
**Earth-moving machinery —
Sustainability — Terminology,
sustainability factors and reporting**

*Engins de terrassement — Durabilité — Terminologie, facteurs de
durabilité et rapport*

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Published in Switzerland

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 10987 was prepared by Technical Committee ISO/TC 127, *Earth-moving machinery*.

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Introduction

Sustainability has become a global concern for all products, including earth-moving machines. Customers buying the machines are requesting information that can be used to promote sustainability for their work projects. With the increased interest in the subject, many organizations are preparing sustainability guidelines and many manufacturers of earth-moving machinery are beginning to provide general information. This International Standard is the first on sustainability for earth-moving machines: a beginning in the definition of the sustainability information that customers can use for their projects.

Sustainability covers a wide range of areas related to social, environmental and economic considerations for the development, manufacturing, useful life and end-of-life phases for earth-moving machines. This International Standard covers

- general sustainability principles,
- terminology, and
- sustainability factors and formats for summarizing sustainability information.

Further International Standards on sustainability for earth-moving machines are planned to cover other areas, including test methods, performance criteria and means of compliance.

Potential sustainability issues relevant to earth-moving machines include the following:

- greenhouse gas/carbon emissions;
- energy use;
- general processes during design, manufacture, machine life, end-of-life;
- management system for sustainability communication, training, development;
- training for machine use — worksite managers, operators, maintenance;
- social aspect: health, safety, comfort, ergonomics;
- noise and vibration (operator);
- impact on environment — noise, dust, ground disturbance, noise and vibration (spectator);
- manufacturing and remanufacturing;
- dismantling and recycling;
- emissions, after treatment;
- bio fuels and oils;
- hazardous substances.

Other existing International Standards on earth-moving machines, while not dealing with sustainability itself, address many of the areas covered in this International Standard:

- general machine safety, ISO 20474 and the safety standards it references;
- noise, ISO 6393, ISO 6394, ISO 6395, ISO 6396;
- ergonomics, ISO 3411 (operator space), ISO 6682 and 10968 (controls), ISO 11112 (seats), and others;
- recyclability, ISO 16714;
- vibration, ISO 7096 and ISO/TR 25398;

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- electromagnetic compatibility, ISO 13766;
- training, ISO 7130 and ISO 8152.

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Earth-moving machinery — Sustainability — Terminology, sustainability factors and reporting

1 Scope

This International Standard sets out general principles for addressing the sustainability of the earth-moving machinery defined in ISO 6165. It establishes a sustainability terminology, identifies significant sustainability factors for earth-moving machines and provides an example of a reporting format for sustainability information.

This International Standard is applicable to the development and manufacturing processes and the useful life and end-of-life of earth-moving machines.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 5349-2, *Mechanical vibration — Measurement and evaluation of human exposure to hand-transmitted vibration — Part 2: Practical guidance for measurement at the workplace*

ISO 6165, *Earth-moving machinery — Basic types — Identification and terms and definitions*

ISO 6395, *Earth-moving machinery — Determination of sound power level — Dynamic test conditions*

ISO 6396, *Earth-moving machinery — Determination of emission sound pressure level at operator's position — Dynamic test conditions*

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

ISO 14044, *Environmental management — Life cycle assessment — Requirements and Guidelines*

ISO 16714, *Earth-moving machinery — Recyclability and recoverability — Terminology and calculation method*

ISO 20474 (all parts), *Earth-moving machinery — Safety*

ISO/TR 25398, *Earth-moving machinery — Guidelines for assessment of exposure to whole-body vibration of ride-on machines — Use of harmonized data measured by international institutes, organizations and manufacturers*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1

sustainability

balance between social, environmental and economic needs that optimizes the current quality of life without sacrificing future quality of life

3.2

machine load factor

parameter used to indicate how a machine is working relative to the capability of the machine, defined by the manufacturer for different types of machine applications, generally using three load factor categories — low, medium and high

Note 1 to entry: It is usually expressed as a percentage of maximum machine capability.

