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BSI Standards Publication

Automation systems and integration - Evaluating energy efficiency and other factors of manufacturing systems that influence the environment

Part 5: Environmental performance evaluation data

National foreword

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Automation systems and integration — Evaluating energy efficiency and other factors of manufacturing systems that influence the environment —

Part 5: Environmental performance evaluation data

Systèmes d'automatisation et intégration — Évaluation de l'efficacité énergétique et autres facteurs de fabrication des systèmes qui influencent l'environnement —

Partie 5: Données d'évaluation de la performance environnementale

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared jointly by Technical Committee ISO/TC 184, *Automation systems and integration*, Subcommittee SC 5, *Interoperability, integration, and architectures for enterprise systems and automation applications*, and Technical Committee IEC/TC 65, *Industrial-process measurement, control and automation*. The draft was circulated for voting to the national bodies of both ISO and IEC.

A list of all parts in the ISO 20140 series can be found on the ISO website.

Introduction

ISO 20140 specifies an environmental performance evaluation (EPE) method for evaluating the energy efficiency and other factors of manufacturing systems that influence the environment (e.g. energy consumption, waste and release). The EPE method includes guidelines for analysing the usage of energy by the manufacturing system and the effects of the manufacturing system on the environment. The method described in ISO 20140 is used to perform systematically an EPE by analysing the manufacturing activities and the manufacturing system.

ISO 20140 is intended for discrete products/parts manufacturing systems used in manufacturing processes such as forming, machining, painting, assembling, testing for the production of products such as aircraft, automobile, electric appliances, machine tools and their components.

ISO 20140 focuses on applying the EPE method on a manufacturing system having a hierarchical structure comprised of work units, work centres and areas. The EPE method can be applied for quantifying the improvements in production management and individual manufacturing equipment operations in various manufacturing system configurations.

The EPE method and underlying concept of ISO 20140 can also be used as the foundation for EPE for continuous processes and batch processes.

ISO 20140 can be used for:

— benchmarking of environmental performance for a generic manufacturing system;

— performing studies of environmental performance for improving a current manufacturing process, reconfiguring a current manufacturing system/equipment and designing a new manufacturing system;

— comparing the environmental performance of different manufacturing systems producing the same product;

— setting the top level target of environmental improvement and the breakdown to constituent systems, work units and individual manufacturing equipment;

— improving the shop floor operations by visualizing the actual status of environmental performance.

Expected users of ISO 20140 are:

— managers for environmental conditions in a factory, site and enterprise;

— engineers for process planning of products;

— planners and designers for manufacturing systems;

— engineers and foremen that produce products by operating a manufacturing system.

ISO 20140-1 provides an overview and general principles of a method for evaluating the environmental performance of manufacturing systems.

Automation systems and integration - Evaluating energy efficiency and other factors of manufacturing systems that influence the environment —

Part 5: Environmental performance evaluation data

1 Scope

This document specifies the types of environmental performance evaluation (EPE) data, including their attributes, which can be used for evaluating the environmental performance of manufacturing systems based on the general principles described in ISO 20140-1. It also provides recommendations for mapping the EPE data on to information models specified by IEC 62264.

This document applies to discrete, batch and continuous manufacturing.

This document is applicable to entire manufacturing facilities and to parts of a manufacturing facility.

This document specifically excludes from its scope the syntax of the data and information models, the protocols to exchange data models, the functions that can be enabled by data models, and the activities in Level 1 and Level 2.

The scope of this document also includes indicating the differences among various data and information models and the differences among various representations of environmental performance by actual data.

This document refers to the semantics of the structured data and information models used by communication protocols. The semantics explain the meaning of the attributes and of the context information.

The following are outside the scope of this document:

— product life cycle assessment;

— EPE data that are specific to a particular industry sector, manufacturer or machinery;

— acquisition of data;

— the activity of data communication.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 20140-1:2013, *Automation systems and integration — Evaluating energy efficiency and other factors of manufacturing systems that influence the environment — Part 1: Overview and general principles*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 20140-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at http://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1
actual data
data (3.2) measured or counted from the *manufacturing system* (3.16) during the *manufacturing process* (3.15)

3.2
data
collection of values of measured or derived characteristics of objects, such as facts, processes, or events, before it is interpreted as an *information* (3.5) in a formalized manner suitable for communication, processing and interpretation

3.3
enterprise domain
domain that includes all the activities in *Level 4* (3.12) and *information* (3.5) that flows to and from *Level 3* (3.11)

[SOURCE: IEC 62264-1:2013, 3.1.11]

3.4
external data
data (3.2) that come from outside of the manufacturing enterprise

3.5
information
combination of *data* (3.2) concerning objects, such as facts, processes or events, in a meaningful form that enables interpretation with a particular meaning within a certain context

Note 1 to entry: Both data and information are collections of items. In the context of this document, data become information when the data structure, model, or object contains also reference elements (see 3.17 and Clause 4).

Note 2 to entry: For the purpose of simplifying the text, unless explicitly specified, this document uses the word "information" with the meaning of the term "information for environmental performance evaluation".

3.6
environmental performance evaluation data
EPE data
data (3.2) that can used for environmental performance evaluation

3.7
key performance indicator
KPI
performance measurement of some critical aspect of the system or component

Note 1 to entry: KPIs are chosen by an organization based on a specific criterion determined by its mission, operating plans and continual improvement procedures.

3.8
Level 0
actual physical process

Note 1 to entry: This term is used in the context of functional hierarchy of enterprise-control systems.

[SOURCE: IEC 62264-1:2013, 3.1.19, modified — Note 1 to entry has been added.]

3.9
Level 1
functions involved in sensing and manipulating the physical process

Note 1 to entry: This term is used in the context of functional hierarchy of enterprise-control systems.

[SOURCE: IEC 62264-1:2013, 3.1.18, modified — Note 1 to entry has been added.]

3.10
Level 2
functions involved in monitoring and controlling of the physical process

Note 1 to entry: This term is used in the context of functional hierarchy of enterprise-control systems.

[SOURCE: IEC 62264-1:2013, 3.1.17, modified — Note 1 to entry has been added.]

3.11
Level 3
functions involved in managing the work flows to produce the desired end-products

Note 1 to entry: This term is used in the context of functional hierarchy of enterprise-control systems.

[SOURCE: IEC 62264-1:2013, 3.1.17, modified — Note 1 to entry has been added.]

3.12
Level 4
functions involved in the business-related activities needed to manage a manufacturing organization

Note 1 to entry: This term is used in the context of functional hierarchy of enterprise-control systems.

[SOURCE: IEC 62264-1:2013, 3.1.16, modified — Note 1 to entry has been added.]

3.13
manufacturing operations and control domain
MO&C domain
domain that includes all the activities and *information* (3.5) that flows in *Level 3* (3.11), *Level 2* (3.10) and *Level 1* (3.9) and information flows to and from *Level 4* (3.12)

Note 1 to entry: Traditional use of the terminology "control domain" included the activities defined here as the terminology "manufacturing operations and control domain".

[SOURCE: IEC 62264-1:2013, 3.1.21]

3.14
manufacturing operations management domain
MOM domain
domain that includes all the activities in *Level 3* (3.11) and *information* (3.5) that flows to and from *Level 1* (3.9), *Level 2* (3.10) and *Level 4* (3.12)

Note 1 to entry: The manufacturing operations management domain is a subset of the *manufacturing operations and control domain* (3.13).

Note 2 to entry: For the purposes of this document, the word "information" in this definition also means *data* (3.2).

[SOURCE: IEC 62264-1:2013, 3.1.23, modified – Note 2 to entry has been added.]

3.15
manufacturing process
set of processes in manufacturing involving a flow and/or transformation of material, *information* (3.5), energy, control, or any other element in a manufacturing area

[SOURCE: ISO 18435-1:2009, 3.16]

3.16
manufacturing system
system comprised of a hierarchical structure of individual manufacturing equipment, coordinated by a particular *information* (3.5) model to support the execution and control of *manufacturing processes* (3.15) involving the flow of information, material and energy in a manufacturing plant

[SOURCE: ISO 16100-1:2009, 3.19, modified — The words "comprised of a hierarchical structure of individual manufacturing equipment" have been added.]

3.17
reference data
data (3.2) concerning aspects of *manufacturing system* (3.16) and *manufacturing process* (3.15), data that are generated or managed by the manufacturing system, other than *actual data* (3.1)

3.18
upstream data
data (3.2) associated with resources incoming through the unit process boundary

4 Classification of EPE data

4.1 EPE data context information

Values of EPE data (actual data obtained by measurements performed in Level 1) are rarely available in the form of a single numerical value (e.g. the instantaneous beer mash temperature in fermenting tank, the instantaneous pump energy consumption). The value of the actual data gets commonly associated with equipment and operation context information by means of structured data models (see Reference [36]). The actual data and context information contained in data models are thereafter processed and aggregated into structured information models (see IEC 62264-1:2013) containing also production control, manufacturing system and process plan context information.

Subclause 5.2 indicates that a same actual data value can be contained in multiple data and information models located in either of the functional Levels 2, 3 and 4 of the manufacturing system.

NOTE An actual data value can be included in a variety of data and information models based on the purpose for which that model is configured: energy management, operation control, etc.

An aspect common to the structured data and the information models is that they can be exchanged among various activities located in different levels of the functional hierarchy while the context information gets successively added by those activities in the model structure.

An EPE data model can contain one or more attributes. Attributes can represent context information, including:

— when the data have been obtained;

— by what method the data have been obtained;

— how the data have been processed;

— the purpose of the data (as a response to information request, for control, for reporting, for EPE, for KPI evaluation, etc.).

4.2 Classification by source and time

The EPE data shall be classified based on source and time, as follows:

— actual data;

— external data;

— reference data.

Figure 1 illustrates that the actual data are being generated in the manufacturing enterprise during the manufacturing process. The reference data are generated also within the manufacturing enterprise but at another timing than during the execution of the manufacturing process.

A distinct category of EPE data is represented by the external data that consists of data that comes from outside of the manufacturing enterprise.

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Figure 1 — Classification of EPE data by source and time

The categories of actual, external and reference data are complementary and, as illustrated in Figure 1, the three data categories contain together the entire amount of data needed for EPE.

The high level classification of data by source and time indicates the requirement for every data to have the following two attributes describing the data:

a) an attribute indicating the data sourcing;

b) an attribute indicating the data timing (the time when data are created with respect to the execution of the manufacturing process).

The two data attributes unequivocally identify whether the EPE data is actual, external or reference data.

4.3 Further classification of data

Figure 2 describes a refinement of the data classification illustrated in Figure 1. The actual, external and reference data classes contain data types as shown in the following not all-inclusive list:

- actual data:
  - actual data in operation step;
  - actual data in the construction, reconfiguration and retirement (CRR) step;
  - other;
- external data:
  - upstream data;
  - environmental characteristic data;
  - residual CRR data;
  - other;
- reference data:
  - process control data;
  - manufacturing system data;
  - process plan data;
  - other.

