Industry Report on Environmental Impact Indicators

Industry Foundation Classes (IFC) for data sharing in the Construction and Facility Management Industries — Integration of Life-Cycle Phases and Environmental Impact Indicators in bSDD

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Version: 1.2
Date: 16-11-2022
Document ID: PR-2022-1042-TR

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2 Foreword

Integration of Life Cycle Phases and Environmental Impact Indicators in BSDD

The Product Room Steering Committee (PRSC) of buildingSMART International (bSI) has added the life cycle stages and environmental impact indicators into the buildingSMART Data Dictionary (bSDD). This is an important prerequisite for the broad implementation of environmental assessment and optimization in construction.

Construction products have an important impact on our environment in production and disposal. The environmental impact can be measured through different indicators over the life cycle stages of a building. This is declared in Environmental Product Declarations (EPDs), but also national authorities provide generic EPD data. This allows a fair and reproduceable environmental assessment in early planning stages or fills gaps in cases where EPDs are missing. With this information available, it is possible to assess and minimize the environmental impact of every building planned within the BIM methodology. Beside Primary Energy (PE), one important environmental impact indicator is the Global Warming Potential (GWP) which represents the relevant emissions to global warming during the production and disposal of construction materials such as carbon dioxide equivalent. With the Paris Agreement in 2015, many countries set reduction goals, which will have to touch not only the impact of construction in its operation but expand the view to all life cycle stages including production and disposal of its materials.

A common digital framework of life cycle phases and environmental impact indicators based on a common digital language, represents an important prerequisite for collaboration. The publication of machine-readable life cycle stages and environmental impact indicators will also allow manufacturers to provide their EPDs in a decentralized way or to refer to the corresponding generic EPD of their association or their government if they have not calculated such data.

The integration was coordinated by Hansueli Schmid (Lignum), member of the Product Room Steering Committee of bSI and the LCA experts Mr. Rolf Frischknecht (treeze Limited) and Dr. Frank Werner. The transformation of the data was facilitated by the data dictionary tool “Define” from Cobuilder. The data was transformed according to standard EN ISO 22057:2022 “Sustainability in buildings and civil engineering works” and is compatible on a European level with EN 15804: “Sustainability of construction works - Environmental product declarations” and on an international level with ISO 21930:2017 “Sustainability in buildings and civil engineering works — Core rules for environmental product declarations of construction products and services”. This digital transformation of LCA indicators proves the concept for the process described in EN ISO 23386, uses the data structure in EN ISO 23387 and was performed by the environmental experts in ISO/TC 59/SC 17, the committee for ISO 22057.

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More information is available in bSDD at the following links:

BSDD: Search 'warming' (bSDD) (buildingsmart.org)
Data available for programmers via API: http://bsdd.buildingsmart.org/docs/
Link for the bSDD API: https://app.swaggerhub.com/apis/buildingSMART/Dictionaries/v1
Information about the model:
https://github.com/buildingSMART/bSDD/tree/master/Model/Import%20Model

3 Introduction

3.1 The relevance of LCA data in bSDD

Using building materials in the right place and in the right amount is not only an economic question but above all, an ecologically relevant issue. The production of cement and steel consume a lot of fossil primary energy. From a global perspective, cement production causes approx. 8% of CO_2 emissions and thus significantly exceeds that of air traffic of approx. 2% (Royal Institute of international Affairs, 2018).

The digital transformation of horizontal standards in relation to ecological Life Cycle Assessment (LCA) is very important to create a digital environment in which LCA Data can be properly provided, processed and exchanged.

3.2 Environmental Impact of Buildings

Legislation in the building sector is still focused on increasing operational efficiency, while the environmental impact of building materials is often not considered. Due to the increasing scarcity of non-renewable resources and the obligation to reduce CO_2 as part of the Paris Climate Agreement, holistic life cycle assessments are becoming increasingly important to achieve the goals set.

In precise terms: In addition to the life cycle phase "Use Stage", the environmental impacts originating the life cycle phases " Product Stage ", “Construction Process Stage” and " End of Life Stage" will now be considered too.