3.3

machine productivity

work performed by a machine as a function of time

3.4

remanufacturing

reconditioning process for a component to return it to a level making it suitable for re-use

3.5

re-use

any operation by which component parts of end-of-life machines are used for the same purpose for which they were conceived

[SOURCE: ISO 16714]

3.6

life cycle assessment

compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle

3.7

end-of-life machine

machine that has completed its useful life and is taken out of service for disposal

[SOURCE: ISO 16714]

3.8

recycling

reprocessing in a production process of the waste materials for the original purpose or for other purposes, excluding processing as a means of generating energy

[SOURCE: ISO 16714]

3.9

recyclability

ability of component parts, materials or both that can be diverted from an end-of-life stream to be recycled

[SOURCE: ISO 16714]

3.10

useful life

period in which a machine is economical to continue to use

Note 1 to entry: The determination of useful life can vary depending on user needs.

3.11

energy efficiency

effectiveness of converting energy into useful work

3.12**greenhouse gas****GHG**

gaseous constituent of the atmosphere, both natural and anthropogenic, that absorbs and emits radiation at specific wavelengths within the spectrum of infrared radiation emitted by the earth's surface, the atmosphere, and clouds

Note 1 to entry: For the purposes of this International Standard, GHGs are the six gasses listed in the Kyoto Protocol: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulfur hexafluoride (SF₆).

3.13**recovery**

reprocessing in a production process of the waste materials for the original purpose or for other purposes, together with processing as a means of generating energy

[SOURCE: ISO 16714]

3.14**recoverability**

ability of component parts, materials or both that can be diverted from an end-of-life stream to be recovered

[SOURCE: ISO 16714]

3.15**CO₂ equivalent**

common unit of measure for greenhouse gas emission used to calculate the total greenhouse gas effect (global warming potential) of different greenhouse gas emissions

3.16**global warming potential****GWP**

relative measure of how much heat a greenhouse gas traps in the atmosphere

4 Sustainability factors**4.1 General**

The sustainability factors presented in Table 1 apply for achieving the sustainability balance between environmental, social and economic needs during an earth-moving machine's useful life and end-of-life. The useful life typically has the greatest impact on that balance. This impact is taken into account in the development process and the sustainability information for both useful life and end of life is covered in Table 1.

The general sustainability principles of ISO 14040 and ISO 14044 apply for the machine development process and manufacturing process.

Estimates taken from the application of these sustainability factors can be used to provide information for the work site or work project. The work-site energy efficiency (see 4.2) and GHG (see 4.3) factors are best evaluated at the actual work site or work project level, where the total amount of energy/fuel used can be measured relative to the amount of work done to complete the work project.

NOTE Due to the variability and variety of machine operations (e.g. applications, operator skill or terrain), the estimates of energy use are not sufficiently accurate to enable comparisons between different machine models and sizes.

Table 1 — Sustainability factors for earth-moving machinery

Sustainability factor	Sustainability area(s)	Description	Information or references supplied by manufacturer
Work-site energy efficiency (see 4.2)	Environmental/ Economic	Work performed on a work site per the amount of energy used/fuel consumed	Information used to estimate machine work done/unit of energy
Work-site greenhouse gas (GHG) emissions (see 4.3)	Environmental	Work-site GHG emissions per amount of work done defined by CO ₂ equivalents	Information used to estimate kilograms of CO ₂ equivalents produced during a work-site project
Product support for improving machine efficiency and use (see 4.4)	Environmental/ Economic	Information and training to improve machine operation efficiency as a function of machine capability	Manufacturer's information used to improve machine efficiency and use
Machine air quality emissions (see 4.5)	Environmental	Engine emission rating	Engine rating level, such as tier or stage level
Machine material re-use, recyclability and recoverability (see 4.6)	Environmental	Remanufacturable content Recyclable content Recoverability	As a percentage of machine mass in accordance with ISO 16714
Safety (see 4.7)	Social/ Economic	Complying with International Standards on safety of earth-moving machinery	List of International Standards on safety with which the machine complies
Sound and vibration (see 4.8)	Social/ Environmental	Sound levels of machine	A-weighted decibels (dB) in accordance with ISO 6393, ISO 6394, ISO 6395 and ISO 6396
		Vibration levels of machine	Metres per second squared (m/s ²) — see ISO/TR 25398 and ISO 5349-2
Total useful life cost parameters (see 4.9)	Economic	Owning and operating costs versus productivity for the machine life cycle	Information on parameters to assist customers to estimate total useful life cost

4.2 Work-site energy efficiency

The work-site energy efficiency factor is defined as the energy used for the work done to complete the project. It is generally expressed in units of material moved per amount of energy used/fuel consumed. Common units are cubic metres or tonnes of material per kilowatt hour of energy used. For some applications, the distance that material is moved can be an important parameter, so the energy efficiency could be given in units of cubic metres or tonnes of material per distance in metres per kWh energy used. Determining energy efficiency for machines requires measuring both their energy use and the machine productivity.