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Figure 2 — Refined classification of EPE data

5 Actual data

5.1 Overview

Physical and chemical systems have measureable properties whose values describe a state of the system. Examples of physical and chemical systems properties include temperature, distance, voltage, flow and level. The measurements are commonly performed by transducers located in Level 1.

Level 1 actual data are rarely available to Levels 3 and 4 in a single value format as measured by a transducer (e.g. an instantaneous temperature or voltage value). An automation system could associate and aggregate actual data with equipment and operation context information into data and information structures. Accordingly, the term “actual data” in this document refers commonly to a data structure that contains an actual data value.

5.2 Sources of actual data

5.2.1 Overview

Figure 3 illustrates that the same value of an actual data value can be contained in data and information models that can have various context information and can be found in multiple levels.

The MO&C domain and the MOM domain include only activities and information flows and do not include actual data. This document specifies the data for EPE and does not describe either the activities that generate actual data (e.g. data acquisition) or how the information is transferred among activities and levels. The shapes illustrating information flows and activities in Figure 3 are marked up with grey for the purpose of emphasizing that those specific topics are out of the scope of this document.

5.2.2 Actual data located in Level 2

Level 2 receives and contains actual data from Level 1 (the transfer of actual data from Level 1 to Level 2 is not depicted in Figure 3 because the data transfer activity is not in the scope of this document).

The MO&C executes the transfer of actual data and context information among levels. The MO&C can, for example, transfer actual data from Level 2 to Level 3 for storage purposes.

Actual data from Level 1 located in Level 2 can be selected for processing and transfer by the MO&C without further processing in Level 2. Alternatively, context information can be added within Level 2 to the actual data from Level 1, either in the same data or information model as received from Level 1 or in a new data or information model.

Level 2 contains also actual data generated by activities prescribed by the MO&C in Level 2. MO&C activities can process one or multiple actual data from Levels 1, 2 and 3 (e.g. calculating power consumption by multiplying the current consumed measured in Level 1 with the value of the line voltage measured at an earlier time in Level 1 and stored for later use in Level 3).

5.2.3 Actual data located in Level 3

Level 2 actual data might be required for processing by activities that are included in Level 3.

NOTE It is common for a manufacturing system to have only a limited number of power meters for measuring the energy consumption of individual pieces of equipment. Consequently, it is common to derive the energy consumption of a piece of equipment from the power line energy consumption (whose value is stored in Level 3) and the measured energy consumption (actual data located in Level 2) of the other pieces of equipment that use same power line as the energy source.

The MO&C activities store selected actual data from Level 2 in Level 3 (e.g. in a historian database). The data stored in Level 3 can be used on a later date for performing an EPE of the manufacturing system.

The Level 3 associates actual data from Level 2 with various context information originated in Levels 0, 1, 2, 3 and 4 in structured documents generated by MO&C activities (e.g. production report, test reports). Those documents, in printed or electronic format, constitute possible sources of actual data available in Level 3.

The historian database and the reports located in Level 3 contain also context information that can be included in Level 2 and Level 4 data and information models.

KPIs reported to Level 3 or calculated in Level 3 can also contain actual data in their model structure (see Annex C).

5.2.4 Actual data located in Level 4

Actual data available for processing in Level 4 are contained in structured information models commonly used by enterprise resource planning (ERP) or manufacturing resource planning (MRP) (e.g. IEC 62264 information models). KPIs reported to Level 4 or calculated in Level 4 can also contain actual data in their model structure (see Annex C).

5.2.5 Selecting the source of actual data

Figure 3 illustrates the multiple choices available for selecting the source of actual data. A measured data value can be available and accessible in multiple levels and in various data and information models. Moreover, a specific data model containing the same actual data can be located also in multiple levels while having different amount of context information added in the model.

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Figure 3 — Locations with actual data

Selection of the source for actual data may depend on:

- the availability of the data (the degree of automation);
- the availability of standardized data and energy models in the manufacturing system;
- the accuracy required by the EPE;
- the granularity required by the EPE;
- the scope of the EPE (e.g. evaluating the energy performance improvement by using the energy use state modes (see Annex G);
- the duration and the frequency of the EPE;
- the cost of storing actual data;
- the availability of actual data.

The actual data in Level 2 have the highest degree of granularity and resolution among the types of available actual data. The actual data contained in the Level 3 historian database have a high content of operation context information over a longer period of time than the actual data in Level 2. The actual data located in Level 4 (e.g. actual data contained in IEC 62264-2 information models) contain information relevant for management and decision making at the enterprise level (e.g. specifying the energy policy).

Data models are generated and configured as prescribed by standards addressing the resource management and communication protocols. It is relevant for the EPE to make use of those data and information models that exist in the manufacturing system.

5.3 Actual data in operation step

5.3.1 Overview

The actual data can be further sorted in four categories as follows:

- Energy actual data: This type of data requires frequent measurements and intense post-processing.

  NOTE 1 Energy data can trigger Level 2 and Level 3 operation control commands and can be used to capture unscheduled operation changes occurring in Level 0. Data models (see Clause A.1) are means to increase the granularity of energy data at high resolution. Information models (see Clause A.2) are means to increase the granularity of energy data at medium resolution.

  NOTE 2 Energy data are described in 5.3.5.

- Material actual data: This type of data are generated by measurement and counting and are mainly used in conjunction with upstream and reference data (e.g. the number of purchased components is counted and thereafter multiplied with the mass of each component as recorded in upstream data). This type of data requires less post-processing and the material usage balance can be easily verified.

  NOTE 3 Material actual data are further described in 5.3.6.

- Manufacturing operations and process actual data.

  NOTE 4 Manufacturing operations actual data and process actual data include context information such as status description (e.g. stand-by, sleep) and the description of perturbations in the process schedule induced by control commands operation alerts;

  NOTE 5 Manufacturing operations actual data and process actual data are further described in 5.3.7.

— Environmental actual data: This type of data includes states and changes in the surrounding environment parameters that might not be controllable by the manufacturing system.

NOTE 6 Real time measurement of environmental actual data can be critical when the manufacturing process includes thermal or chemical processes. Demand response data exchanged with the smart grid are also a type of environmental actual data.

NOTE 7 Weather can be considered as an environmental data, unless the manufacturing system boundaries are factored into a controlled environment, such as an air conditioned manufacturing facility.

NOTE 8 Environmental data are further described in 5.3.8.

The four categories of environmental data listed above can be used by inter-related optimization functions that can have, at times, objectives conflicting with the objective of minimizing the energy consumption. Variances in the manufacturing process or demand response transactions may negatively affect the planned energy efficiency.

A relevant difference among the four categories of actual data consists in the quantity of measured data needed for the EPE. The energy data requires the largest amount of measurements among these four categories of actual data. The energy data is described in more details in 5.3.3.

5.3.2 Requirements for actual data in operation step

The actual data in operations step shall be associated with context information describing:

a) actual data source;

b) actual data timing.

The actual data source is a key piece of context information for aggregating the EPE data along the hierarchy of a manufacturing system. The actual data source selection determines the granularity of the actual data and information models.

The actual data timing is the key piece of context information for determining whether the actual data describes:

— the operations of the manufacturing equipment performing value adding functions in actual product; or

— The operations that support the functionality of the manufacturing equipment.

The actual data timing determines also the resolution of the actual data and information models.

5.3.3 Accessibility of actual data for EPE

Actual data is not commonly available in a manufacturing system in a data or information model structure that contains the exact piece of context information needed for executing the allocation and aggregation processes that will be described in ISO 20140-3[1)] and executing until completion an EPE.

This document classifies actual data and provides examples on how actual data are generated, how actual data are successively associated with context information, and how the actual data is transferred among various location in the manufacturing system.

This document describes where and when actual data and the related context information needed for the allocation and aggregation process that will be described in ISO 20140-3 are available in the manufacturing system during the manufacturing process. The actual data and the context information

1) Under preparation.

needed by the allocation and aggregation process that will be described in ISO 20140-3 may not be available at the same moment in time and location in the manufacturing system.

EXAMPLE Relevant context information (e.g. the energy source is solar energy) is available in Level 3 but the associated actual data are not available for processing (e.g. the actual data are being measured and used for operation control of equipment in Level 1 but are not being reported and stored for further processing).

This document indicates the various locations where the data and context information is accessible in the manufacturing system at various times during the manufacturing process. The availability of the actual data and of the context information is constrained by the cost of investment in automation, data acquisition and data storage. While actual data and context information needed by allocation and aggregation process that will be described in ISO 20140-3 may be available in a manufacturing system, accessing the actual data and context information may be curtailed by the need for dedicated software and hardware for the purpose of collecting that actual data and context information.

5.3.4 Representation of environmental performance by actual data

ISO 20140-2[2)] will specify how to represent the environmental performance.

There are two commonly used options to represent environmental performances by using the Level 3 production tracking activity defined in IEC 62264-3:

— representing environmental performances of the manufacturing system during a specified time period;

— representing environmental performances while producing a specified amount of a certain product.

Activities in Level 3 can merge and split production tracking data contained in IEC 62264-2 information models for representing environmental performances in either of the two ways listed in this subclause.

The energy consumption can be measured for a single piece of equipment or it can total the energy consumption of an entire assembly line. Additionally, equipment and devices capable to exchange advanced energy data models, can further itemize the description of the energy consumption. Equipment and devices capable to exchange energy data models could report in data models the actual energy data (e.g. energy consumption) for each step in the process operation. Equipment and devices capable to exchange energy data models (e.g. a drill machine) could also report calculate and provide aggregated data by using a process that will be specified in ISO 20140-3.

The use case presented in Annex D provides an example of measuring and processing energy data at different levels within the role based hierarchy of a manufacturing system. The total energy consumption is measured by different methods at equipment, area, or plant level for the purpose of performing energy balance with various degrees of accuracy. The use case presented in Annex D shows how to calculate and report the total energy consumption as well as itemized types of energy consumption (e.g. gas, steam). The use case presented in Annex D can also be used to itemize the direct and indirect energy consumption if the equipment and devices are enabled for using energy data models [e.g. Open DeviceNet Vendor (ODVA) (see Reference [32]), Serial Real-Time Communication System (SERCOS)[3)]] that can make distinction between direct and indirect energy consumption.

NOTE 1 In the context of the energy consumption itemization described in Annex D, the term direct energy consumption is the energy consumed by a manufacturing equipment while performing value-adding functions in actual product production mode of the manufacturing equipment.

NOTE 2 In the context of the energy consumption itemization described in Annex D, the term indirect energy consumption is the energy consumed by a manufacturing equipment while performing functions to support its direct operation.

NOTE 3 The term “direct operation” is defined in ISO 20140-1.

2) Under preparation.

3) ODVA and SERCOS are examples of suitable products available commercially. This information is given for the convenience of users of this document and does not constitute an endorsement by ISO of these products.

