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

Part 2: Environmental performance evaluation process

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

Partie 2: Processus d'évaluation de la performance environnementale

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Foreword

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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).

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For an explanation of 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 www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 184, *Automation systems and integration*, Subcommittee SC 5, *Interoperability, integration and architectures of enterprise systems and automation applications*.

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

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

ISO 20140 specifies a method for evaluating the energy efficiency and other factors of a manufacturing system that influence the environment, e.g. energy consumption, waste and release.

ISO 20140 is applicable to manufacturing systems for discrete, batch, and continuous manufacturing.

ISO 20140 focuses on manufacturing systems that have a hierarchical structure.

ISO 20140 can be used for:

— benchmarking of environmental performance against a generic reference manufacturing system or comparing between different manufacturing systems;

— alternative studies for improving environmental performance;

— setting targets of environmental performance improvement;

— visualizing the environmental performance of a manufacturing system under operation.

Expected users of ISO 20140 are:

a) managers who are responsible for environmental conditions of a manufacturing system;

b) engineers who design manufacturing processes for products;

c) engineers who design a manufacturing system;

d) engineers and foremen who are responsible for manufacturing products.

This document specifies a process for environmental performance evaluation of activities executed by a manufacturing system based on the general principles described in ISO 20140-1. The process uses environmental performance evaluation data based on ISO 20140-5.

This document does not specify any evaluation process specific to particular implementations of manufacturing systems.

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

Part 2:
Environmental performance evaluation process

1 Scope

This document specifies a process for environmental performance evaluation of activities executed by a manufacturing system based on the general principles described in ISO 20140-1. The process uses environmental performance evaluation data based on ISO 20140-5.

This document does not specify any evaluation process specific to particular implementations of manufacturing systems.

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, *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 https://www.iso.org/obp

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

3.1
aggregated EPE data
numerical representation of *environmental influence* (3.3) caused by a manufacturing process in a given type of environmental influence and in a given mode

3.2
energy efficiency
ratio or other quantitative relationship between an output of performance, service, goods or energy, and an input of energy

[SOURCE: ISO 50001:2011, 3.8, modified — Example and Note to entry have been deleted.]

3.3
environmental influence
result of manufacturing process that can cause environmental impacts and that is considered throughout the life cycle of the manufacturing system associated with the process

Note 1 to entry: Environmental influence, such as energy consumed and CO_2 emitted, can cause environmental impacts, such as global warming and sea level rise.

EXAMPLE Amount of electric energy consumed; amount of CO_2 emitted; amount of hazardous substance discharged.

3.4
environmental KPI
key performance indicator (3.7) that represents *environmental performance* (3.5)

3.5
environmental performance
measurable results related to environmental aspects

[SOURCE: ISO 14045:2012, 3.5]

3.6
environmental performance evaluation data
EPE data
data that is used to evaluate the *environmental performance* (3.5)

[SOURCE: ISO 20140-5:2017, 3.6, modified.]

3.7
key performance indicator
KPI
quantifiable level of achieving a critical objective

Note 1 to entry: The KPIs are derived directly from, or through an aggregation function of, physical measurements, data and/or other KPIs.

[SOURCE: ISO 22400-1:2014, 2.1.5]

3.8
system value
worth or desirability ascribed to a manufacturing process

4 Framework of environmental performance evaluation process

The environmental performance evaluation process shall comprise the sub-processes of developing a specification of environmental performance evaluation, specifying the environmental KPIs, calculating the environmental KPIs, and reporting the evaluation results as illustrated in Figure 1. This document specifies the requirements for these sub-processes.

a) Developing specification of environmental performance evaluation

   A specification of environmental performance evaluation is developed in this process. This specification includes requirements for aggregated EPE data.

b) Specifying environmental KPIs

   Environmental KPIs are specified by a formula with the necessary conditions, according to the specification of environmental performance evaluation specified by the process described in a) above.

c) Calculating the environmental KPIs

Values of each environmental KPI are calculated according to the environmental KPI specification specified by the process described in b) above.