The contributions of individual machines to the work-site energy efficiency can be estimated by the energy use/fuel consumption of machines versus the amount of work done. The amount of energy/fuel that a machine uses depends upon the particular application and on the machine load factor for the application. An example of a method for estimating machine energy efficiency is provided in Annex B.

4.3 Work-site greenhouse gas emissions

The work-site greenhouse gas (GHG) emissions factor for earth-moving-machinery consists of GHGs generated as a by-product of the energy/fuels used within earth-moving machines on a project to

complete the work. This source of work-site GHG emissions considered includes the use of earth-moving machinery within the boundaries of a worksite over a typical eight-hour workday and does not include GHG emissions attributed to any additional stages of a product's lifecycle. GHG emissions from all forms of energy/fuel used, such as fossil fuels, renewable fuels and electrical power, should be included in the accounting to determine the total of GHGs generated.

Hydrofluorocarbon emissions potentially associated with leakage and service within the worksite boundary on machines fitted with air conditioning should be identified by listing the amount of refrigerant charge in the air-conditioning system in kilograms.

4.4 Product support for improving machine efficiency and use

The work-site energy efficiency and resulting work-site GHG emission for earth-moving-machine applications vary significantly depending upon the skill of and technique used by the operator, as well as the specific work-site operations. Operator training and work-site management aids can be used to improve the energy efficiency for machines. Manufacturers should provide operator training instruction and work-site operation aids that can enable the improvement of the machine application efficiency. Such information and aids provide an immediate short-term opportunity for work sites to reduce the amount of GHGs.

NOTE Experience has shown that the most significant improvement in sustainability is from operator training and work-site management.

4.5 Machine air quality emissions

The machine air quality emissions factor refers to the engine emissions measured during engine emissions testing. The air quality emissions factor can be defined by providing the engine emissions level, such as the tier or stage level. These ratings define the maximum engine emission levels for nitrogen oxide (NO_x), hydrocarbon (HC), carbon monoxide (CO) and particulate matter (PM).

4.6 Machine material re-use, recyclability and recoverability

The machine material re-use factor provides information related to disposing of or dismantling machines at the end of their life. The three material re-use categories are as follows:

- **remanufacturable content** is the percentage of the machine mass that could be used again after a remanufacturing process in accordance with ISO 16714;
- **recyclable content** is the percentage of a machine that could be recycled in accordance with ISO 16714;
- **recoverability** is the percentage of the machine that can be diverted from an end-of-life stream to be recovered in accordance with ISO 16714.

4.7 Safety

The safety sustainability factor for earth-moving machinery shows that a machine has been developed to be safely used during its useful life with trained operators, maintained machines and safe work-site organization. International Standards are available that define the technical performance parameters for earth-moving machinery safety, and machine safety levels may be determined by listing the standards with which the machine is compliant. ISO 20474 is one such standard addressing significant safety aspects of earth-moving machines. National or regional standards may also be listed, as appropriate.

4.8 Sound and vibration

The sound and vibration factor provides information relative to the sound and vibration levels of machines. Machine sound levels, if included in the sustainability factor information, shall be according to the test methods specified in ISO 6393, ISO 6394, ISO 6395 and ISO 6396 for both the operator of, and spectators around, the machine. Machine vibration levels should be estimated using ISO/TR 25398 for whole body vibration and ISO 5349-2 for hand and arm vibration.

4.9 Total useful life cost parameters

The total useful life cost information allows machine users to calculate the cost of an earth-moving machine during its useful life, for estimating the cost of the machine for work projects. The total useful life cost is the cost of owning and operating a machine relative to its productivity on a work project. It is typically defined as the cost per tonne of material loaded or cost per tonne of material moved per distance hauled.