5.3.5 Actual energy data

Subclause 5.2 describes the existence of multiple options that will be available to ISO 20140-3 and ISO 20140-4[4)] for collecting actual energy data. Energy data are available for EPE at different levels and in a variety of data and information models. A list of non-inclusive criteria for determining the source of actual data is included in 5.2.

Figure 4 illustrates locations in Levels 2, 3 and 4 where actual energy data are available for the EPE. The arrows suggesting the data transfer are marked up with grey colour to emphasize that the actual transfer of data is out of the scope of this document. The "Measured data" block also in Level 1 is marked up with grey colour because the activities performed in Level 1 and the data existing in Level 1 are outside the scope of this document.

4) Under preparation.

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Figure 4 — Options to process and deliver Level 2 actual data

The data measured in Level 1 can be transferred by MO&C activities to Levels 2 or 3.

Four options for selecting a source of energy data from Levels 2 or 3 are illustrated in Figure 4:

— Option 1: The metering device reading represents the simplest structure model that can be encountered in Level 2. The energy data has been subjected to minimal amount of processing and the model contains minimal amount MO&C of context information. They are a series of standards specifying the syntax and semantics of data and information models used for communication protocols. Power meters can provide the real, reactive and apparent power by performing additional calculations with the measured data. IEC 62056 provides semantics of models for electricity metering data exchange. The power meters provide high resolution. Due to cost constraints, the power meters are generally not used to measure the power consumption of individual pieces of equipment, thus they usually provide energy data with a low granularity;

— Option 2: The managed energy data are a more complex structure model than the meter reading encountered in Level 2. This category of data model include energy data models standardized by various organization in the field of automation (e.g. ODVA and SERCOS). These data models contain context information describing the constraints within which devices can operate and manage their own energy (e.g. sleep modes). This type of data model can contain high granularity and resolution energy data (see Annex G). PLC can also process this type of data model and can provide the energy data by request;

— Option 3: Energy data associated with MO&C context information in structured models can also be encountered in Level 2. These structured models and contain:

  1) instantaneous energy data; or

  2) processes energy data (e.g. averaged values, equipment specific KPI).

  NOTE Human machine interfaces (HMIs) process a large amount of actual energy data. HMIs commonly transfer energy data in formats appropriate for the activity of data storage in the historian database or for reports. The access to the actual energy data available to HMIs is limited unless dedicated programmes are written to deliver data.

— Option 4: Level 3 provides actual energy data with MO&C, MOM and enterprise management context and with a lower granularity and resolution than options 2 and 3. Level 3 can provide additional MOM and enterprise resource management context information since Level 3 is the only Level that exchanges data with Level 4 commonly in a format compatible with the IEC 62430 information models. While the IEC 62264-2 information models are comprehensive and associate energy data to operation and management data, the actual data incorporated in those information models is losing its granularity and resolution.

5.3.6 Actual material data

Material consumption is relatively easier to monitor than the energy consumption. The material inventory ascertains that the material is accounted for. The actual material data is usually associated with context information usually stored in Level 3: the material properties and the material's inherent environmental performances along the material's life cycle before and after the manufacturing step. Therefore, information models containing actual material data are commonly available at Levels 3 and 4.

Subclause 6.3 elaborates on the material properties and the material environmental characteristics data (ECD) that can be made available through manufacturing automation for the EPE. As detailed in Clause A.2, activities within Level 4 such as materials requirements planning and spare parts procurement can use the IEC 62264-2 information models for determining the optimum inventory levels of raw materials, spare parts and goods in process at each storage point.

The execution of materials as they move through the process is described by actual material data that include:

— the ability to add or remove production or consumption declarations;

— tracking and modification of material events or actions;

— tracking of all movement of materials (lot and sub lots) amongst storage locations;

— control of the consumption of inventory based on process order, recipe version, lot and sub lot capabilities;

— information to support full product genealogy including vendor lot data and production line tracking.

ISO 20140-2 will consider the following not all inclusive list of categories of materials when assessing whether the actual data represents a direct or indirect influence on the environmental performance:

— raw material;

— consumables;

— purchased parts;

— packaging (receiving);

— materials used by equipment during maintenance and service;

— final product;

— waste;

— re-usable materials;

— hazardous materials (e.g. batteries).

The granularity and resolution of the EPE depends on the combination of means and tools used by the manufacturing enterprise to manage the materials, among which the following are commonly used:

— enterprise resource planning (ERP);

— manufacturing resource planning (MRP);

— data models and objects (see Clause A.1);

— IEC 62264-2 information models (see Clause A.2);

— plant automation.

Materials and material flows that encapsulate energy include:

— water;

— wood;

— compressed air;

— fuel (as a material captured in the inventory until burned and then it becomes energy);

— materials that contain energy but are not used for energetic purposes (see definition of feedstock energy in ISO/IEC 13273:2015, 3.1.3);

— materials that become heat sources or heat sinks while the material experiences changes (heat generated during metal cutting, exothermic or endothermic process reaction).

The transfer of material itself within the manufacturing enterprise can be associated also with energy consumption.

The IEC 62264 material information models capture also information related to the product quality and rejects. This type of actual data can be used for a statistical analysis for possible correlation among quality, rejects and environmental performance improvement measures.

5.3.7 Manufacturing operations and process actual data

Actual data from Level 2 can include also high granularity manufacturing operations and process data as context information. This type of context information can be used in Level 3 for further processing of the actual data and for:

— mapping the actual data in IEC 62264-2 information models exchanged between Levels 3 and 4 and within Level 4;

NOTE 1 IEC 62264 describes in detail the manufacturing operations and process data. See Clause A.2 for examples of information models using manufacturing operations and process data.

— aggregating the actual data in conformance with ISO 20140-3.

NOTE 2 ISO 20140-3 will specify how manufacturing operations and process data are used for aggregating EPE data.

5.3.8 Environmental actual data

This type of data includes states and changes in the surrounding environment parameters that might not be controllable (e.g. weather) by the manufacturing system.

The air quality of the environment surrounding the manufacturing system (e.g. air conditioned manufacturing facility) as well as weather parameters are relevant environmental characteristics data needed for the EPE of a manufacturing system.

The differences in environmental data shall be considered when comparing the environmental performance of any two manufacturing systems (e.g. the availability of solar energy or any other renewable energy source to the manufacturing systems being compared).

Environmental data such as the average ambient temperature are relevant when assessing the environmental benefits of using various sources of energy such as heat pumps or electrical heating and cooling. An analysis based on the second law of thermodynamics should be used to determine the environmental impact of using thermal energy sources and recovering thermal energy.

5.4 Actual data in CRR step

The actual data in the CRR step is gathered at the time of the construction and reconfiguration and then the data is stored in Level 3 records.

The CRR data are considered an actual data if the CRR activity is linked with the manufacturing process for which the environmental performance is being evaluated (e.g. the two activities take place at same time and in the same physical boundary and there is energy exchange among the activities or one of the activities affects the ECD of the other activity). The CRR activity can be directly linked with a manufacturing process also if the CRR activity is included in the temporal extent of the manufacturing system boundary.

6 External data

6.1 General

The external data include data obtained from literature, standards, product specifications and product labels.

Calculations using external data could provide results as accurate as by using actual data. The external data can be a good source of data when the production schedule, the operations and the equipment proceed and perform as planned. Proper document and data management enables consistency in using the external data (no multiple instances of same data).

External data are stored and reside mainly in Level 3. External data can be stored also in Level 2 controllers and drives. Controllers can add external data as context information in data models sent to Level 1. The Level 1 may thereafter add actual data in the data model and report actual data associated with external data for EPE (see Option 2 in 5.3.5).

6.2 Upstream data

6.2.1 General

Definition 3.18 describes upstream data as a flow of external data that enters the unit process boundary.

Energy used by the manufacturing system can be obtained from various sources. For example, the electric energy can be generated by hydroelectric or fossil-fuel power plants or by power plants using renewable sources of energy such as wind and solar energy. The environmental impact of generating, transmitting, storing and distributing energy depends on the energy resource and the technology used to convert and supply the energy to the manufacturing system.

Raw materials can be obtained from different sources and those materials go through a series of processes such as extraction and welding, or machining along the product life cycle. Materials used by the manufacturing system could also be obtained by recycling used products. The environmental performance of producing the materials that enter the boundaries of the EMU depends greatly on the material resources, the process used to produce the material, as well on the geographical location of the material with regard to the manufacturing system location.

The upstream data captures the influence on the environmental performance of all inputs, outputs and processes in the life cycle phase of the energy and the material before entering the boundary of the manufacturing system being assessed.

The upstream data can consist of material and energy input life cycle inventory and the results of the inventory in the form of environmental performance objective figures. The life cycle assessment stages are described in ISO 14040.

6.2.2 Material upstream data

Material upstream data include material declaration information provided by suppliers. The electrical and electronics industry and its supply chain use material declarations to track and declare specific information about the material composition of its products. IEC 62474 covers the exchange of material composition data and provides requirements for material declarations for harmonizing the requirements across the supply chain. IEC 62474 benefits the electrotechnical industry by establishing requirements for reporting substances and materials, standardizing protocols, and facilitating transfer and processing of data.

Given the interdependency on a global scale among suppliers, manufacturers and customers, governments have taken the initiative, before international standard organizations, to regulate nationally and across wider regions means to monitor and control use of raw substances and substances in articles.

Annex E provides examples of legislations and internationally agreed upon systems commonly used by suppliers and manufacturers for reporting on material data.

6.2.3 Energy upstream data

Level 4 of the manufacturing system plans the production based on the variable cost of the energy resources. Industrial automation can be used in a manufacturing system to reduce the energy usage peaks and the reactive power for the purpose of reducing the energy losses the energy distribution line. The energy resource supplier can provide the enterprise in a timely manner the cost of the energy, quality factors and a prediction about the availability of the energy being provided.

Information about the resource of energy is relevant for the evaluation of the EPE. A fossil fuel power plant and a solar power plant cause different environmental impact for same amount of energy produced. The EPE should take into account the influence on the environmental performance caused by the production of the energy used by the manufacturing system.

EXAMPLE The burning of fuels at the power plant produces nitrogen oxides and carbon dioxide, sulphur dioxide and mercury compounds and that contributes to greenhouse effect.

The environmental impact associated with the life cycle of energy encompasses the methods used for extraction of fossil fuels and nuclear ore, manufacturing of renewable technologies (solar panels, concentrating solar, windmills), construction of power plants, cultivating and harvesting of biomass, transportation of all sources to and from various processing facilities to end use, construction, maintenance and operation of distribution systems (pipeline networks, electrical grids, fuelling stations) and, finally, consumption of the fuels.

The environmental impacts of energy generation and transmission can be classified as follows:

— air quality impacts;

— water resources impacts;

— surface disturbances;

— biological resource impacts;

— noise impacts;

— visual impacts.

6.3 Environmental characteristics data (ECD)

Environmental characteristics data (ECD) include characteristics and performance specifications related to environmental aspect of manufacturing equipment and manufacturing support equipment.