An aggregated EPE data, which represents the environmental influence, is provided by the aggregation process for each KPI.

A system value is obtained for each KPI according to the specification of environmental performance evaluation specified by the process described in a) above.

NOTE The actual capture and calculation of system value for use in calculating each KPI is outside the scope of ISO 20140.

d) Reporting

The results of the environmental performance evaluation, such as environmental KPI specification and its calculated values, are reported with respect to the objectives of the environmental performance evaluation.

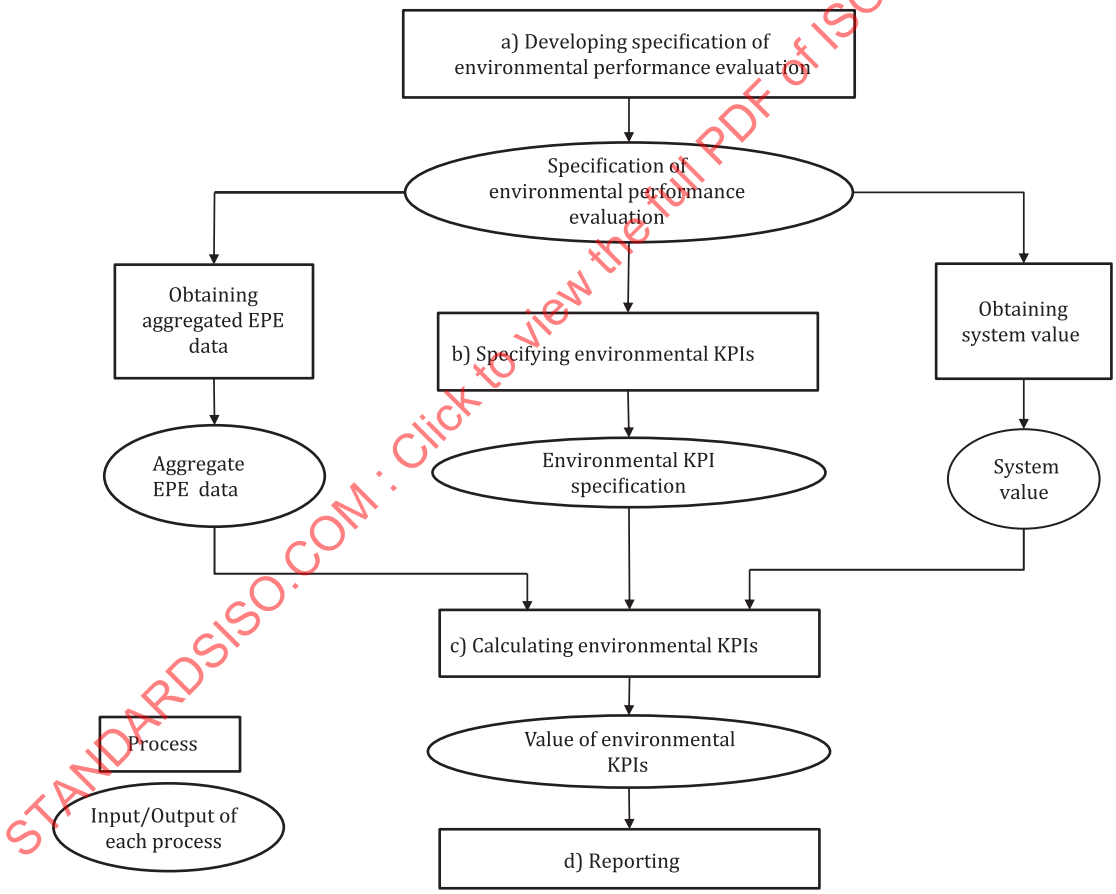

Figure 1 — Environmental performance evaluation process

5 Sub-processes of the environmental performance evaluation

5.1 Developing a specification of environmental performance evaluation

5.1.1 General

A specification of environmental performance evaluation may be dedicated to a particular manufacturing system for determining the effectiveness of improvement of environmental performance. It may also be specified for multiple individual manufacturing systems in order to compare them as described in Annex A.