Relevant reduction of environmental impact would often be possible without reducing performance or comfort. For example, reductions by optimizing material use, the change from non-renewable to renewable building materials, connections designed for disassembly and robust and durable low-tech solutions. However, between the many mandatory requirements on buildings it is often difficult to keep environmental impact minimized in each planning stage. The use of BIM with machine readable information based on a common digital framework, represents an important methodology to overcome this problem: With digital building models in combination of machine-readable Environmental product declaration (EPD), the environmental impact of building materials can be continuously calculated by algorithms and minimized over the whole planning process. The calculations can finally be used as a declaration for the impact of the building.

A generic LCA framework in IFC property set could further facilitate the application of algorithms in BIM and supports software providers in their development of new solutions.

This grid of generic Identifications forms the link on the transition from generic to specific Information within the planning process as well as the development from integrated to linked data. The developed algorithms need unambiguous identification of the indicators. The process is similar to the one with the costs, only that we are dealing with significantly more indicators as well as pre-defined life cycle stages, creating a matrix of information which can hardly be handled without integrated software processes.

3.3 The Need for Reliable LCA Results

Reliable databases and robust processes are important for reliable environmental impact Information. Only under these conditions those aspects can also be taken into account in public tenders, which are carried out within the framework of the international WTO treaty.

There is also an urgent need to develop solutions for assessing sustainable financial products in the real estate sector. Specially to apply LCA Information for Sustainable Finance for example to assess buildings according to national or international definitions of green finance (EU Taxonomy).

3.4 Developing LCA Data into Added Value

National databases with the impact of products withing relevant indicators and Life cycle stages already exist or are under development. This very valuable information has to be made available for digital networking. Solutions are now needed to generate high-quality planning results from this data. The demand exists: For example in Sweden, where from 2022 onwards, building applications require an easy-to-create climate declaration.

4 Specifications for use in IFC

4.1 Scope

This document specifies minimum requirements for construction product information to indicate quantitative environmental impact over the whole lifecycle of resource extraction, manufacturing, construction, operation, maintenance and disposal.

It is applicable to all products used for building construction, including those sold by unit, length, area, volume, or weight.

It defines software encoding requirements for files using Industry Foundation Classes 4.0.

4.2 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 22057:2022, Sustainability in buildings and civil engineering works — Data templates for the use of environmental product declarations (EPDs) for construction products in building information modelling (BIM)
- ISO 21930:2017 Sustainability in buildings and civil engineering works — Core rules for environmental product declarations of construction products and services.
- ISO 14025:2006, Environmental labels and declarations — Type III environmental declarations — Principles and procedures
- ISO 14044:2006, Environmental management — Life cycle assessment — Requirements and guidelines
- ISO 16739-1:2018, Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries — Part 1: Data schema

- EN 15804:2012+A2:2019, Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products
- EN ISO 23386 ISO 23386:2020, Building information modelling and other digital processes used in construction — Methodology to describe, author and maintain properties in interconnected data dictionaries
- EN ISO 23387 ISO 23387:2020, Building information modelling (BIM) — Data templates for construction objects used in the life cycle of built assets — Concepts and principles

4.3 Terms and Definitions

For purposes of this document, the following terms and definitions 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
— ISO Electropedia: available at http://www.electropedia.org/

- Pset_EnvironmentalImpactIndicators
- PEnum_LifeCycleStage
- PEnum_LifeCyclePhase
- PEnum_LifeCycleModul

4.3.1 General Specifications

Product information may be provided in the form of an IFC file describing one or more manufactured product models or configurations.

Figure 1 illustrates an instance diagram using (Unified Modeling Language) UML notation, where a single IfcProject has a breakdown structure of IfcElementType instances for each product model, then