The measured values of the equipment environmental characteristics data and the environmental characteristics data of manufacturing system disclosed by equipment suppliers should be substitutable in studies for environmental performance improvement.

Environmental characteristics data describe properties of the energy and materials used in production as well as the environment of the manufacturing system itself.

The emission rate of a given pollutant from a given source relative to the intensity of a specific activity can be measured in grams of carbon dioxide released per mega Joule of energy produced. The terms emission factor and carbon intensity are often used interchangeably, but “factors” exclude aggregate activities such as gross domestic product (GDP) and “carbon” excludes other pollutants.

The US Voluntary Reporting of Greenhouse Gases Program (Voluntary Reporting of Greenhouse Gases Program Fuel Carbon Dioxide Emission Coefficients) provides values for the carbon, methane and nitrous oxide emission factors for US power generation. The emission is itemized for a variety of fuel types (coal, petroleum, natural gas, good, biogenic fuel, waste, etc.). The emission factors are quantified in CO2 emissions per kWh from electricity generation. However, these values vary significantly depending on the individual countries that produce the energy.

Other environmental characteristics data associated with the energy generation, transportation and distribution can be considered according to the purpose and the scope of the EPE.

There is a difference between the environmental influence on the environmental performance of the recycled materials crossing the manufacturing system boundaries and that of newly processed materials. The processes for material recycling the processes for materials mining and processing use different amount of energy and have different environmental performances.

EXAMPLE The burning of fuels at the power plant produces nitrogen oxides and carbon dioxide, sulphur dioxide and mercury compounds and that contributes to greenhouse effect.

The EPE should consider in its implementation the environmental influence on the environmental performance of generating the energy used by the manufacturing system. Annex F provides data for comparing the greenhouse gas emission along the entire life cycle of various energy sources.

Water availability represents another relevant environmental characteristics data.

6.4 Exchanged residual CRR data

The residual CRR influence on the environmental performance of a piece of equipment is being sequentially reduced along its life cycle when a part of the piece of equipment's CRR influence on the environmental performance is charged to the manufacturing system by a process as will be described in ISO 20140-4.

When a piece of equipment is transferred from a manufacturing system to another manufacturing system, the residual CRR data of the first manufacturing system is reduced with an amount equal with the residual CRR influence on the environmental performance of the piece of equipment being transferred to the second manufacturing system.

When a piece of equipment is introduced in the manufacturing system, the residual CRR influence on the environmental performance of the manufacturing system increases with an amount equal with the residual CRR influence on the environmental performance of the equipment being introduced in the manufacturing system.

Similarly, new construction structures can contribute to an increase of the manufacturing system CRR influence on the environmental performance.

The exchanged residual CRR data of the added or removed pieces of equipment induces a variation of the manufacturing system residual influence on the environmental performance.

7 Reference data

7.1 Overview

Reference data reside in records located in Level 3.

Reference data include the following data types (see also Figure 2):

— residual CRR data;

— production control data;

— manufacturing system data.

An example that shows how reference data is mapped onto information models specified in IEC 62264-2 is provided in Clause A.2.

The four categories of reference data are detailed further in this clause by providing examples of data types that are contained in the IEC 62264-2 information models.

This document makes reference to IEC 62264 as a representative method for mapping the reference data into information models. The user of this document can choose any other information models or sources of information for gathering the reference data that will be required by ISO 20140-3. Reference data described in this document are commonly available in information models specified in IEC 62264-2.

7.2 Residual CRR data

The residual CRR data resides in Level 3 records.

An enterprise is comprised of machines, buildings, cooling towers, storage tanks, roads, etc. that need to be built and installed or reconfigured prior to the start the manufacturing process. Facilities and manufacturing equipment may need to be further reconfigured or retired after the completion of their life cycle use phase.

The CRR influence on the environmental performance is associated with the construction, reconfiguration and retirement of the manufacturing system.

Every piece of equipment or construction element has associated a residual CRR data value. The value of the residual CRR influence on the environmental performance changes when CRR influence on the environmental performance is charged to the manufacturing system by a process as will be described in ISO 20140-4.

The manufacturing system's CRR influence on the environmental performance is charged upon each manufactured product. The charge process of the CRR influence on the environmental performance onto the environmental performances of a manufacturing system will be specified by ISO 20140-4.

NOTE It could be difficult to charge indirect and CRR influences on the environmental performance induced by a manufacturing process (e.g. a water cooling tower) by determining in what percentage in which multiple pieces of equipment are using that manufacturing process. In such a case, the aggregation process can plan, offset and charge evenly the indirect and CRR influence on the environmental performance on every product. The charge process of the CRR influence on the environmental performance onto the direct influence on the environmental performance of a manufacturing system is outside the scope of this document.

The residual CRR data represents the CRR influence on the environmental performance that remains yet to be charged after the manufacturing system charges and includes CRR influence on the environmental performance.

7.3 Production control data

The production control functions described in IEC 62264 include most of the functions associated with manufacturing operations and control. A list of functions of production control typically include:

— controlling the transformation of raw materials into the end-product in accordance with the production schedule and production standards;

— producing reports of performance and costs;

— evaluating constraints to capacity and quality;

— self-testing and diagnosis of production and control equipment;

— creating production standards and instructions for SOPs (standard operating procedures);

— recipes;

— equipment handling for specific processing equipment.

The main functions in production control include:

— process support engineering;

— operations control;

— operations planning.

The production control data include:

— planning data;

— operation plan data of manufacturing system;

— production plan data;

— execution plan data of manufacturing activity;

— status records;

— status record of manufacturing execution;

— status record of production control;

— status record of manufacturing system operation;

— material tracking data.

7.4 Manufacturing system data

The manufacturing system data category of reference data contains information describing the inventory of:

— equipment;

— physical assets;

— persons;

— material.

7.5 Process plan data

The process plan data category of reference data contains information describing manufacturing process in higher resolution and granularity than the production control data. The process plan data typically include:

— production operations management;

— maintenance operations management;

— quality operations management;

— inventory operations management;

— time elements;

— logistical terms;

— maintenance terms;

— logistical terms;

— organizational terms;

— quality terms.

8 Mapping of EPE data

8.1 Overview

Clause 8 and Annex F shows how standardized energy data model exchanged among Level 1, Level 2 and Level 3 enable:

— high resolution and granularity EPE;

— quantifying the influence of the automation on the energy performance improvements;

— multi-functional optimization of the environmental performance.

Clause 8 and Annex F provide examples of data and information models that are described by industry standards and international standards. The ISO 20140 user has the option to use the information models described in IEC 62264.

This subclause describes a method of mapping of EPE data onto data and information models for manufacturing systems defined in international or consortia standards.

Actual data values (i.e. obtained by measurements performed in Level 1) are rarely available in single value format (e.g. the instantaneous beer mash temperature in fermenting tank, the instantaneous pump energy consumption).

The value of the actual data gets commonly associated with equipment and operation context information into data models. The actual data and context information contained in data models are thereafter processed and aggregated into information models containing also production control, manufacturing system and process plan context information.

Data and information models containing external, reference and actual data and not individual data are commonly exchanged among levels of the functional hierarchy.

An automation system aggregates and exchanges a variety of data and energy models among and within Levels 1, 2, 3 and 4 with data and context information relevant to the Level and the activity for which the data model is generated. The relevant actual data can be obtained for the EPE by selecting the appropriate data models and information models or a combination thereof, depending on the selected environmental performance to be evaluated.

Figure 4 illustrates how an actual energy data get successively mapped onto various data and information models along its life cycle. The EPE data could be mapped onto the following not all inclusive list of model types:

— classifications relevant to automation & control:

  — data models (see Clause A.1);

  — information models (e.g. Clause A.2);

— classifications relevant to energy management:

  — performance indicators (e.g. ISO 22400, ISO 50006).

The information models described in IEC 62264-2 collect comprehensively context information and associate it at the enterprise level with data and information provided by the industrial automation. Those information models are used by activities Level 3 MO&C and Level 4 MOM as well as for communication between Level 3 and Level 4.

The information model defined by IEC 62264-2 is a common framework for manufacturing systems. The way to represent data for an EPE should be consistent with the information model for other activities of manufacturing system. For these reasons, mapping of the data within Levels 3 and 4 onto the information model defined by IEC 62264-2 can be a solution for making data and context information available for storage and further analysis.

A shortcoming in mapping actual data upon existing standards consists in the fact that there is not an international standard on how to store the data contained in data and information models. A solution to this gap is to use automation system to perform the EPE by using the data and context information that are available and are transferred among activities in all levels of the manufacturing system and thereafter store only the EPE results and the relevant factors.

The strength of the IEC 62264-2 information models is in relating actual data with context information for providing actionable information at enterprise level. The resolution, the granularity and the completeness of the actual data integrated in the IEC 62264-2 information models depend on the Level of automation of the manufacturing enterprise. If a specific detailed information needed for EPE is not readily available in the IEC 62264-2 information models, the search for actual data should include other actual data sources in available in Level 3 and Level 2.

The actual data exchanged with and within Level 2 commonly are not captured in entirety in information models described in IEC 62264-2. While acknowledging this gap in international standardization, there is a series of standard development organizations (e.g. ODVA and SERCOS) that have developed voluntary standards relevant to energy monitoring and energy management. Those consortia standards have defined energy data objects that enable:

— Level 2 controllers and devices to perform Level 3 actual data aggregation and energy management functions;

— the association of actual data with relevant context information in a format that meets the specific needs for evaluating performance analysis and managing the energy of a manufacturing work units, work centres, or areas.

Figure 4 illustrates that the value of the measured actual data can be obtained for further processing from various locations in Levels 2, 3 and 4. It is expected to be differences among the value of the actual data and the context information contained by models available at various locations in Levels 2, 3 and 4 and at different times.

8.2 Classifications relevant to energy management

ISO 50001 provides a series of terms and data types to be used for enterprise energy management. Data for EPE could be mapped onto the following not all inclusive list of categories of data types specified by ISO 50001:

— operating parameters;

— energy consumption;

— asset energy efficiency;

— energy service parameters.

8.3 Differences between Levels 2 and 3 and Levels 3 and 4 actual data

Figure 5 illustrates a sequential mapping of data circulated across Levels 1, 2, 3 and 4 into data models and information models. The multitude of actual data and information models can be grouped in two categories

— the data models generated and exchanged among Levels 0, 1 and 2 contain actual data with high resolution and fine granularity. However, those actual data models might not contain context information about the batch of products being manufactured at the time the actual data has been measured;

— the data models generated and exchanged between Levels 3 and 4.

The grey arrows and rectangles in Figure 5 suggest how actual data models and context information are exchanged among locations in Levels 0 to 4. However, the data exchanges per se as well as the activities taken place in Levels 0 and 1 are not in the scope of this document. Those exchanges and activities are illustrated for the sole purpose of indicating the bidirectional flow of data among various location in the manufacturing system. The syntax of data models as well as the usage of data models in Level 2 are also out of the scope of this document.

