INTERNATIONAL STANDARD

ISO 13602-2

First edition
2006-03-15

Technical energy systems — Methods for analysis —

Part 2:
Weighting and aggregation of energywares

Systèmes d'énergie technique — Méthodes d'analyse —

Partie 2: Pondération et agrégation des produits énergie

Reference number
ISO/FDIS 13602-2:2006(E)

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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 13602-2 was prepared by Swedish National Technical Committee SIS/TK 420 *Energyware balances* (as SS 13602-2:2005) and was adopted, under a special “fast-track” procedure by Technical Committee ISO/TC 203, *Technical energy systems*, in parallel with its approval by the ISO member bodies. The only technical difference between the two standards is that Annex A is normative in SS 13602-2:2005 and informative in ISO 13602-2.

ISO 13602 consists of the following parts, under the general title *Technical energy systems — Methods for analysis*:

— *Part 1: General*

— *Part 2: Weighting and aggregation of energywares*

A part 3 dealing with methodology for energy statistics and forecasting is planned.

Introduction

There are a number of situations and applications in which aggregation of energywares is performed, for example in energyware statistics, time series analysis, cross-sector comparisons, and characterisation of an energyware mix. In many cases weighting is applied on the components, sometimes based on different principles due to different underlying reasons for the weighting, i.e. energywares are added up by various common properties. Examples, that can be found in practise are weighting by *market price*, *substitution coefficients*, *energy content* or *exergy*.

In most cases energywares are aggregated by their *energy content* (e.g. *heat of combustion*). This means that no weighting is performed in the aggregation, and the result is globally valid. In other cases aggregation by *energy content* may not serve the purpose of the aggregation and some form of weighting is applied, which typically depends on local conditions. Thus, this result will not be globally valid. For this reason, it is important to establish a procedure for the weighting and aggregation to ensure transparency and comparability.

ISO 13602 belongs to the 13600-series, all Standards of which have the introductory element: Technical energy systems.

Technical energy systems — Methods for analysis —

Part 2: Weighting and aggregation of energywares

1 Scope

In this part of ISO 13602 are established guiding principles for the weighting and aggregation of energywares to ensure that energyware statistics at different levels of aggregation are transparent and comparable. Weighting and aggregation of energywares according to this part of ISO 13602 are only to be performed at the final stage of the energyware life cycle, where the energyware is a direct input to the users´ conversion system.

2 Normative references

The following referenced documents are indispensable for the application 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 13600:1997, *Technical energy systems — Basic concepts*

SO 13600:1997, *Technical energy systems — Basic concepts,* Technical Corrigendum 1

ISO 13601:1998, *Technical energy systems — Structure for analysis — Energyware supply and demand sectors*

ISO 13602-1:2002, *Technical energy systems — Methods for analysis — Part 1: General*

ISO 14040:1997, *Environmental management — Life cycle assessment — Principles and framework*

ISO 14041:1998, *Environmental management — Life cycle assessment — Goal and scope definition and inventory analysis*

ISO 14042:2000, *Environmental management — Life cycle assessment — Life cycle impact assessment*

3 Terms and definitions

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

3.1
energy content
enthalpy difference of the input state and a declared reference state of an energy carrier

3.2
primary capital goods
plants and equipment directly needed to produce the energyware for fuel extraction, fuel refinement, and energy conversion

4 Principles for weighting and aggregation

4.1 General

The basic principle for weighting and aggregation is that all energywares are measured by a uniform quantity that enables them to be summed up by a common property of the energywares. Which quantity to chose depends on the purpose of the application. These quantities form the basis for the weighting methods, and they may vary from one application to another. They may be grouped into several different categories according to:

— an inherent physical property, e.g. *heat of combustion*,

— type of *energy resource*, e.g. a renewable or non-renewable resource,

— characteristics of the energy conversion process, e.g. emissions such as nitrogen oxides, or

— the service provided by the energyware, e.g. heating of a building.