Specifications of environmental performance evaluation shall specify the following items:

a) objective of the evaluation;

b) scope of the evaluation;

c) requirements for aggregated EPE data.

5.1.2 Objective of environmental performance evaluation

The objective of environmental performance evaluation shall clearly describe the reason why the evaluation is performed and which types of environmental influence are taken into account.

EXAMPLE 1 An objective is visualization and improvement of energy efficiency of a given manufacturing system under a particular production plan during a given period of time.

EXAMPLE 2 A company has two production facilities with different processes and performance criteria for the same type of car product. The company is planning to construct a new facility, and wants to select one of the existing facilities as a base design.

EXAMPLE 3 An objective is to evaluate the effect of replacing equipment for a particular step of a manufacturing process by comparing the new performance with the performance before the modification.

EXAMPLE 4 An objective is to calculate the advantageous effects of an improvement measure, such as reducing power during idle states, reducing idle time and coordinated scheduling of production.

5.1.3 Scope of environmental performance evaluation

5.1.3.1 General

The scope of environmental performance evaluation shall be appropriately determined so that environmental KPIs can be specified to satisfy the objectives.

5.1.3.2 Target manufacturing process to be evaluated

The scope shall include the description of the target manufacturing process to be evaluated.

NOTE A target manufacturing process can be defined by a combination of a physical boundary and a time boundary or by a set of values characterizing the manufacturing process.

EXAMPLE If a manufacturing process is a batch process, an evaluation period is synchronized with a batch cycle of a process.

5.1.3.3 Level of detail of environmental performance evaluation

The scope should also include the decision regarding the level of detail of data for environmental performance evaluation according to the objective.

NOTE The level of detail could differ depending on the objective of the evaluation. This could, for example, include frequency of measurements (e.g. update every day, year, or month), cut-off intervals for data values and resolution of measurement.

5.1.4 Requirements for aggregated EPE data

The requirements for aggregated EPE data shall be specified according to the specification of environmental performance evaluation.

NOTE The requirements are used in the aggregation process. ISO 20140-3 specifies an aggregation process that provides aggregated EPE data in accordance with a given environmental performance evaluation specification by this document.

5.2 Specifying environmental KPIs

5.2.1 General

One or more environmental KPIs of the target manufacturing process shall be specified by environmental KPI specifications.

Environmental KPI specifications should include:

a) objectives;

b) types of the environmental influence considered;

c) formulae to evaluate the environmental KPI;

d) constraints.

Environmental performance of manufacturing systems may be expressed by multiple KPIs. See Figure A.2.

5.2.2 Environmental KPIs

5.2.2.1 General

Since different manufacturing processes can produce different types of products, values of environmental influence of different manufacturing processes cannot be compared directly. In order to normalize the values of environmental influence, the concept of system value is used to determine environmental KPIs.

NOTE Some KPIs defined by ISO 22400-2, such as comprehensive energy consumption, production loss ratio and storage and transportation loss ratio, can be an environmental KPI and can be used in formulae of environmental KPI specifications.

A general formula of an environmental KPI is expressed as a function F of system value and environmental influence, which can be represented by aggregated EPE data. See Formula (1).

$$P_E = F(v_S, i_E) \quad (1)$$

where

P_E is the environmental KPI;

v_S is the system value generated by the target manufacturing process;

i_E is the environmental influence caused by the target manufacturing process.

Function F is defined depending on objectives of the evaluation.

5.2.2.2 Efficiency based formulae

Environmental efficiency, which is a type of environmental KPI, can be expressed by a ratio between a system value generated and environmental influence caused by the target manufacturing process given as in Formula (2).

$$e_E = \frac{v_S}{i_E} \quad (2)$$

where e_E is the environmental efficiency of the target manufacturing process.