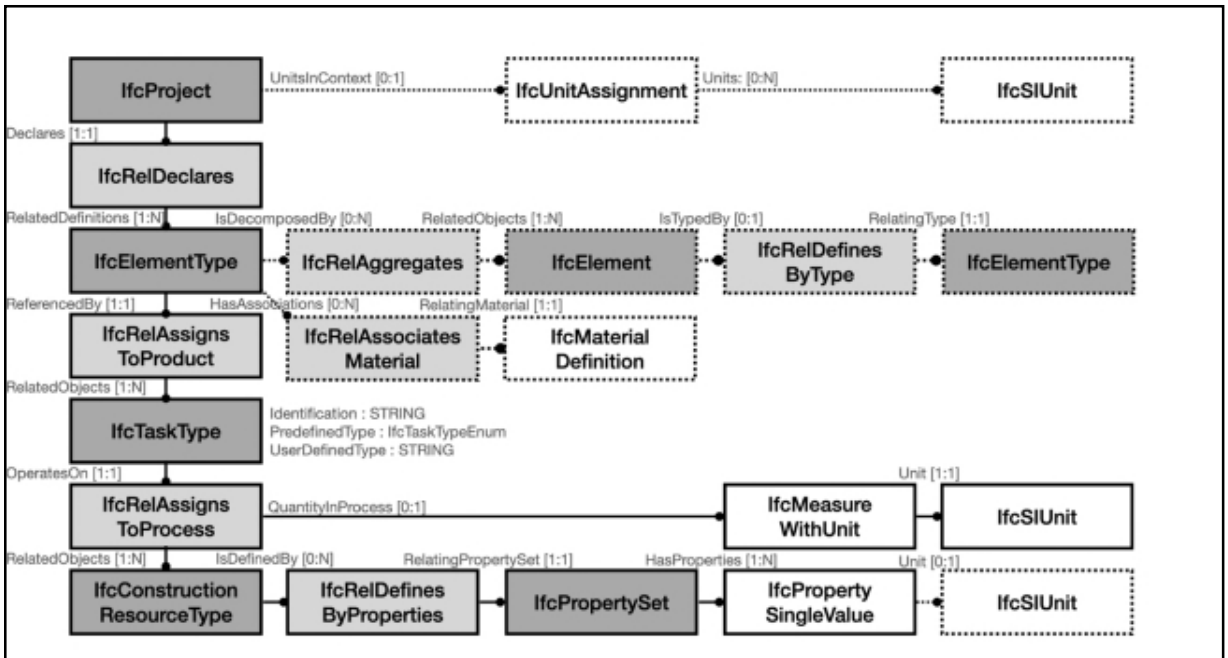

Figure 1: Instance diagram

IfcTaskType instances for each lifecycle phase, and then IfcConstructionResourceType instances describing resource usage of energy and natural resources. Additional data may also be included such as geometry of product models, part composition, and materials, as described in the IFC specification.

An IFC file shall include a single IfcProject instance to provide context describing units for each applicable measure, for which SI base units according to the International System of Units (SI) are implied for measures without units provided.

The *IfcProject* instance shall contain a set of product configurations using the *IfcRelDeclares* relationship, where *RelatingContext* refers to the *IfcProject* instance and *RelatedDefinitions* refers to one or more instances of *IfcElementType* subtypes for each product configuration.

4.4 Product Specifications

An *IfcElementType* instance describes the physical form of a product.

If such product refers to a manufactured unit with fixed dimensions, 3D geometry may be provided using *RepresentationMaps* as described within the IFC specification.

4.4.1 Product Material Definitions

If the product refers to a variable quantity, material layout information may be provided using the *IfcRelAssociatesMaterial* relationship where *RelatedObjects* refers to the *IfcElementType* and *RelatingMaterial* refers to an *IfcMaterialDefinition* as listed in Table 1.

Table 1: Product material definitions

RelatingMaterial	Usage
IfcMaterial	Product is sold per volume or per mass
IfcMaterialConstituentSet	Product is sold per unit
IfcMaterialProfileSet	Product is sold per unit length
IfcMaterialLayerSet	Product is sold per unit area

4.4.2 Product Part Definitions

If a product is comprised of multiple parts, it may be decomposed into objects for each part using the *IfcRelAggregates* relationship where *RelatingObject* refers to the *IfcElementType* instance and *RelatedObjects* refers to one or more *IfcElement* subtype instances describing each part. Parts may be decomposed recursively and may refer to other product types using the *IfcRelDefinesByType* relationship where *RelatedObjects* refers to an *IfcElement* part instance and the *RelatingType* refers to another *IfcElementType* corresponding to the part definition. Lifecycle information and resource usage as described herein may also be provided for specific parts. For variable quantities where material layer sets or profile sets are provided, the *Name* of each *IfcElement* shall equal the *Name* of each corresponding *IfcMaterialLayer*, *IfcMaterialProfile*, or *IfcMaterialConstituent*.