Only the inherent physical properties are global and objective quantities. Others are local and value based. Principles for both types of weighting and aggregation are given in this part of ISO 13602.

Several different quantities may be used for weighting and aggregation. The most common are:

— *Energy content* (*heat of combustion*)
No weighting is performed, i.e. the weighting factor is 1 for all energywares.

— *Economy* (*price*)
Weighting may be based on for example market price exclusive of consumption taxes, production costs, etc.

— *Exergy*
This method values the energywares according to their theoretical capacity of generating mechanical work, given a defined ambient temperature.

— *Substitution coefficients*
In this method the relative value of different energywares are decided by their capacity to replace each other when providing a particular service. The substitution coefficients are only valid for a particular functional unit, and they may vary from case to case.

4.2 Weighting methods

Weighting methods can be divided into four categories that they may be based on:

1. An inherent physical property of the energyware, such as for example *heat of combustion*, *Gibbs free energy*, etc. These measures are unambiguously determined by the chemical and physical content of the energywares when the system boundaries have been defined.[1]

2. The *energy resource*.

3. The properties of the energyware conversion process, e.g. emissions, which also shall include the properties when using the energyware, e.g. emissions during the use phase.

4. The service that the energyware is generating, for example transportation work or paid price.

[1] This applies to energywares that are entirely consumed or transformed when used. Nuclear fuels need to be handled by special rules.

5 Weighting factors

5.1 General

A weighting method defines a method by which the weighted amount of a particular energyware shall be calculated. This calculation results in a weighting factor. A weighting factor may be global or local, and may be time dependent. Weighting factors are calculated as reciprocal equivalency factors, for example the reciprocal value of the quantity of an energyware that consumes one unit of a non-renewable resource, is associated with one unit of environmental impact, or generates one unit of service. Thus, weighted amounts of energywares are neutral with respect to for example resource depletion, environmental impact, or service provided.

5.2 Structure

Weighting or aggregation of energywares for energy statistic purposes shall be based on the *gross calorific values* of energyware flows for a defined period of time. This measure, which is defined as *the base system*, is a non-weighted absolute measure. The weighting factor is defined as the *global factor.*

In addition to this non-weighted measure, different types of weighting principles may be added defined as *value based systems*. If any other aspect than flows of energywares based on their *gross calorific values* is to be reported, e.g. climate change impact or provided service, this shall be reported through a weighting factor added to the base system. The weighted value may be reported as an absolute measure or a normalized measure. The weighting factor is defined as a *value based factor.*

The structure is further described in Table 1.

Table 1 — Structure for weighting

Name	Type	Explanation or definition	Examples
Base system	Global factor (non-weighted)	An inherent physical property of the energyware	*Gross calorific value*
Impact factors	Value-based factors (weighted)	1. The origin of the energyware or resource base 2. The properties of the energyware conversion processes (this shall also include the properties when using the energyware)	1. Depletion factors 2. Emissions, e.g. GWP
Provided service factors	Value-based factors (weighted)	The service generated by the energyware	Transportation work, exergy, price, substitution coefficients

6 Requirements on reporting weighted or aggregated energywares

The requirements on reporting are:

1. The base system without weighting shall always be reported based on the *gross calorific value* of energy flows for each energyware, and for a specified period of time. This shall be reported as an absolute measure.

When weighted or aggregated energywares are reported:

2. Weighted measures of energywares shall be separately reported. These may either be reported in absolute terms or in normalized terms.

3. The methods for the calculation of the applied weighting factors shall be reported in a transparent manner.

Base system

The inherent property that shall be used for the calculation of the *global factor* in the base system is the *gross calorific value* of the energyware.

Value based systems

Impact factor

Depending on the purpose of the weighting, different impact factors may be used. The procedures for applying impact factors shall follow standardized principles according to ISO 14042:2000. The impact factors shall be clearly described and derivable.

Provided service factor

Depending on the purpose with a study, different provided service factors may be used. These factors shall be clearly described and derivable.