The purpose of Figure 5 is to illustrate that relevant differences between Levels 2 and 3 and Levels 3 and 4 data and information models consist of:

— various degrees of resolution and granularity;

— the type of context information;

— data availability and accessibility (data models available in Level 2 may have a very short life time while data in information models in Levels 3 and 4 have more opportunities to be stored in a digital factory repository (e.g. a historian)).

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Figure 5 — Successive mapping of EPE data

Figure 5 indicates data and information exchanges that can take place between Level 2 controls and Level 1 transducers and Level 0 operators. The context information describing this type of communication and changes in operating modes can be included in the context information of actual data models transferred within and with Level 2.

Since this actual data captured in Level 2 is commonly obtained at a high rate in time (e.g. milliseconds), the activities in Level 3 capture in information models and are able to store only a small amount of Level 2 actual data and context information.

Clause A.1 provides an example of how energy data can be mapped in Level 1 and Level 2 energy data models available for Level 3 for EPE. They are currently broadly used consortia standards for energy data models used in communication among Levels 1, 2 and 3. The consortia standards have common features and concepts (see Annex G).

The more the data models provided by Level 2 conform with a standard structure, the more Level 2 data will be available for EPE and the less Level 3 activities need to process those data for the purpose of incorporating actual data and context information into IEC 62264 information models.

Clause A.2 provides an example of how energy data can be mapped in the energy information models specified in IEC 62264. The IEC 62264 information models are widely used in the management of manufacturing enterprises and they contain detailed context information related to manufacturing operations management and control.

Annex A
(informative)

Mapping of EPE data

A.1 Level 1 and Level 2 data models

A.1.1 Overview

A very large amount of actual data are being generated, processed and exchanged within and with Level 2 but only a small part of that data are transmitted to Level 3 and an even smaller amount is commonly transmitted further to Level 4.

The data being generated, processed and exchanged within Level 2 is expected to be in a wide variety of formats. The data being generated, processed and exchanged within Level 2 represent a wealth of information with a high degree of granularity and resolution that ISO 20140-3 will be able to use for evaluating environmental performance of manufacturing system. The challenge with using this wealth of information is the large variety of formats in which the actual data is available in Levels 1 and 2 in the absence of an international standard for energy data models.

Consortia and organizations such as ODVA and SERCOS have developed standards for energy data models that can be used also for communication within and among activities in Levels 1, 2 and 3. The existence of those standards will open the possibility for ISO 20140-3 to use for an EPE contained in energy data models generated in Level 2 or aggregated with data in Level 2. Those energy data models exist, can be transmitted and are available for further processing in Level 3, therefore it is in the scope of this document to list the Level 1 and Level 2 energy data models among the options of input for the ISO 20140-3 allocating and aggregating processes. It is outside the scope of this document to describe energy data models generation and usage within Level 1 or Level 2.

By using standardized energy data models for activities in Levels 1 and 2 and for communication with Level 3, actual energy data such as the operating mode or the usage load of a manufacturing equipment can be exchanged at an increased rate. Additionally, actual energy data such as the energy usage measurement and the operating mode context information can be exchanged among more devices in Levels 1 and 2, and that enables the safe management of machine energy consumption by devices in Level 2 with some independence from Level 3 controller.

A.1.2 Energy data models

Manufacturing enterprises can use revenue-accurate meters to measure energy consumption from the energy distribution network. However, cost constraints limit the usage of revenue-accurate for measuring the energy consumption of work units.

There are many devices in Level 2 that measure and use for control actual energy data such as voltage and current measurements but may not transmit further the actual energy data because energy data reporting is not the primary function of the device.

The use of a standardized energy data object for communication within and among devices and activities in Levels 1, 2 and 3 are intended to cost-effectively fill in missing pieces of the energy usage picture where today little or no information exists. Energy data models exchanged among automation devices provide consistent and highly granular energy-related information – making it easier to support important use cases (e.g. sleep mode). A more complete energy picture would provide valuable information on the energy consumption behaviour of a machine, work unit, zone and area, allowing users to make decisions that result in reduced energy usage and cost.

Energy data objects have two primary purposes:

— transport of control-oriented data associated with I/O devices;

— transport of other context information which is related to the system being controlled, such as configuration parameters and diagnostics.

Figure A.1 illustrates a variety of devices that use standardized energy data models for communication within and between Levels 1 and 2 and provide highly granular energy-related information.

A power monitor can make an accurate measurement of the work unit energy consumption. The energy data models transmitted by a

A motor overload relay can report on the motor's energy performance by using energy data models. Based on the information contained in the energy data model reported by the motor relay, any entity that reads the energy data model can calculate the motor power consumption.

A controller can report on the energy consumption of and context information about the generic device that it controls. The controller c send the energy data models either by request or every time the operation mode of the generic device is changing or it is about to change its operation mode (e.g. starting the wake-up mode).

Energy devices can report the energy consumption to the energy source and the energy source can further report individual or aggregated energy consumption. Software applications can aggregate energy data models and perform complex functions for providing the energy performances of a group of devices. The power consumption of an energy user not able to exchange any energy data models can be deduced by simple arithmetic operations. Software applications can aggregate also non electrical energy data.

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NOTE Figure A.1 is adapted from ODVA *Technology at a Glance*[32], which also provides definitions for the terms “energy measured”, “energy derived”, “energy proxy”, “energy aggregated” and “energy fixed”.

Figure A.1 — Example of using energy data objects

The following context information can be mapped in energy data models within and among Levels 1, 2 and 3:

— energy/resource type;

— energy object capabilities;

— energy accuracy;

— data status;

— consumed energy odometer (counter);

— generated energy odometer (counter);

— energy identifier;

— metering state.

Annex G provides more details about the semantics of energy data model attributes commonly encountered in consortia standards.

Standardized energy data objects enable the automation system to associate actual energy data with operation and equipment context information, record historical data, analyse and report the flow of data, correlate data sources within the plant and enable the monitoring and optimization of the energy usage.

Level 3 can use for allocation and aggregation processes that will be described in ISO 20140-3 energy data models reported from Level 2 that contain actual energy data and high granularity energy-related information. Level 3 can also use for allocation and aggregation processes that will be described in ISO 20140-3 lower granularity and resolution actual energy data available in the IEC 62264 information models such as responses to manufacturing operation management requests (see Figure A.8).

Standardized energy objects can provide the means to aggregate energy information at various levels in the manufacturing enterprise functional or role hierarchy and can be used for reporting the actual energy data in a consistent format and content at all levels.

A.2 Level 3 and Level 4 information models of IEC 62264

A.2.1 Overview

IEC 62264 defines two groups of models using the Unified Modelling Language (UML) notational methodology, which is defined in ISO/IEC 19501:

— common object models;

— operations management information models.

The common object models are used in information exchange that relate to personnel, equipment, physical asset and material. The common object models are used also in the operations management information models. A summary of common object models are explained in Annex B.

The operations management information models are used to represent the information exchanged among operations management areas or among activities.

Actual data could be mapped, upon the appropriate data processing and data aggregation, in the production performance model management shown in Figure A.2.

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NOTE Source: IEC 62264-1.

Figure A.2 — Production performance model management

The production operations management model described in IEC 62264-3 is expanded into a detailed activity model of production operations shown in Figure A.3. The four elements of information (product definition, production capability, production schedule and production performance) correspond to the exchanged information defined in IEC 62264-1. The oval-labelled “production level 1-2 functions” represent the Level 1 and Level 2 sensing and control functions that deliver actual data. The other ovals (with solid outlines) represent the activities of production operations.

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NOTE Source: IEC 62264-3.

Figure A.3 — Activity model of production operation management

The operational responses delivered to the Production execution management is defined in IEC 62264-3 as information received from Level 2 in response to commands. These typically correspond to the completion or status of elements of work orders.

NOTE This information exchange corresponds to the recipe-equipment interface defined in IEC 61512-1.

A more detailed look at interface in the production data collection activity model is presented in Figure A.4 reveals the type of information exchanged among production operation management activities.

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NOTE Source: IEC 62264-3.

Figure A.4 — Interfaces in the production data collection activity model

A.2.2 Common object models

IEC 62264 specifies two types of objects related to resources of manufacturing system as follows:

— Resource category (class) includes:

  — personnel classes (e.g. welding technician);

  — equipment classes (e.g. welding workshop);

  — physical asset classes (e.g. model of welding machine from a manufacturer);

  — material classes (e.g. welding electrode);

— Resource includes:

  — persons (e.g. Mr. Joseph Briant);

  — equipment (e.g. Work cell #001 for product XXX);

  — physical asset (e.g. particular welding machine with serial # of ABC123);

  — material lot (e.g. welding electrode purchased on September 29th).

Capability and specification are properties of resources and resource classes.

EXAMPLE 1 An example of property of physical asset class is the power consumption of the particular machine model.

EXAMPLE 2 An example of property of physical asset is the voltage of the power source to which a particular machine is being connected.

A.2.3 Operations management information models

IEC 62264 specifies the following operations management information object models:

— process segment model which describes what functions are available;

— operations definition model which describes how to perform an operation;

— operations schedule model which describes what is it to be made and used;

— operations performance model which describes what was made and used;

— operations capability model which describes what is available.

Operations management information models can be applied to the following operations management categories:

— production operations;

— maintenance operations;

— quality operations;

— inventory (handling) operations.

While production operations usually bring the most significant environmental performance, other operations can also cause influences on the environmental performance because those operations:

— use energy;

— can use harmful material.

Figure A.5 shows operation management models for four operation management categories.

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NOTE Source: IEC 62264-3.

Figure A.5 — Operations information models for operations management

A.2.4 EPE data in the operations management information object models

A.2.4.1 Relevant data in process segment model

A.2.4.1.1 Process segment model

Process segments are the smallest elements of manufacturing activities that are visible to business processes. They are also logical grouping of personnel resources, equipment resources, physical asset resources and material required to perform an operations step.

The process segment model is shown in Figure A.6.

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NOTE Source: IEC 62264-2.

Figure A.6 — Process segment model

Process segments are independent of any particular product or operations task.

Significant EPE data in a process segment are included in the following information models:

— physical asset segment class specification;

— process segment dependency.

A.2.4.1.2 Relevant data in physical asset segment class specification

A physical asset class segment specification specifies the physical asset class that is required for the process segment.

Physical asset segment class specification can be derived from lists of product properties such as the ones standardized in the IEC 61360 database (IEC Component Data Dictionary).