4.4.3 Product Environmental Declaration

An *IfcElementType* instance provides properties as listed in Table 2 using IfcPropertySet with Name "Pset_ProductEnvironmentalDeclaration"

Table 2: Product environmental declaration properties

Name	Type	Description
ManufacturerAddress	IfcPostalAddress	Physical address of the manufacturer as required by ISO 21930.
OpertorAddress	IfcPostalAddress	Physical address of the program operator as required by ISO 21930.
PeriodOfValidity	IfcDate	Period of validity of the declaration as required by ISO 21930.
IssueDate	IfcDate	Date the declaration was issued as required by ISO 21930.
StandardAuthority	IfcLabel	Identification of standard authority using recognized abbreviation, e.g. ISO (International), CEN (Europe), DIN (German), SIA (Swiss)
StandardNumber	IfcInteger	Reference to standard number issued by StandardAuthority which defines methods of measurement for environmental impact values.
Points	IfcReal	Calculated value of environmental impact if applicable, based on weighting factors prescribed by referenced StandardAuthority, and StandardNumber.

4.4.4 Product Service Life Properties

An *IfcElementType* instance provides properties as listed in Table 3 using IfcPropertySet with Name "Pset_ServiceLife".

Table 3: Product service life properties

Name	Type	Description
ServiceLifeDuration	IfcDuration	The length or duration of a service life.
MeanTimeBetweenFailure	IfcDuration	The average time duration between instances of failure of a product

4.5 Process Specifications

For capturing life cycle phases, an *IfcElementType* instance contains a set of process types using the *IfcRelAssignsToProduct* relationship, where *RelatingProduct* refers to the *IfcElementType* instance and *RelatedObjects* refers to one or more IfcTaskType instances.

4.5.1 Process Lifecycle Properties

An *IfcTaskType* instance provides properties using *IfcPropertySet* as listed in Table 4 with *Name* "Pset_ProcessLifecycle".

Table 4: Process lifecycle properties

Name	Type	Description
LifecycleStage	PEnum_LifeCyclePhase	Lifecycle stage according to EN 15804 Section 6.3.5.2.

Each lifecycle property of type "PEnum_LifeCycleStage" uses a value as listed in Table 5.

Table 5: Lifecycle stage values

Name	Description
A1	Extraction and processing of raw materials and processing of secondary materials used as input
A2	Transport to the manufacturer
A3	Manufacturing
A4	Transport to the construction site
A5	Installation in the building
A1_A3	A1 thru A3
A4_A5	A4 thru A5
B1	Use or application of the built-in product
B2	Inspection, maintenance, cleaning
B3	Repair
B4	Exchange, replacement;
B5	Improvement, modernization
B6	the use of energy to operate the building
B7	the use of water to operate the building.
B1_B7	B1 thru B7
C1	Dismantling, demolition
C2	Transport to waste treatment;
C3	Waste treatment for reuse, recovery and / or recycling;
C4	Elimination

Name	Description
C1_C4	C1 thru C4
D	Credits and loads outside the system boundary

4.6 Resource Specifications

For capturing the environmental impact of a certain indicator specific to a life cycle phase, an *IfcTaskType* instance contains resource information using the *IfcRelAssignsToProcess* relationship, where *RelatingProcess* refers to the *IfcTaskType* instance, *RelatedObjects* refers to one or more instances of *IfcConstructionResourceType* subtypes, and *QuantityInProcess* indicates the applicable unit quantity of the product. If specific resources are not known or are otherwise unavailable, then a single *IfcConstructionProductResourceType* instance shall be used to capture aggregate information for all resources.

4.6.1 Resource Functional Unit

For assigning resources, the functional unit (as defined by ISO 21930:2017) is indicated using the *IfcRelAssignsToProcess* relationship, where *QuantityInProcess* field shall refer to an *IfcMeasureWithUnit* instance where *ValueComponent* is set to one of the types listed in Table 6.