7 Calculation rules

7.1 Base system — Global factor

The inherent property that shall be used for the calculation of *global factor* is the *gross calorific value* of the energyware. An exception is made for nuclear fuels where the *global factor* is calculated as three times the energy delivered by the nuclear fuel as electricity, and equal to the energy delivered by the fuel as heat.

7.2 Value-based system — Impact factor

7.2.1 General

Impact factors are based on LCI/LCA data, which shall be calculated according to the rules specified in this part of ISO 13602.

7.2.2 Non-renewable energy resources

Use of non-renewable *energy resource*s (such as crude oil, etc.) causes resource depletion and shall be accounted for as a depletion of resources, quantified in mass or energy units.

NOTE Peat is accounted for as a non-renewable resource.

7.2.3 Renewable energy resources

Use of renewable *energy resource*s (such as solar heat, wind, water, etc.) does not cause any resource depletion.

A special case is biomass, e.g. wood, where one of two different principles applies.

Principle 1: If the biomass is re-established, the activities required for the re-establishment (i.e. to start the cycle again) shall be included. The only resource used in this case is solar energy but this does not cause any resource depletion (however, the manufacturing of the capital goods may cause resource depletion).

Principle 2: If no re-establishment is made, i.e. no re-plantation is done or occurs naturally, a natural resource has been consumed and therefore this shall be accounted for as a depletion.

7.2.4 Calculation of Global Warming Potential (GWP)

Biogenic carbon dioxide shall not be accounted for when calculating Global Warming Potentials.

7.2.5 Capital goods

Main principle: The primary capital goods shall be included. All equipment needed to produce the energyware shall be included if it is not an item of consumption according to the rules applied to financial accounting. Dismantling of capital goods and waste management shall not be included. However, transportation of the capital goods shall be included.

7.2.6 Allocation between technical systems

7.2.6.1 General

There are two situations when allocation could be necessary; when a product that is an output from one technical system is an input to another technical system (open loop recycling), or when several products are produced from one technical system (multi-output).

If allocation can be avoided by dividing the system into sub-systems, this is preferable. When this is not possible the following principles for allocation shall be applied:

7.2.6.2 Open loop recycling

Main principle: A waste flow without a commercial value, which will be lost if it is not used in another system is *not* declared as a resource, and no impacts from up-stream processes shall be allocated to it (not being an energyware). A waste flow with a commercial value is considered as a by-product.

EXAMPLE

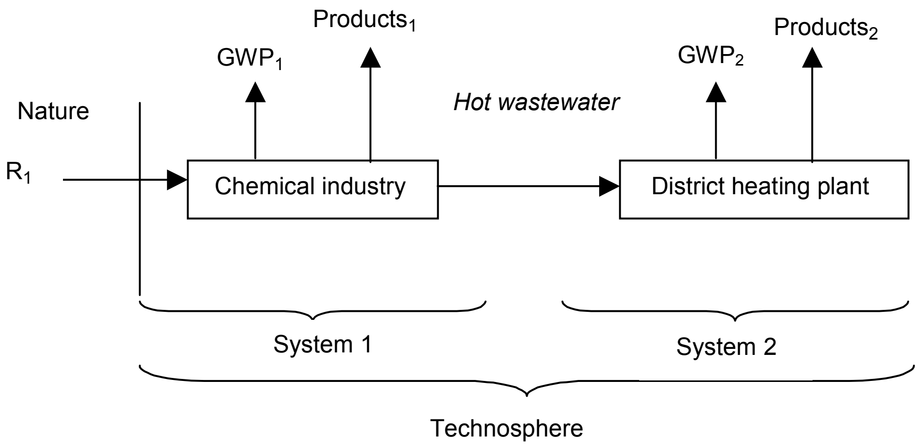

Figure 1 – Open loop recycling

If the hot wastewater from system 1 is a waste: no part of environmental impact (GWP_1) and no part of the resource depletion (R_1), respectively, from system 1 shall be allocated to it according to multi-output allocation (see 7.2.6.3). Furthermore, the hot wastewater is not considered as depletion. However, the flow shall be declared as a 'technical *energy resource*'[2].