Examples of EPE data which are included in the physical asset class segment specification are listed below:

— basic performance related energy consuming, which includes:

  — rated input power voltage;

  — nominal energy consumption;

  — energy modes;

  — power consumption for each energy mode;

  — timing specification related to energy modes;

  — dependency of energy consumption against operating conditions;

— energy used to produce the physical asset, which is captured during:

  — manufacturing process of elements of the physical asset before installation;

  — transportation of elements of the physical asset;

  — assembling process, construction process and installation process of the physical asset into the particular manufacturing system being evaluated;

— quantity of CO2 emitted to produce the physical asset, which is captured during:

  — manufacturing process of elements of the physical asset before installation;

  — transportation of elements of the physical asset;

  — assembling process, construction process and installation process of the physical asset into the particular manufacturing system being evaluated;

— information about harmful material, which includes:

  — kinds of harmful material;

   — quantity of the harmful materials;

— energy needed to discard the physical asset, which is estimated by considering:

   — transportation for disposal;

   — dismantling and scrapping;

   — reuse and recycle.

A.2.4.1.3 Relevant data of process segment dependency

Process segment dependencies are process dependencies that are independent of any particular product or operations task.

Examples of EPE data which are included in the process segment dependencies are listed below:

— sequence of steps;

— restriction of interval time between steps;

— restriction of parallel operation of steps.

A.2.4.2 Relevant data in operations definition model

A.2.4.2.1 Operations definition model

An operations definition defines the resources required to perform a specified operation. The actual definition of how to perform the operation is not included, which is defined in a work definition.

The operations definition model is shown in Figure A.7.

Missing image: D:/PAYLOAD/Filestore/Workflows and Output/BS-ISO PDF Body Final/2017-05-04 13.23.54/source/fig_A.7.eps.

NOTE Source: IEC 62264-2.

Figure A.7 — Operations definition model

Significant EPE data of an operations definition are included in:

— operation definition;

— operations segment;

— parameter specification;

— material class specification;

— equipment class specification;

— physical asset class specification;

— operations segment dependency.

A.2.4.2.2 Relevant data of operation definition

An operation definition presents the resources required to perform a specified operation.

Examples of EPE data which are included in the operation definition include

A reference to an external bill of material including energy related information, which can be used for capturing quantities indirect materials or materials common to multiple operations represents an example of EPE data which are included in the operation definition.

A.2.4.2.3 Relevant data of operations segment

An operations segment presents the information needed to quantify a segment for a specific operation. An operations segment identifies, references, or corresponds to a process segment.

The time duration of the operations segment represents an examples of EPE data which are included in the operations segment.

A.2.4.2.4 Relevant data of parameter specification

Parameter specifications present specific parameters required for an operations segment.

A basic specification of the product to be produced, independent of particular work orders represents and examples of EPE data which are included in the parameter specifications.

A.2.4.2.5 Relevant data of material class specification

A material specification presents an identification or correspondence to a material class capability. A specific material class specification is associated with the identified operations segment.

Examples of EPE data which are included in the material class specification are listed below:

— required specification of materials for the operation, which includes:

  — calorific value of fuel;

— required specification of energy for the operation, which includes:

  — type of energy source;

  — voltage of electric power source;

  - temperature of steam;
- required quantity of the material and energy for the operation, which includes:
  - quantity of material;
  - quantity of fuel;
  - input power of electricity;
  - quantity of steam.

A.2.4.2.6 Relevant data of equipment class specification

An equipment specification presents an identification, reference, or correspondence to an equipment class capability. An equipment specification identifies the specific equipment class capability that is associated with the operations segment.

Examples of EPE data which are included in the equipment class specification are listed below:

- required functions and capability of the equipment class;
- required quantity of the equipment class.

A.2.4.2.7 Relevant data of physical asset class specification

A physical asset specification presents an identification, reference, or correspondence to a physical asset class capability. A physical asset class specification identifies the specific physical asset class capability that is associated with the operations segment.

Examples of EPE data which are included in the physical asset class specification are listed below:

- required performance of the physical asset class, which includes:
  - energy consumption in the context of the operations segment;
- required quantity of the physical asset class for the operations segment;
- required operation time of the physical asset class for the operations segment.

A.2.4.2.8 Relevant data of operations segment dependency

Operations segment dependencies present operations segment dependencies are process dependencies that are operation or product specific.

Examples of EPE data which are included in the operations segment dependencies are listed below:

- sequence of steps;
- restriction of interval time between steps;
- restriction of parallel operation of steps.

A.2.4.3 Relevant data in operations schedule model

A.2.4.3.1 Operations schedule model

An operations schedule is a request for operations to be performed. It is made up of one or more operations requests. An operations request contains at least one segment requirement.

The operations schedule model is shown in Figure A.8.

Missing image: D:/PAYLOAD/Filestore/Workflows and Output/BS-ISO PDF Body Final/2017-05-04 13.23.54/source/fig_A.8.eps.

NOTE Source: IEC 62264-2.

Figure A.8 — Operations schedule model

Significant EPE data of an operations schedule are included in:

— operations request;

— segment requirement;

— segment parameter;

— resource requirement.

A.2.4.3.2 Relevant data of operations request

An operations request presents a request for an element of an operation schedule. An operations request contains the information required by manufacturing to fulfil the scheduled operation.

Examples of EPE data which are included in the operations request are listed below:

— reference to the operation definition to be requested;

— scheduled start time and end time of the operation.

A.2.4.3.3 Relevant data of segment requirement

An operations request is made up of one or more segment requirements. Each segment requirement corresponds to, or references, an identified operations segment or process segment. The segment requirement identifies or references the segment capability to which the associated personnel, equipment, physical assets, materials and segment parameters correspond.

Examples of EPE data which are included in the segment requirement are listed below:

— expected earliest start time of the operations segment;

— expected latest end time of the operations segment.

A.2.4.3.4 Relevant data of segment parameter

Segment parameters present specific parameters required for a segment requirement. A segment parameter includes a set of limits that apply to any change to the value.

Examples of EPE data which are included in the segment parameters are listed below:

— additional segment specification such as quality grade of the product;

— expected operating conditions such as ambient temperature.

A.2.4.3.5 Relevant data of resource requirement

Resource requirement consists of personnel requirement, equipment requirement, physical asset requirement and material requirement.

A personnel requirement presents the identification of the number, type, duration and scheduling of specific certifications and job classifications needed to support the current operations request.

An equipment requirement presents the identification of the number, type, duration and scheduling of specific equipment and equipment classifications or equipment constraints needed to support the current operations request.

A physical asset requirement presents the identification of the number, type, duration and scheduling of specific physical assets and physical asset class constraints needed to support the current operations request.

Examples of EPE data which are included in the resource requirements are listed below:

- assignment of particular resources to the defined resource classes such as:
  - identifier of energy source;
  - identifier of material lot;
  - identifier of equipment to be used;
  - identifier of physical asset to be used.

A.2.4.4 Relevant data in operations performance model

A.2.4.4.1 Operations performance model

An operations performance is a report on requested operations and is a collection of operations responses.

The operations performance model is shown in Figure A.9.

Missing image: D:/PAYLOAD/Filestore/Workflows and Output/BS-ISO PDF Body Final/2017-05-04 13.23.54/source/fig_A.9.eps.

NOTE Source: IEC 62264-2.

Figure A.9 — Operations performance model

Significant EPE data of an operations performance are included in:

— operations response;

— segment response;

— segment data;

— resource actual.

A.2.4.4.2 Relevant data of operations response

Operations responses present the responses from manufacturing that are associated with an operations request.

Response states that represent examples of EPE data which are included in the operations response are listed below:

— result if the request completed successfully;

— percentage of completion;

— finished status;

— aborted status.

A.2.4.4.3 Relevant data of segment response

A segment response presents Information on a segment of an operations response.

Response states that represent examples of EPE data which are included in the segment response are listed below:

— actual start time of the operations segment or process segment;

— actual end time of the operations segment or process segment.

A.2.4.4.4 Relevant data of segment data

Segment data present other information related to the executed operations.

Examples of EPE data which are included in the segment data are listed below:

— actual quantity of product produced by the operation of the segment;

— actual quality of product produced by the operation of the segment;

— operating conditions in which the operation of the segment was executed, which include:

  — ambient temperature;

  — humidity;

  — atmospheric pressure;

  — voltage of power source.

A.2.4.4.5 Relevant data of resource actual

Resource actual consists of personnel actual, equipment actual, physical asset actual and material actual.

Personnel actual presents an identification of a personnel capability used during a specified segment.

Equipment actual present an identification of an equipment capability used during a specified segment.

Physical asset actual present an identification of a physical asset capability used during a specified segment.

Material actual presents an identification of a material that was used during a specified segment. Material actuals contain definitions of materials that have been consumed, produced, replaced, sampled, or otherwise used in manufacturing.

Examples of EPE data which are included in the resource actual are listed below:

- personnel actual which have been actually used for the segment including:
  - number of persons;
  - man-hours;
- equipment actual which have been actually used for the segment including:
  - load/duty factor;
  - equipment condition after completion;
  - time spent for each operation mode;
- physical asset actual which have been actually used for the segment including:
  - machine operation time;
  - setup time;
- material actual which have been actually used for the segment including:
  - quantity of material;
  - quantity of fuel;
  - input power of electricity;
  - quantity of steam;
  - temperature of coolant;
  - quantity of CO2 emission;
  - quantity of harmful material emitted;
  - quantity of spent consumable;
  - quantity of the waste.

A.2.4.5 Relevant data in operations capability model

A.2.4.5.1 Operations capability model

An operations capability is a collection of information about all resources for operations for selected future and past times. This is made up of information about equipment, physical assets, material, personnel and process segments. Operations capability describes the names, terms, statuses and quantities of which the manufacturing control system has knowledge.

An operations capability presents a collection of personnel capabilities, equipment capabilities, physical asset capabilities, material capabilities and process segment capabilities, for a given slice of time (past, current, or future), and defined as committed, available and unattainable.

The operations capability model is shown in Figure A.10.

Missing image: D:/PAYLOAD/Filestore/Workflows and Output/BS-ISO PDF Body Final/2017-05-04 13.23.54/source/fig_A.10.eps.

NOTE Source: IEC 62264-2.

Figure A.10 — Operations capability model

Operations capability information can be used to translate time based data into environmental evaluation data which can be user to obtain an environmental performance by producing a specified amount of product.

EXAMPLE Machine operation time of the operation performance information can be translated into energy data by using average power consumption in the past of the machine which can be calculated from physical asset capability data.

Operations capability information in the past can be used to obtain an environmental performance during a specified time period.

Significant EPE data of an operations capability include:

— resource capability;

— resource class capability.

A.2.4.5.2 Relevant data of resource capability

Resource capability consists of personnel capability, equipment capability, physical asset capability and material capability.

Resource capability presents capability of the resource with confidence factor.

A personnel capability presents the capability of persons that is committed, available, or unattainable for a defined time.

An equipment capability presents a representation of the capability of equipment that is committed, available, or unattainable for a specific time.

A physical asset capability presents a representation of the capability of a physical asset that is committed, available, or unattainable for a specific time.

A material capability presents a representation of the capability of material that is committed, available, or unattainable for a specific time. Material capability is used for material lots and material sub lots. This includes information that is associated with the functions of material and energy control and product inventory control. The currently available and committed material capability is the inventory.