The owning cost includes the initial machine cost minus any residual value at replacement, as well as the costs for the interest on the purchase cost, insurance and taxes.

The operating cost includes parameters such as the costs of

- fuel,
- operator,
- fluids consumed (oils, grease, etc.),
- tires or undercarriage,
- maintenance (filters, belts, hoses, etc.),
- repairs (failed parts and labour), and
- wear on parts (ground engaging tools, brake friction material, etc.).

The operating cost depends on the hours that the machine is used and the type of machine application and load factor for the application. For some types of machines that perform multiple types of operations with various attachments, the cost per hour may be used as an estimate of the useful life cost.

The owning and operating costs can be estimated from information provided by the machine manufacturer or by the machine distributor who sells or leases the machine. The owning and operating costs can be also estimated from experience on the work site with similar machines.

5 Reporting format

Manufacturers should use the format presented in Annex A to provide sustainability factor information, thereby demonstrating sustainability for earth-moving machines in a consistent manner.

Other information may be provided to meet national or regional requirements.

Annex A (informative)

Format for providing sustainability factor information for earth-moving machines

Table A.1 shows the format for providing sustainability factor information, based on Table 1. “Information or references supplied by the manufacturer” has been completed using the example of a wheeled loader for illustrative purposes only; the manufacturer may provide the information or references to other documents.

Table A.1 — Work-site sustainability contribution format and example manufacturer-supplied information

Sustainability factor	Description	Unit or information	Information or references supplied by manufacturer
Work-site energy efficiency (see 4.2)	Work performed on work site per amount of energy or fuel consumed	Information used to estimate machine work done per unit of energy	Information per Annex B or similar manufacturer's estimate
Work-site greenhouse gas emissions (see 4.3)	Work-site GHG emissions per amount of work done	Information used to estimate kilograms of CO ₂ produced during work-site project	2,6 kg of CO ₂ per litre of diesel fuel used by machine on project over typical 8 h work day or other stated period
Product support for improving machine efficiency and use (see 4.4)	Information and training to improve machine operation efficiency as function of machine capability	Manufacturer's information used to improve machine efficiency	Information provided in machine operator's, use and operator training manuals or classes
Machine air quality emissions (see 4.5)	Engine emission rating	Engine rating level, such as tier or stage level	Stage IV engine
Machine material re-use, recyclability and recoverability (see 4.6)	Remanufacturable content	Percentage of machine mass as per ISO 16714	65 %
	Recyclable content	Percentage of machine mass as per ISO 16714	96 %
	Fluids consumed	Volume per machine hour per system	0,2 l/h
Safety (see 4.7)	Complying with International Standards on safety of machinery	List of machine safety standards (include year issued) with which machine complies	ISO 20474
Sound and vibration (see 4.8)	Sound levels of machine	A-weighted decibels (A-weighted dB) as per ISO 6395 and ISO 6396. Include year issued.	103 dB A-weighted spectator per ISO 6395:2008 82 dB A-weighted operator per ISO 6396:2008
	Vibration levels of machine	Metres per second squared (m/s ²)	ISO/TR 25398: 0,80 m/s ² whole body ISO 5349-2: < 2,5 m/s ² hand and arm
Total useful life cost parameters (see 4.9)	Owning and operating costs versus productivity for machine life cycle	Information on parameters and processes for estimating useful life	Information provided in wheeled loader owning/operating cost summary

Annex B (informative)

Example for estimating machine energy efficiency

Estimates of energy use can be made based on the machine load factor and the energy use of the machine. These estimates should be provided by the machine manufacturer as a range of energy uses for different machine load factors. As an example, the fuel consumption for a medium wheeled loader is shown in Table B.1.