If the hot wastewater from system 1 is sold it has a value. In that case the environmental impact (GWP_1) and resource depletion (R_1), respectively, from system 1 shall be allocated to system 2. The resource shall be declared as reclaimable hot wastewater.

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2 A technical energy resource is a waste without value that is taken care of, i.e. a technically generated flow.

7.2.6.3 Multi-output allocation (several products)

Main principle: When a system produces several products, the resource depletion and environmental impact shall be allocated between these products based on the energy balance, and proportional to the *energy content* of the product and co-product flows. This is illustrated in examples below.

Combined heat and power generation: Allocations between heat and power in combined plants shall be performed according to informative Annex A.2.

EXAMPLES

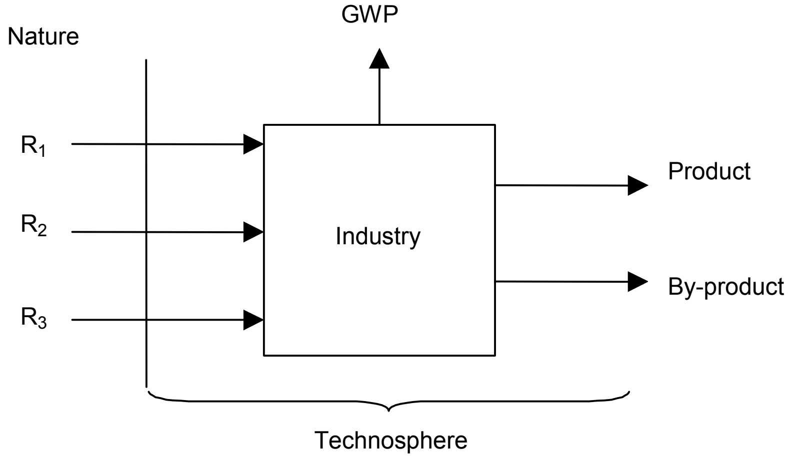

Figure 2 – Multi-output, example 1

The allocation shall be performed using the energy balance as base.

If losses occur they shall be allocated proportionally between the product and by-product.

In a steel plant, for example, two resources into the system are dressed iron ore and coal, while steel and burning gas are two products out from the system. The allocation of e.g. the resource depletion shall be based on the energy balance and the losses shall be allocated proportionally between the products. The principle is illustrated in the following example:

If:

the input to the system is 100 MJ totally, and 50 MJ is found in the steel, 40 MJ in the burning gas and 10 MJ is losses.

Then:

50/90 of the losses shall be allocated to the steel and 40/90 to the burning gas.