Table 6: Resource functional unit

Type	Description
IfcCountMeasure	Product is sold per unit.
IfcMassMeasure	Product is sold per unit mass.
IfcVolumeMeasure	Product is sold per unit volume.
IfcAreaMeasure	Product is sold per unit area.
IfcLengthMeasure	Product is sold per unit length.

4.6.2 Resource Use Properties

An *IfcConstructionResourceType* instance provides properties as listed in Table 7 using *IfcPropertySet* with *Name* "Pset_ResourceUse". Resource use properties are defined by ISO 14025 according to names listed.

Table 7: Resource use properties

Name	NominalValue	Unit	Description
PrimaryEnergyRenewableEnergy	IfcEnergyMeasure	MJ	Use of renewable primary energy excluding renewable primary energy resources used as raw materials as defined by ISO 14025 [PERE].
PrimaryEnergyRenewableMaterial	IfcEnergyMeasure	MJ	Use of renewable primary energy resources used as raw materials as defined by ISO 14025 [PERM].
PrimaryEnergyRenewableTotal	IfcEnergyMeasure	MG	Total use of renewable primary energy resources (primary energy and primary energy resources used as raw materials) as defined by ISO 14025 [PERT].
PrimaryEnenergyNonRenewable	IfcEnergyMeasure	MJ	Use of non-renewable primary energy excluding non-renewable primary energy resources used as raw materials as defined by ISO 14025 [PENRE].
PrimaryEnergyNonRenewableMaterial	IfcEnergyMeasure	MJ	Use of non-renewable primary energy resources used as raw materials as defined by ISO 14025 [PENRM].
PrimaryEnergyNonRenewableTotal	IfcEnergyMeasure	MJ	Total use of non-renewable primary energy resources (primary energy and primary energy resources used as raw materials) as defined by ISO 14025 [PENRT].
PrimaryEnergyTotal	IfcEnergyMeasure	MJ	Total use of primary energy resources as defined by ISO 14025 [PET].
SecondaryMaterials	IfcMassMeasure	Kg	Use of secondary materials as defined by ISO 14025 [SM].
RenewableSecondaryFuels	IfcEnergyMeasure	MJ	Use of renewable secondary fuels as defined by ISO 14025 [RSF].
NonRenewableSecondaryFuels	IfcEnergyMeasure	MJ	Use of non-renewable secondary fuels as defined by ISO 14025 [NSRF].
FreshWater	IfcVolumeMeasure	m3	Net use of fresh water as defined by ISO 14025 [FW].

4.6.3 Resource Impact Properties

An *IfcConstructionResourceType* instance provides properties as listed in Table 8 using *IfcPropertySet* with *Name* "Pset_ResourceImpact" with properties corresponding to EN 15804 Annex C Table C.1 and Table C.2.

