) reflect environmental performance, (*2*) set a normative standard for assessment in the organization, (*3*) be operational and applicable to all stakeholders, (*4*) be quantitative and measurable, (*5*) be easy to understand and communicate, (*6*) have a specific time frame, and (*7*) respect local, state/provincial, and national policies, and international priorities. For sustainability improvements, a KPI objective will support a sustainability objective as stated in Guide E2986, 5.2 Setting Sustainability Objective.

NOTE 1—*KPI Environmental Objective Example*—Reduce CO_2 emission 20 % within a year in a concrete-making process.

5.3 *Identification and Definition of Candidate Environmental KPIs*—When choosing candidate KPIs, stakeholders identify the necessary metrics to address the KPI objective. Examples of metrics include, but are not limited to, energy consumption in kJ, water consumption in liters, material use in kg, emissions in metric ton, etc. These metrics can either be measured directly or estimated through physics-based equations (see examples in Notes 2 and 3). KPI developers should determine what new metrics are necessary to address the KPI objective. When a new metric is selected, KPI users should consider measurement methods (such as sensors or human input), cost to measure, and implementation time in deciding how to proceed. If applicable KPIs are available from literature sources, those KPIs can be adopted. 5.3.1 describes a procedure to identify sources of KPIs. If appropriate KPIs are not available, new KPIs may be defined. 5.3.2 describes how users can define new KPIs.

NOTE 2—*Metric Example*—Energy consumption measured with a power meter.

NOTE 3—*Physics-based Equation Example*—Energy required for a metal cutting process on a steel workpiece, such as E (cutting energy) = F (cutting force) × S (cutting speed) × T (duration).

5.3.1 *Identification of Sources of Standards and Literature for KPIs*—Candidate KPIs can be defined using available information from literature. Some examples of literature sources are in Appendix X1. Initial candidate KPIs should be developed using the format in ISO 22400-1 for ease of communication among stakeholders. Some example KPIs are described in Appendix X2.

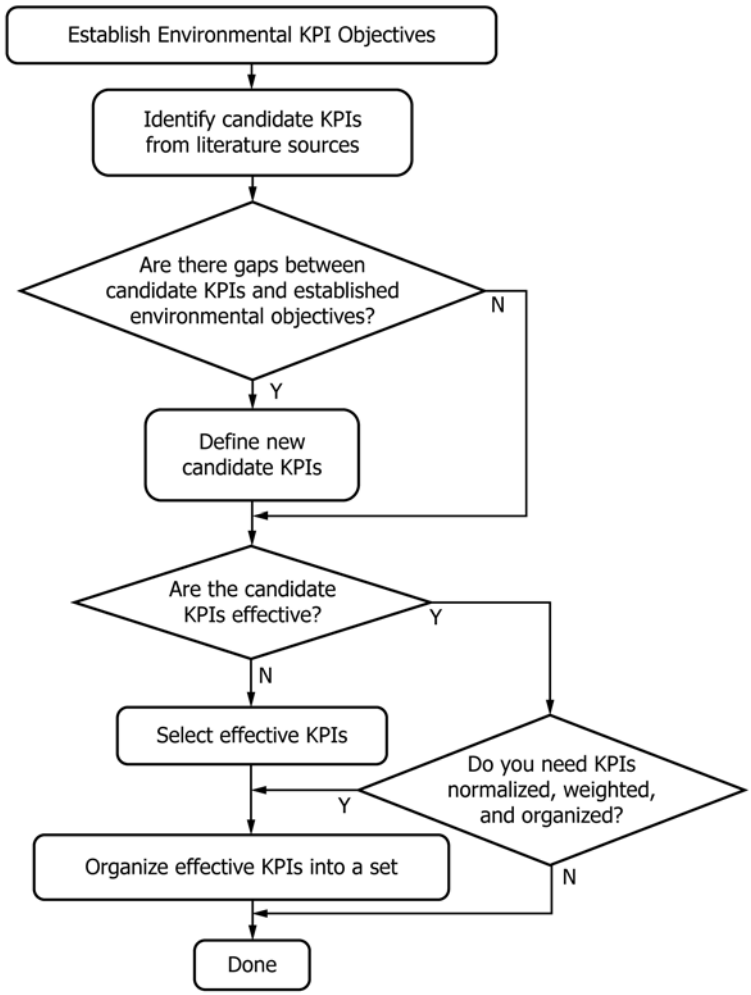

FIG. 1 KPI Definition, Selection, and Organization Flow Chart

5.3.2 *Procedure for Defining New Environmental KPIs*—If applicable KPIs cannot be found in literature sources or Appendix X2, new KPIs must be defined to measure environmental aspects of manufacturing processes. This procedure is described in the following two subsections (5.3.2.1 and 5.3.2.2).

5.3.2.1 *Identify Gaps in Currently Used KPIs*—KPI developers should analyze KPIs that are currently in use for the manufacturing process and identify gaps in the KPIs necessary to monitor a defined sustainability objective. If all the candidate KPIs are found in literature sources, the KPI developers can skip the step of defining new KPIs and go to the step of evaluating the candidate KPIs. If gaps are identified and KPIs that address the need cannot be found, then a new KPI should be created.

5.3.2.2 *Define New KPIs*—There are two approaches to defining a new KPI: bottom-up and top-down. The bottom-up approach starts with identifying current and necessary metrics and then assembling them into a new KPI. The top-down approach focuses on defining a new KPI and then identifying the necessary metrics to calculate that KPI. The method chosen will be based on the manufacturer's situation. The bottom-up approach is useful if addressing the improvement of a single process, and the top-down approach is driven by organizational objectives.

(1) Bottom-Up Approach—Once a gap is identified between KPIs currently in use and those that are needed to achieve environmental objectives, the next step is to identify metrics needed to fill these gaps. KPI developers should first focus on metrics that are already being used for the manufacturing process. If metrics are available and can address the gap in candidate KPIs, then these metrics are used in the development of a new KPI. If no available metrics address the gaps for the candidate KPIs, then new metrics must be developed. This will be addressed in the top-down approach next. The developed metrics can be arranged into a new KPI based on the KPI objectives.

NOTE 4—*Example*—If an objective is to reduce energy waste at a specific process, then measuring both total energy and energy that is needed to perform the task (necessary energy) can be used to form a KPI of energy efficiency.

NOTE 5—*Example*—KPIs could be "total energy waste = total energy – necessary energy" or "energy efficiency = necessary energy/total energy."