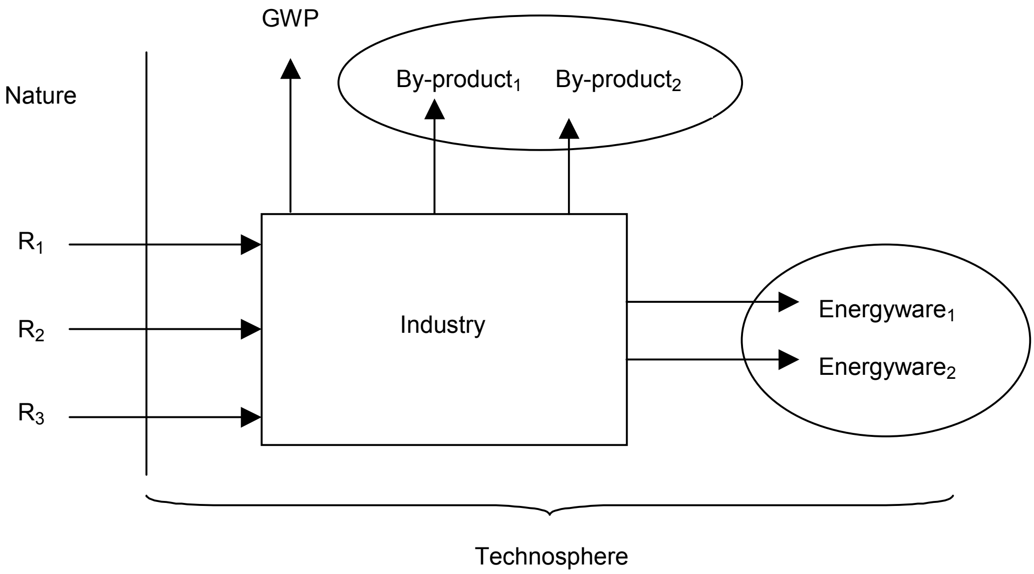

Figure 3 – Multi-output, example 2

The environmental impact (GWP) shall also be allocated using the energy balance as base.

The allocation shall be performed using the energy balance as base.

Allocation between by-products and energywares: The allocation shall be made proportional to the energy flows.

Allocation between energyware 1 *and* 2: After having subtracted the by-products share, the remaining part shall be allocated between the enerywares proportional to the energy flows.

7.3 Value based system – Service factor

Depending on the purpose of a study, different service factors may be used. The service factors shall be clearly described and derivable.

Annex A
(informative)

Allocation

A.1 Allocation by the “Alternative Generation Method”

This Annex provides a description of the allocation method for the distribution of the environmental impact associated with the generation of electricity and heat in a combined heat and power plant. The facility parameters to be used for this allocation are also specified.

Description of the “Alternative Generation Method”

The Finnish District Heating Association originally developed this allocation method as a proposal for a new and uniform reporting method for European combined heat and power plant generation statistics. The method is still being discussed within Euroheat, Eurostat, and Eurelectric. At present there is no uniform standard for the selection of facility parameters.

The method is available in different versions, with varying degrees of complexity of the calculation process. The simplest version is used in this application.

The allocation method is based on the fact that benefits gained from improved fuel utilisation as well as the environmental impacts connected to combined heat and power generation, are distributed between the two products – electricity and heat – in the same proportion as the fuel needed for separate electricity and heat generation processes. The relation of distribution is expressed as fraction of the fuel needed for each alternative process with respect to the total quantity needed.

The principle behind the allocation method is illustrated in the Example below:

EXAMPLE

Existing combined heat and power generation plant for which the allocation is to be made:

Net electricity generation	30 units
Net heat generation	60 units

Alternative generation facilities:

Heat generation (no fuel gas condensation)	η_h = 90 %
Electricity generation	η_e = 40 %
Fuel used by alternative electricity generation	30/0,4 units = 75 units
Fuel used by alternative heat generation	60/0,9 units = 67 units
Total fuel used by alternative generation	142 units
Allocate to electricity:	75/142 = 53 %
Allocate to heat:	67/142 = 47 %

The choice of parameters for the alternative generation facilities has a direct impact on how the environmental impact is distributed. Various alternative approaches exist for the selection of facility data for alternative generation. The following principle shall apply to allocations upon which Environmental Product Declarations are to be based:

Facility data for the best possible facility performance for the same type of technology and fuel as the facility studied.

In the case of co-combustion of several fuels in a facility, it is up to the author of the Life Cycle Assessment to select facility data and to provide justification for the allocation calculations.

A.2 Basis for Allocation – Facility Parameters for Alternative Facilities

The table below shows the facility parameters to be used in allocation for a number of different combined heat and power generation methods. The reported efficiencies in the table below are based on the net calorific values of the fuels to be considered with the Product Specific Requirements (PSR) for preparing an environmental product declaration (EDP) for Electricity and District Heat Generation.