Table 8: Resource impact properties

Name	NominalValue	Unit	Description
ClimateChangeTotal	IfcMassMeasure	kg	Global Warming Potential total (GWP-total) of CO2 as defined by EN 15804.
ClimateChangeFossil	IfcMassMeasure	kg	Global Warming Potential fossil fuels (GWP-fossil) of CO2 as defined by EN 15804.
ClimateChangeBiogenic	IfcMassMeasure	kg	Global Warming Potential biogenic (GWP-biogenic) of CO2 as defined by EN 15804.
ClimateChangeLandUse	IfcMassMeasure	kg	Global Warming Potential land use and land use change (GWP-luluc) of CO2 as defined by EN 15804.
OzoneDepletion	IfcMassMeasure	kg	Depletion potential of the stratospheric ozone layer (ODP) of CFC11 as defined by EN 15804.
Acidification	IfcAmountOf SubstanceMeasure	mol	Acidification potential, Accumulated Exceedance (AP) as defined by EN 15804
EutrophicationAquaticFreshwater	IfcMassMeasure	kg	Eutrophication potential, fraction of nutrients reaching freshwater end compartment (EP-freshwater) of PH4 as defined by EN 15804
EutrophicationAquaticMarine	IfcMassMeasure	kg	Eutrophication potential, fraction of nutrients reaching marine end compartment (EP-marine) of N as defined by EN 15804
EutrophicationTerrrestial	IfcAmountOf SubstanceMeasure	mol	Eutrophication potential, Accumulated Exceedance (EP-terrestrial) of N as defined by EN 15804.
PetrochemicalOzoneFormation	IfcMassMeasure	kg	Formation potential of tropospheric ozone (POCP) of Sb as defined by EN 15804.
DepletionOfMineralsAndMetals	IfcMassMeasure	kg	Abiotic Depletion Potential (ADP-mineral&metals) for non-fossil resources as defined by EN 15804.
DepletionOfFossilFuels	IfcEnergyMeasure	MJ	Abiotic Depletion Potential (ADP-fossil) for fossil resources as defined by EN 15804.
WaterUse	IfcVolumeMeasure	m3	Water (user) deprivation potential, depreciation-weighted water consumption (WDP) as defined by EN 15804
ParticulateMatterEmissions	IfcNormalisedRatio Measure		Potential incidence of disease due to PM emissions (PM) as defined by EN 15804.
IonisingRadiationHumanHealth	IfcNormalisedRatio Measure		Potential human exposure efficiency relative to U235 (IR) as defined by EN 15804.
Ecotoxicity	IfcPositiveRatioMea sure		Potential Comparative Toxic Unit for ecosystems (ETP-fw) as defined by EN 15804.
HumanToxicityCancer	IfcPositiveRatioMea sure		Potential Comparative Toxic Unit for humans (HTP-c) as defined by EN 15804.

Name	NominalValue	Unit	Description
HumanToxicityNonCancer	IfcPositiveRatioMeasure		Potential Comparative Toxic Unit for humans (HTP-nc) as defined by EN 15804.
LandUseImpact	IfcReal		Potential Soil quality index based on LANCA as defined by EN 15804.

4.6.4 Resource Waste Properties

An *IfcConstructionResourceType* instance provides properties as listed in Table 9 using *IfcPropertySet* with *Name* "Pset_ResourceWaste".

Table 9: Resource waste properties

Property	NominalValue	Unit	Description
HazardousWasteDisposed	IfcMassMeasure	kg	Hazardous Waste Disposed (HWD) as defined by ISO 14025.
NonHazardousWasteDisposed	IfcMassMeasure	kg	Non-Hazardous Waste Disposed (NHWD) as defined by ISO 14025.
RadioactiveWasteDisposed	IfcMassMeasure	kg	Radioactive Waste Disposed (RWD) as defined by ISO 14025.
ComponentsForReuse	IfcMassMeasure	kg	Components for Re-Use (CRU) as defined by ISO 14025.
MaterialsForRecycling	IfcMassMeasure	kg	Materials For Recycling (MFR as defined by ISO 14025.
MaterialsForEnergyRecovery	IfcMassMeasure	kg	Materials for Energy Recovery (MET) as defined by ISO 14025.
ExportedEnergyElectric	IfcEnergyMeasure	MJ	Exported electrical energy (EEE) as defined by ISO 14025.
ExportedEnergyThermal	IfcEnergyMeasure	MJ	Exported thermal energy (EET) as defined by ISO 14025.

4.6.5 Resource Transport Properties

An *IfcConstructionResourceType* provides properties as listed in Table 10 using *IfcPropertySet* with *Name* "Pset_ResourceTransport".

Table 10: Resource transport properties

Property	NominalValue	Unit	Description
TransportFuelConsumption	IfcVolumeMeasure	m3	Fuel used per unit distance at full capacity.
TransportPowerConsumption	IfcPowerMeasure	kg	Electrical energy used per unit distance at full capacity
TransportDistance	IfcLengthMeasure	km	Total distance of transportation
TransportUtilization	IfcNormalisedRatioMeasure		Utilization of transport capacity (including empty runs)

Property	NominalValue	Unit	Description
GrossDensity	IfcMassDensityMeasure		Bulk density of the transported products.
VolumeUtilizationFactor	IfcPositiveRatioMeasure		Volume utilization factor indicating the ratio of volume transported relative to delivered state (over 1 for compressed or packaged products)