Examples of EPE data which are included in the resource capability are listed below:

— accumulated capability of a particular resource, which includes:

  — operating time;

  — quantity of the production;

  — energy consumption;

  — quantity of material consumed;

  — quantity of the waste.

— statistically calculated capability of a particular resource, which includes:

  — average energy consumption per unit of time;

  — average quantity of material consumed per unit of time;

  - average quantity of the waste per unit of time;
  - average calorific value of fuel;
  - average value of time spent for each operation mode;
  - average load/duty factor.
- estimated capability in future of a particular resource, which includes:
  - estimated energy consumption per unit of time;
  - estimated quantity of material consumed per unit of time;
  - estimated quantity of the waste per unit of time;
  - estimated calorific value of fuel;
  - estimated value of time spent for each operation mode;
  - estimated load/duty factor.

Physical asset capabilities accumulated since the physical asset's installation, such as total operating time and total quantity of the production, can be used to charge CRR influence onto the environmental performance of a single product or a lot of products.

NOTE The concept of charge of CRR influence on the environmental performance is specified in ISO 20140-1:2013, 6.3.

A.2.4.5.3 Relevant data of resource class capability

Resource capability consists of personnel class capability, equipment class capability, physical asset class capability and material class capability.

Resource class capability presents capability of the resource class with confidence factor.

A personnel class capability presents the capability of personnel class that is committed, available, or unattainable for a defined time.

An equipment class capability presents a representation of the capability of equipment class that is committed, available, or unattainable for a specific time.

A physical asset class capability presents a representation of the capability of a physical asset class that is committed, available, or unattainable for a specific time.

A material class capability presents a representation of the capability of material class that is committed, available, or unattainable for a specific time.

Examples of EPE data which are included in the resource class capability are listed below:

- statistically calculated capability of resource class, which includes:
  - average energy consumption per unit of time;
  - average quantity of material consumed per unit of time;
  - average quantity of the waste per unit of time;
  - average calorific value of fuel;
  - average value of time spent for each operation mode;

  - average load/duty factor;
- estimated capability in future of resource class, which includes:
  - estimated energy consumption per unit of time;
  - estimated quantity of material consumed per unit of time;
  - estimated quantity of the waste per unit of time;
  - estimated calorific value of fuel;
  - estimated value of time spent for each operation mode;
  - estimated load/duty factor.

Annex B
(informative)

Common object model of IEC 62264-2

B.1 Overview

This annex explains the summary of the common object models defined by IEC 62264-2.

The common object models include:

— personnel model;

— role based equipment model;

— physical asset model;

— material model;

— process segment model.

A container for material is presented as role based equipment, physical asset, or both of type storage zone or storage unit.

A tool and software are presented as role based equipment, physical asset, or both.

B.2 Personnel model

The personnel model shown in Figure B.1 contains the information about specific personnel, classes of personnel and qualifications of personnel.

Missing image: D:/PAYLOAD/Filestore/Workflows and Output/BS-ISO PDF Body Final/2017-05-04 13.23.54/source/fig_B.1.eps.

NOTE Source: IEC 62264-2.

Figure B.1 — Personnel model

B.3 Role based equipment model

The role based equipment model shown in Figure B.2 contains the information about specific equipment, the classes of equipment and equipment capability tests.

Missing image: D:/PAYLOAD/Filestore/Workflows and Output/BS-ISO PDF Body Final/2017-05-04 13.23.54/source/fig_B.2.eps.

NOTE Source: IEC 62264-2.

Figure B.2 — Role based equipment model

B.4 Physical asset model

The physical asset model shown in Figure B.3 contains information about the physical piece of equipment, usually managed as a physical asset within the enterprise often utilizing a specific serial number.

Missing image: D:/PAYLOAD/Filestore/Workflows and Output/BS-ISO PDF Body Final/2017-05-04 13.23.54/source/fig_B.3.eps.

NOTE Source: IEC 62264-2.

Figure B.3 — Physical asset model

B.5 Material model

The material model shown in Figure B.4 contains information about the actual materials, material definitions and information about classes of material definitions.

Missing image: D:/PAYLOAD/Filestore/Workflows and Output/BS-ISO PDF Body Final/2017-05-04 13.23.54/source/fig_B.4.eps.

NOTE Source: IEC 62264-2.

Figure B.4 — Material model

B.6 Process segments model

Process segments are the smallest elements of manufacturing activities that are visible to business processes. The process segment model is a hierarchical model, in which multiple levels of abstraction of manufacturing processes may be defined because there can be multiple business processes requiring visibility to manufacturing activities. Figure B.5 presents the process segment model.

Missing image: D:/PAYLOAD/Filestore/Workflows and Output/BS-ISO PDF Body Final/2017-05-04 13.23.54/source/fig_B.5.eps.

NOTE Source: IEC 62264-2.

Figure B.5 — Process segment model

Annex C
(informative)

Structure of a KPI record described by ISO 22400-2

C.1 Attributes of KPIs

C.1.1 General

Data that can be used for EPE can be found stored in KPI records structured in accordance with ISO 22400-1 and ISO 22400-2. The KPI record associates relevant data in its structure with:

— a description of the content of the KPI record;

— context information.

Explanations of a not all inclusive list of KPI record attributes are provided in the remaining subclauses of Clause C.1.

C.1.2 Name / title of indicator

Expression or designation of the KPI.

C.1.3 Application

A brief description of the benefits provided by the KPI, including its use and consequences in control applications.

C.1.4 Timing

A KPI can be calculated either in real-time (i.e. after each new data acquisition event), on demand (i.e. after a specific data selection request), or periodically (i.e. done at a certain interval, e.g. one time per day).

C.1.5 Formula

The mathematical formula of the KPI based on its elements.

C.1.6 Unit/dimension

The basic unit or dimension in which the KPI is expressed.

C.1.7 Rating

The upper and lower logical limits of the KPI and the trend indicating improvement.

C.1.8 Analysis / drill down

Description of related KPI elements to drill down and analyse the root cause of KPI results.

C.1.9 User group:

Description of the user groups that utilize the KPI.

C.1.10 Effect model

An assessment method used to find root causes of KPI value change and how it relates to other elements and KPIs

C.1.11 Manufacturing type

The type of manufacturing (continuous, batch, discrete) for which the KPI can be used.

C.2 Time model for production units

C.2.1 General

ISO 22400 provides a model that applies to time considerations for the use of production units. Figure C.1 shows the relationship of the defined periods. In Figure C.1, the difference between time elements constitutes a specific loss.

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Figure C.1 — Time lines for production units

There is a different time model based on partitioning of the total time such as amount of loss time for operation. KPIs defined in ISO 22400-2 are generated using this type of time model and are different from the KPIs defined in Clause 8.

C.2.2 Time model for manufacturing order

This time model is valid for executing the order. Figure C.2 shows the manufacturing order processing time line consisting of multiple occurrences of production unit time lines (see Figure C.1). The production unit time lines for a production order may be carried out in separate operations at several production units.

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Figure C.2 — Time lines for production order processing

C.2.3 Time model for employment

The model presented in Figure C.3 applies to time considerations for the employment of staff.

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Figure C.3 — Time lines for employment

Annex D
(informative)

Use case: Measuring the itemized and the total actual energy consumption

D.1 Overview

Before calculating the energy efficiency, the energy consumption needs to be known.

The energy consumption is being measured commonly by a variety of means and multiple instances of the same parameter can be identified. For example, a meter can measure the energy consumption of an area containing ten pieces of equipment. At same time, one can calculate the energy consumption of the ten pieces of equipment by measuring with a sub-meter the energy consumption of each of the ten pieces of equipment and thereafter summing the ten individual energy consumption values. Knowing the value of the area energy consumption is important because that value is compared to the grid's capability of providing the capacity required by the area. It is important to know the total energy consumption of every piece of equipment in order to assess what energy load can be shed or to compare the energy performance among similar pieces of equipment. The benefit of measuring the energy consumption by using both measuring methods is that the balance of the energy consumed can reveal the accuracy of the energy consumption measurements.

The following use case describes the actors, their actions and the results of the actions in the process of measuring energy consumption in an automated plant that has equipment and drives enabled to exchange energy data models (see Clause A.1). The actual and external energy data measurements are placed in context by using reference data contained in IEC 62264 information data models (see Clause A.2).

D.2 Use case

D.2.1 General

Actors: Utility meter, sub-metering devices, areas and equipment, historian, energy display, energy engineer, MES system, engineering cost system.

D.2.2 Plant wide measurement

Action: A set of sub-metering devices measures total energy over a time period to validate utility billing through aggregated shadow metering.

Result: The energy bill is audited.

D.2.3 Validate plant wide

Action: A set of sub-metering devices measures total energy over a time period to validate utility billing through aggregated shadow metering.

Result: The energy bill is audited (the energy balance is performed to prevent aggregation and calculation error build-up).

D.2.4 Measure energy consumption itemized per operation, where possible

Action: Per area and per equipment a set of sub-metering devices measures itemized energy consumption over a time period through aggregated shadow metering. The energy measurement is itemized per each operations step.

Result: Actual itemized energy usage for each area and equipment is now known. The energy balance is audited (the energy balance is performed to prevent aggregation and calculation error build-up).

D.2.5 Measure per area and equipment and derive the total and total itemized energy consumption

Action: Per area and per equipment a set of sub-metering devices measures total and total itemized energy over a time period through aggregated shadow metering. Derive total and the total itemized energy consumption using the actual total and itemized energy usage per operation and the IEC 62264 information models containing reference data. The total itemized energy consumption represents the total energy measurement is itemized per each operations step.

Result: The actual total and the total itemized energy consumption for each area and equipment is now known. The energy balance is audited (the energy balance is performed to prevent aggregation and calculation error build-up).

D.2.6 Levels 1 and 2 energy management and optimization

Action: Level 2 devices are interfacing with other Level 2 devices and Level 1 instruments towards managing the load shedding and sleep and break modes of Level 1 assets within limits prescribed by Level 3 controls and reference data. Energy data objects are used for communication among devices and levels and may be used for deriving granular energy data based on other measured values and operating status, etc. Per area and per equipment a set of sub-metering devices measures total and total itemized energy over a time period through aggregated shadow metering.

Result: Actual total and total itemized energy consumption for each equipment is now optimized and for each area and equipment is now known. It is possible now to evaluate the energy efficiency through automation at Levels 1 and 2 by comparing the managed and optimized actual total and actual total itemized energy consumption to the reference data contained in the IEC 62264 information models.

D.2.7 Calculate energy consumption per batch and per part

Action: Groups of production equipment measure total and itemized energy over a time period corresponding to a recipe or production step enabling per batch and per part energy measurement for engineering costing and optimization.

Result: The energy bill is reduced (the energy balance is performed to prevent aggregation and calculation error build-up). The energy consumption per batch and per part is now known.