Table A.1 – Facility parameters

Combined heat and power		Alternative heat	Alternative electricity
Fuel type	***Technology***	***Efficiency, heat*** η_h	***Efficiency, electricity*** η_e
Biofuel	Steam cycle, heat and power	90 %	38 %
	Steam cycle, heat and power, flue gas condensation	110 %	38 %
Waste	Steam cycle, heat and power,	90 %	35 %
	Steam cycle, heat and power, flue gas condensation	100 %	35 %
Black coal	Steam cycle, heat and power	90 %	46 %
Natural gas	Steam cycle, heat and power	90 %	47 %
	Steam cycle, heat and power, flue gas condensation	105 %	47 %
	Combined cycle, heat and power	90 %	58 %
Oil	Steam cycle, heat and power	90 %	46 %

Annex B
(informative)

Case studies of weighting and aggregation

B.1 Calculation examples

Absolute factors

Below is an example of energyware flows, associated GWP flows, and Provided Service flows in Xcity year 2000.

EXAMPLE

Table B.1 — Annual flows

	ANNUAL FLOWS XCITY YEAR 2000		
	Global	**Impact**	**Provided Service**
Energyware	**Energy flow** (TJ)	**GWP, CO_2-eqv** (kt)	**Driving a car** (Gm)
Electricity, hydro power	32000	47	29000
Ethanol	1100	36	330
Solar power	3600	200	3700
District heating	14000	310	–
TOTAL	51000	590	33000

This example may be used to calculate weighting factors.

Table B.2 — Weighting factors

	Weighting factors		
	Global	**Impact factors**	**Provided Service factors**
Energyware	**Energy flow** (TJ)	**GWP factors** (kg/MJ)	**Driving a car factors** (km/MJ)
Electricity, hydro power	32000	0,0015	0,91
Ethanol	1100	0,032	0,30
Solar power	3600	0,056	1,0
District heating	14000	0,022	–
TOTAL	51000	–	–

Relative factors

The example above may be used to calculate relative weighting factors of dimension one for Xcity 2000. When calculating relative factors all figures are normalized to the highest figure. This is illustrated in the example below:

EXAMPLES

Normalized weighting factors for energywares based on Climate Change.

> When producing 1 MJ of electricity from hydropower, this causes an emission of greenhouse gases according to 1,58 g GWP (i.e. CO_2 equivalents, net-emissions). Furthermore, 56 g GWP is generated when 1 MJ of electricity from solar power is produced. If comparing the above energywares with regard to their relative GWP value (so called GWP coefficient) they shall be divided by the highest value (the highest impact), i.e. the GWP coefficient is:
>
> 1 for the solar power, and
>
> 0,03 for the hydropower.

A comparison of the provided service of grid electricity and district heating, i.e. the substitution coefficients.

> In this example two alternatives for providing the service heating of a building are compared. If the heat delivered to the building by district heating Q is 30 MJ, and the alternative amount of electricity E needed to replace the heat amount Q, is 19,5 MJ. Then the substitution coefficient S is:
>
> $S = E/Q$ = 19,5 MJ/30 MJ = 0,65
>
> Hence the substitution coefficients are:
>
> 1 for the electricity and
>
> 0,65 for the district heating
>
> This means that 1 MJ of district heating provides 65 % of the service heating of buildings as compared to electricity.

Table B.3 — Absolute factors

	ABSOLUTE FACTORS					
	Global factor *G*	Impact factor *F*			Provided service factor *S*	
	Flow	Resource extraction		Emissions	Provided service	
	Total energy content (MJ)	Total non-renewable natural resources with energy content (MJ/MJ)	Total land use (km^2/MJ)	Total GWP, CO_2-eqv, net-emissions (g/MJ)	Total price, inclusive taxes (EUR/MJ)	Total distance driven with a car (km/MJ)
Hydropower						
Station 1	flow	0,0025	64	1,42	0,030	1,04
Station 2	flow	0,0024	64	1,39	0,030	1,04
Station 3	flow	0,0019	64	1,34	0,030	1,04
Station 4	flow	0,0043	64	1,58	0,030	1,04
Ethanol	flow	0,23	220000	34	0,044	0,30
Solar power	flow	0,70	90	56	0,060	0,96
District heating	flow	0,33	57	22	0,0072	

ICS 27.010

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