EXAMPLE 1 Energy efficiency, defined in ISO 50001, is a type of environmental efficiency specific to energy.

EXAMPLE 2 Finished goods ratio, defined in ISO 22400-2, is a type of environmental efficiency specific to material.

5.2.2.3 Derived coefficient

The specific environmental coefficient is given as in Formula (3).

$$c_E = \frac{i_E}{v_S} \quad (3)$$

where c_E is the specific environmental coefficient of the target manufacturing process.

EXAMPLE 1 Comprehensive energy consumption, defined in ISO 22400-2, is a type of specific environmental coefficient specific to energy.

EXAMPLE 2 Scrap ratio, defined in ISO 22400-2, is a type of specific environmental coefficient specific to waste.

5.3 Calculating environmental KPIs

An environmental KPI shall be calculated according to the environmental KPI specification. The environmental influence is provided by the aggregation process as an aggregated EPE data according to the requirements for aggregated EPE data. The system value is obtained according to the specification of environmental performance evaluation in individual cases. An example of environmental performance evaluation processes including sub-process of calculating an environmental KPI is described in Annex B.

The calculation of an environmental KPI may be repetitively executed for ordinary monitoring of manufacturing processes, or may be executed for evaluating the environmental performance of manufacturing processes after improvement of a manufacturing system at a particular timing. In other cases, the calculation may be also executed for multiple manufacturing systems to compare their environmental performance.

5.4 Reporting

The results of the environmental performance evaluation should be reported to the intended audience. The report should include the following elements:

a) specification of environmental performance evaluation;

b) environmental KPI specifications;

c) aggregated EPE data used for calculating values of environmental KPIs;

d) methods for calculation of environmental KPIs;

e) values of environmental KPIs calculated;

f) assumption and limitation of calculation.

6 System value

6.1 General

System values are used to define environmental KPIs.

NOTE 1 The system value conforms to the principle for specifying product system values, as described in ISO 14045:2012, 5.2.7.

There are different types for specifying system values, depending on the objective and scope, e.g. as described in 6.2, 6.3 and 6.4.

NOTE 2 The system value produced by the process with one input and one output can be categorized into any type.

6.2 System value based on the output from the process

This type of system value is applicable to the process with multiple inputs and one significant output. The system value is specified based on the significant output from the target manufacturing process.

EXAMPLE The number of products produced by a manufacturing system can be a system value.

6.3 System value based on the input to the process

This type of system value is applicable to the process with one significant input and multiple outputs. The system value is specified based on the significant input to the target manufacturing process.

EXAMPLE The system value of an oil refinery can be calculated corresponding to the amount of crude oil as an input to the process.

6.4 System value based on the service provided by the process

This type of system value is applicable to the process with multiple inputs and multiple outputs. The system value is considered with respect to the target manufacturing process. The amount of service of the manufacturing process during a unit of time may be a system value.

EXAMPLE A painting process painting multiple sizes of works.

Annex A
(informative)

Environmental performance evaluation of manufacturing systems

A.1 Comparing environmental performance of different manufacturing systems

Figure A.1 shows use cases of the environmental performance evaluation process. An environmental performance evaluation specification is developed and applied to multiple different manufacturing processes. The target manufacturing processes are executed by different manufacturing systems. Every environmental KPI of the manufacturing process executed by each manufacturing system is obtained according to the same specification of environmental performance evaluation. Therefore, values of environmental KPI for each manufacturing system can be compared each other.