D.2.8 Energy management and optimization at plant level

Action: Groups of production equipment measure total and itemized energy over a time period corresponding to a recipe or production step enabling per batch and per part energy measurement for engineering costing and optimization.

Result: The energy bill is reduced.

Annex E
(informative)

Material upstream data — Regional regulations and international standards

E.1 Overview

Given the interdependency on a global scale among suppliers, manufacturers and customers, governments before international standard organizations have taken the initiative to regulate nationally and across wider regions means to monitor and control use of raw substances and substances in articles

Material safety data sheets are documents that contain detailed information about each substances present in a product, in a manufacturing plant, or in a transportation unit.

European Union has chosen to develop a comprehensive list of materials that manufacturers should use in order to assess the environmental and health impact of their product.

E.2 Material safety data sheets

Many countries have legislation that requires chemical producers or suppliers to prepare material safety data sheets (MSDS). In Canada this legislation is generally called Workplace Hazardous Materials Information System (WHMIS). Safety data sheets include information about the properties of the substance (or mixture), its hazards and instructions for handling, disposal and transport and also first-aid, fire-fighting and exposure control measures. This information can be found in the main body of the safety data sheet or in the annexed exposure scenarios (where applicable). The requirements for the compilation of the safety data sheets in Europe are specified in Annex II of REACH.

The Globally Harmonized System of Classification and Labelling of Chemicals (GHS) is an internationally agreed-upon system, created by the United Nations. GHS is a globally harmonized hazard classification and compatible labelling system, including material safety data sheets and easily understandable symbols.

The GHS safety data sheet (SDS) provides comprehensive information about the chemical substances that allows employers and workers to obtain concise, relevant and accurate information that can be put in perspective with regard to the hazards, uses and risk management of the chemical substance in the workplace. The SDS contains 16 sections:

a) identification;

b) hazard identification;

c) composition/information on ingredients;

d) first-aid measures;

e) fire-fighting measures;

f) accidental release measures;

g) handling and storage;

h) exposure control/personal protection;

i) physical and chemical properties;

j) stability and reactivity;

k) toxicological information;

l) ecological information;

m) disposal considerations;

n) transport information;

o) regulatory information;

p) other information.

E.3 Material declarations

Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) is a European Union Regulation of 18 December 2006. REACH addresses the production and use of chemical substances, and their potential impacts on both human health and the environment. The European Chemical Agency (ECHA) maintains the list of substances published under REACH.

A number of countries outside of the European Union have regulations similar to REACH or are in the process of adopting a regulatory framework to approach a globalized system of chemicals registration under the Globally Harmonized System of Classification and Labelling of Chemicals (GHS).

REACH requests for manufacturers to report information on:

— basic physical and chemical properties:
  — odour;
  — pH;
  — initial boiling point and boiling range;
  — flash point;
  — evaporation rate;
  — flammability (solid, gas);
  — relative density;
  — solubility;
  — auto-ignition temperature;
  — decomposition temperature;
  — explosive properties;
  — oxidising properties;
— stability and reactivity:
  — reactivity;
  — chemical stability;
  — possibility of hazardous reactions;
  — conditions to avoid;

  - incompatible materials;
  - hazardous decomposition products;
- toxicological information:
  - information on toxicological effects;
- ecological information:
  - toxicity;
  - persistence and degradability;
  - bio accumulative potential;
  - mobility in soil;
  - results of PBT and vPvB assessment;
- disposal considerations:
  - waste treatment methods.

Materials enter the boundary of the manufacturing system under EPE not only as substances (propane, acetone, lead, copper, etc.) but also as components and supplies used in manufacturing. Examples of components and supplies are: bolts, drill bits, gloves, packaging, cables, transducers, printer paper. The suppliers of those components and supplies can provide additional environmental condition data besides the information contained in material declarations as the GHS safety data sheets. The information provided by supplier can contain information about the environmental cumulative effect of the materials and energy used for building the manufacturing system, the manufacturing process (i.e. see also Annex F for emissions) as well as for the entire life cycle of the component or resource supply.

E.4 Environmental profile declarations

Companies can choose to provide voluntary eco-declarations that contain environmental characteristic data to be used for the EPE of the manufacturing system that uses the respective materials/products. The voluntary eco-declarations are not standardized. A voluntary eco-declaration can provide, for example, the following information, split into legal and market requirements on:

- hazardous substances content (e.g. cadmium, lead, mercury);
- batteries (e.g. “The battery cell does NOT contain lead, cadmium and mercury”);
- safety and EMC;
- consumable materials;
- material and substance requirements (e.g. electrical cable insulation materials of power cables are PVC free);
- packaging materials (e.g. “the product packaging does NOT contain ozone depleting substances as listed in the Montreal protocol”);
- treatment information;
- environmental conscious design (such as disassembly, recycling, product lifetime);
- power consumption (e.g. sleep mode, 0,7 W measured according to ENERGY STAR Monitor v4.1);
- emissions (e.g. electric field ELF ≤ 10V/m, magnetic field ELF ≤ 200nT);

— disassembly and recycling (e.g. "Mechanical plastics parts, heavier than 25g have material codes in accordance with ISO 11469, ISO 14040 and ISO 14044 to facilitate plastics recycling");

— ergonomics;

— documentation;

— environmental certifications (e.g. ISO 14001).

Manufacturers can also provide product environmental profiles (PEPs). Life cycle assessment can be performed and the product environmental impacts evaluated on the following life cycle phases: materials and manufacturing, distribution, installation, use and end of life. The following is a list commonly presented in PEPs.

— Raw material depletion (RMD) This indicator quantifies the consumption of raw materials during the life cycle of the product. It is expressed as the fraction of natural resources that disappear each year, with respect to all the annual reserves of the material.

— Energy depletion (ED) This indicator gives the quantity of energy consumed, whether it be from fossil, hydroelectric, nuclear or other sources. This indicator takes into account the energy from the material produced during combustion. It is expressed in MJ.

— Water depletion (WD) This indicator calculates the volume of water consumed, including drinking water and water from industrial sources. It is expressed in dm^3.

— Global warming (GW) The global warming of the planet is the result of the increase in the greenhouse effect due to the sunlight reflected by the earth's surface being absorbed by certain gases known as "greenhouse-effect" gases. The effect is quantified in gram equivalent of CO2.

— Ozone depletion (OD) This indicator defines the contribution to the phenomenon of the disappearance of the stratospheric ozone layer due to the emission of certain specific gases. The effect is expressed in gram equivalent of CFC-11.

— Air toxicity (AT) This indicator represents the air toxicity in a human environment. It takes into account the usually accepted concentrations for several gases in the air and the quantity of gas released over the life cycle. The indication given corresponds to the air volume needed to dilute these gases down to acceptable concentrations.

— Photochemical ozone creation (POC) This indicator quantifies the contribution to the "smog" phenomenon (the photochemical oxidation of certain gases which generates ozone) and is expressed in gram equivalent of ethylene (C2H4).

— Air acidification (AA) The acid substances present in the atmosphere are carried by rain. A high Level of acidity in the rain can cause damage to forests. The contribution of acidification is calculated using the acidification potentials of the substances concerned and is expressed in mode equivalent of H+.

— Water toxicity (WT) This indicator represents the water toxicity. It takes into account the usually accepted concentrations for several substances in water and the quantity of substances released over the life cycle. The indication given corresponds to the water volume needed to dilute these substances down to acceptable concentrations.

— Hazardous waste production (HWP) This indicator calculates the quantity of specially treated waste created during all the life cycle phases (manufacturing, distribution and utilization). For example, industrial waste in the manufacturing phase is expressed in kg.

Annex F
(informative)

Greenhouse gas emission along the life cycle

Table F.1 extracted from the WNA Report Comparison of Life cycle Greenhouse Gas Emissions of Various Electricity Generation Sources compares the greenhouse gas emission along the entire life cycle of various energy sources.

Table F1 — Summary of Life cycle GHG Emission Intensity

Technology	Mean	Low	High
	tonnes CO2e/GWh		
Lignite	1 054	790	1 372
Coal	888	756	1 310
Oil	733	547	935
Natural gas	499	362	891
Solar PV	85	12	731
Biomass	45	10	101
Nuclear	29	2	130
Hydroelectric	26	2	237
Wind	26	6	124

Annex G
(informative)

Commonly used energy data models attributes

While there is no international standard for energy data models, there are consortia standards that describe energy models largely used in industrial automation (e.g. ODVA and SERCOS). The structure and syntax of the data models described in consortia standards are different among each other but all of them have a common framework because each data model is designed to support the same task and that includes:

a) describing the energy usage profile of a machine, work unit, or work area;

b) exchanging parameter based commands for mode changes.

The data models can contain the following attributes:

— power: real, reactive, apparent, consumed;

— real energy: consumed, generated, net, required;

— line frequency;

— current, L-L voltage, L-N voltage: instantaneous, averaged, percent unbalance;

— current, voltage, Ampere- hours, power, energy;

— phase rotation;

— resource type;

— conversion constant to Kilowatt-hours;

— engineering unit description;

— activity information (describing the current status of components);

— energy transfer rate (averaged power);

— energy flow rate time period.

An advantage of using the energy data models is that, while the energy source can have a multitude of types, the power consumption measured in kW. The data models report the energy data in units specific to electric energy while indicating also the effective resource type and the conversion constant to kilowatt-hours.

The resource types attribute in energy data models can include:

— vendor specific;

— not specified;

— electricity;

— natural gas;

— compressed air;

— steam, saturated;

— steam, superheated;

— chilled water;

— hot water;

— biogas;

— coal;

— resource-, device-, or manufacturer specific energy resource.

Assets can consume energy in a variety of operating conditions that can be resource, device, or manufacturer specific, including:

— short breaks (scheduled);

— long breaks (scheduled);

— unscheduled breaks;

— partial machine operation;

— partial load operation.

Consortia based standards for energy data models identify and predefine a series of modes commonly encountered in automation, including:

— power off;

— initializing (start);

— ready for power;

— ready to operate;

— operational;

— pausing/sleeping;

— resuming;

— owned/not owned.

The terminology used to describe the modes listed above varies among the consortia standards. In addition to describing the energy status of the assets in the predefined modes listed above, the energy data models enable the definition of user specific modes.

The energy data models can contain parameter based commands for mode changes. The commands for mode changes could be due to a variety of factors, including energy demand changes or changes in the production schedule that affect the machine load. The commands for changing the operating mode are not in the scope of this document, but the capability of widely used energy data models to transfer mode change commands reflects the fact that the energy management and energy data reporting can be delegated downward in the functional hierarchy to the asset capable to communicate using energy data models. Accordingly, requests for reporting of energy data needed for EPE can be sent directly to assets capable to communicate by using energy data models.

The standardized semantics provided by the data model oriented approach to the energy data allows for scalability in implementation of the energy data model across all levels of the functional hierarchy. Assets using a standardized semantics energy data objects may support advanced functions for control of energy, aggregation and reporting of energy information.

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