Table B.1 — Example of fuel consumption versus machine application for wheeled loader, as estimated by manufacturer

Wheel loader application	Percentage of rated power fuel consumption, %
Low machine load factor	20 to 50
Medium machine load factor	50 to 70
High machine load factor	70 to 90
Where the load factors for different applications are estimated as follows:	
— Low machine load factor: Intermittent aggregate truck loading from stockpile, hopper charging or load and carry on firm, smooth surfaces for short distances with minimal grades. Free-flowing, low-density materials.	
— Medium machine load factor: Continuous truck loading from stockpile and hopper charging, loading from bank or load and carry on normal surfaces with low to medium rolling resistance and slight adverse grades. Low-to-medium-density materials.	
— High machine load factor: Continuous work on rough or very soft surfaces with high rolling resistance or load and carry in hard digging material with longer travel distances on poor surfaces with adverse grades. Handling high-density material.	
NOTE Load factors can vary from manufacturer to manufacturer.	

Annex C (informative)

Additional sustainability terminology

Table C.1 — Additional sustainability terminology

Term	Definition	Source
completeness check	process of verifying whether information from the phases of a life cycle assessment is sufficient for reaching conclusions in accordance with the goal and scope definition	ISO 14044
consistency check	process of verifying that the assumptions, methods and data are consistently applied throughout the study and are in accordance with the goal and scope definition performed before conclusions are reached	ISO 14044
critical review	process intended to ensure consistency between a life cycle assessment and the principles and requirements of the International Standards on life cycle assessment	ISO 14044
dismantlability	ability of component parts to be removed from the machine	ISO 16714
energy recovery	use of combustible waste as a means to generate energy through direct incineration with or without other waste but with recovery of the heat	IEC Guide 109
environment	surroundings in which an organization operates, including air, water, land, natural resources, flora, fauna, humans, and their interrelation	ISO 14001
environmental aspect	element of an organization's activities or products or services that can interact with the environment	ISO 14001
environmental impact	any change to the environment, whether adverse or beneficial, wholly or partially resulting from an organization's environmental aspects	ISO 14001
evaluation	<p>element within the life cycle interpretation phase intended to establish confidence in the results of the life cycle assessment</p> <p>NOTE Evaluation includes completeness check, sensitivity check, consistency check, and any other validation that may be required according to the goal and scope definition of the study.</p>	ISO 14044
heat recovery	reprocessing in a production process of the waste materials for the original purpose or for other purposes, together with processing as a means of generating energy	
hazardous substance	substance which can adversely affect human health or the environment with immediate or retarded effect	IEC Guide 109
life cycle	consecutive and interlinked stages of a product system, from raw material acquisition or generation from natural resources to final disposal	ISO 14040

Table C.1 (continued)

Term	Definition	Source
life cycle impact assessment	phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product	ISO 14040
life cycle inventory analysis	phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product, throughout its life cycle	ISO 14040
life cycle interpretation	phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations	ISO 14044
life-cycle thinking	consideration of all relevant environmental aspects (of a product) during the entire (product) life cycle	IEC Guide 109
material recycle	use of recycled materials	JCMAS H016
packaging	material that is used to protect or contain a product during transportation, storage, marketing or use NOTE For the purposes of this International Standard, the term "packaging" also includes any item that is physically attached to, or included with, a product or its container for the purpose of marketing the product or communicating information about the product.	ISO 14021
pollution	all adverse effects on the environment caused by the release of organic or inorganic materials, hazardous substances, radiation or noise	IEC Guide 109
prevention of pollution	use of processes, practices, materials or products that avoid, reduce or control pollution, which may include recycling, treatment, process changes, control mechanisms, efficient use of materials and material substitution NOTE The potential benefits of prevention of pollution include the reduction of environmental impacts, improved efficiency and reduced costs.	ISO 14001
process energy	energy input required for operating the process or equipment within a unit process, excluding energy inputs for production and delivery of the energy itself	ISO 14044
product	any goods or service	ISO 14024
product category	group of products which have equivalent function	ISO 14024
product environmental criteria	environmental requirements that the product shall meet in order to be awarded an environmental label	ISO 14024
product function characteristic	attribute or characteristic in the performance and use of a product	ISO 14024
raw material	primary or secondary material that is used to produce a product	ISO 14044
rebuilding	action following the dismantling of an item and repair or replacement of those sub-items that are approaching the end of their useful life and/or should be regularly replaced	EN 13306
releases	emissions to air and discharges to water and soil	ISO 14044
recyclability rate	percentage by mass (mass fraction in percent) of the new machine potentially able to be recycled, reused or both	ISO 16714