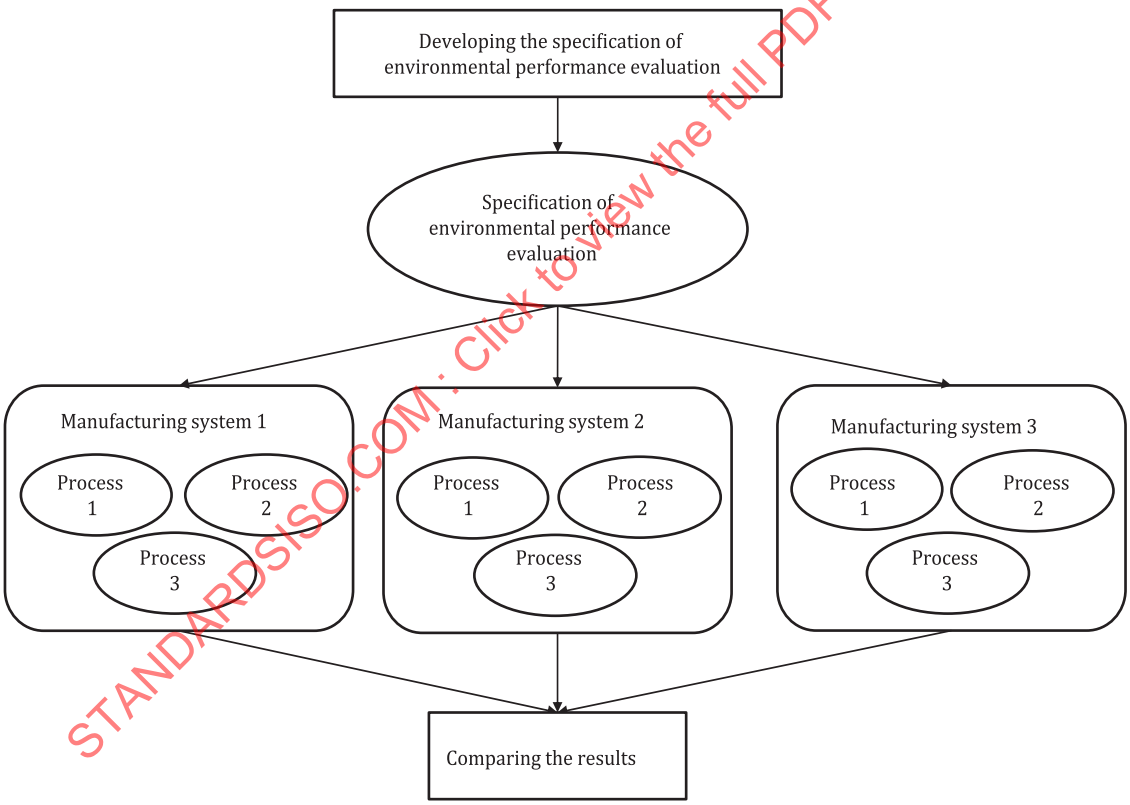

Figure A.1 — Comparing environmental performance of different manufacturing systems

A.2 Evaluating a KPI that represents multiple types of environmental influence

A manufacturing process can have different environmental aspects associated with different types of environmental influence. For example, a manufacturing process can consume energy and discharge a hazardous substance, illustrating two types of environmental influence. In this case, two different KPIs, energy efficiency and amount of hazardous substance per unit of production volume, could be used to evaluate the two types of environmental influence. The value of each environmental KPI is calculated according to the environmental KPI specification. In order to evaluate overall environmental performance taking into account multiple types of environmental influence, a high level KPI can merge multiple KPIs into a single result. This is executed in the reporting process. Since dimensions and units of measure of KPIs can be different from each other, a technique such as a weighted calculation might be required.

Figure A.2 gives an example of evaluating a KPI that represents multiple types of environmental influence.

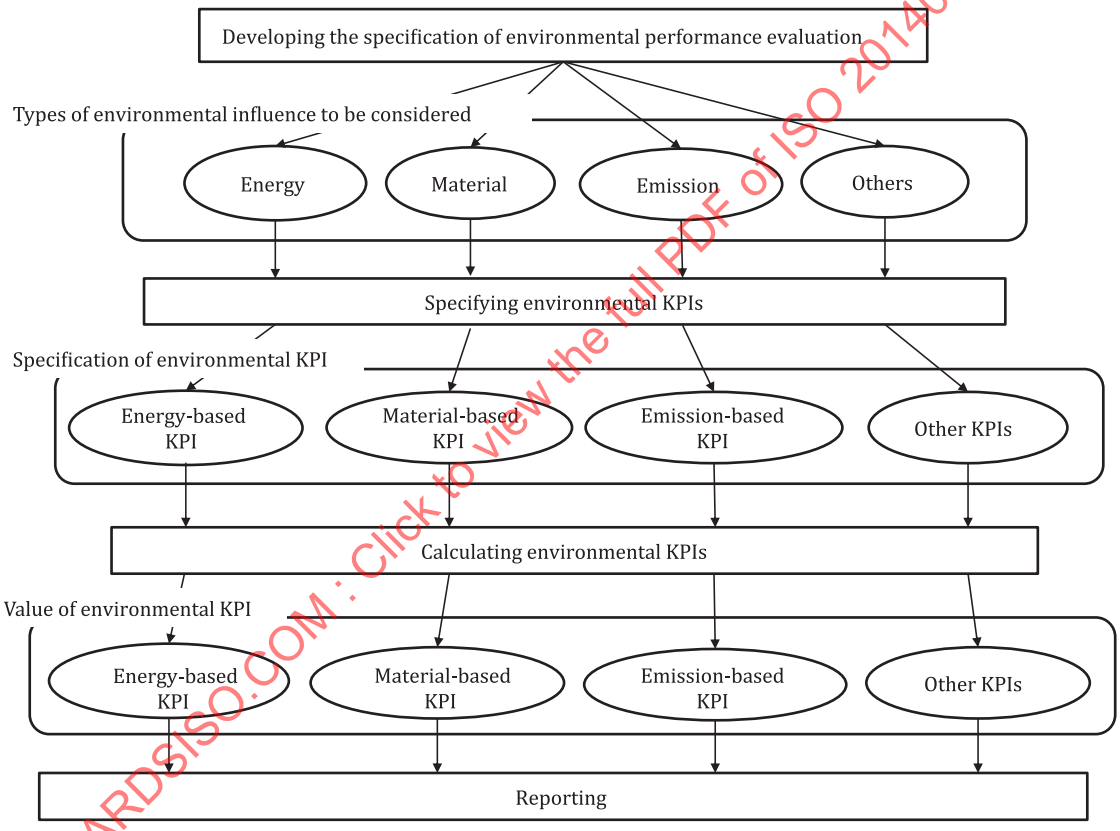

Figure A.2 — Example of evaluating a KPI that represents multiple types of environmental influence

Annex B
(informative)

Example of environmental performance evaluation

B.1 Objective of environmental performance evaluation

a) Estimation of energy consumption to produce a product.

b) Identification of improvement approach to enhance energy efficiency of a manufacturing system.

B.2 Scope of environmental performance evaluation

a) Environmental performance to be evaluated:

— Energy efficiency.

b) Target manufacturing process to be evaluated:

— Physical boundary is a machine tool including a pump for coolant; air-conditioner commonly used for keeping ambient condition is excluded.

— Time boundary is period of manufacturing process including stand-by.

c) System value:

— 20 pieces of automobile parts.

B.3 Requirements for aggregated EPE data

In order to calculate energy efficiency, total amount of energy consumption during each status of a machine tool such as stand-by and in-process is respectively necessary:

a) total amount of energy consumption during stand-by [kWh];

b) total amount of energy consumption during in-process [kWh].

B.4 Environmental KPI

a) Energy consumption rate = [total energy consumption]/[number of manufactured products]

b) Energy efficiency of manufacturing process = [energy consumption while the status of a machine tool is in-process]/[total energy consumption]

B.5 Calculating environmental KPI

It is assumed that the data of energy consumption of a machine tool is obtained as shown in Figure B.1. In this case, the energy consumption rate and the energy efficiency of the manufacturing process is calculated as follows:

a) Energy consumption rate = [energy consumption A+ energy consumption B]/[20 pieces of products] = 0,15 kWh/unit