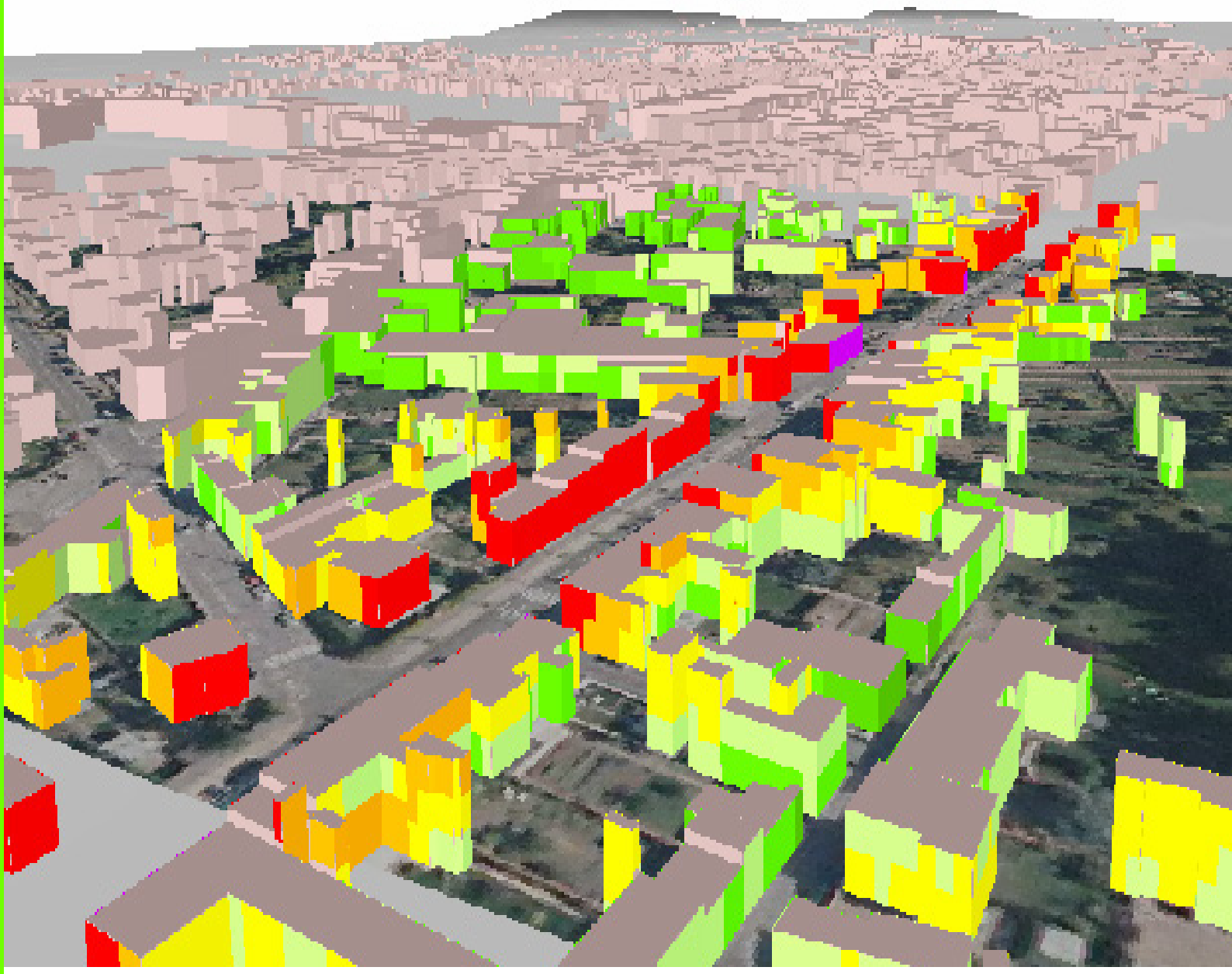
Sustainable Building Alliance

Linking SBA metrics with construction products manufacturers' BIM e-Catalogues



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“Linking SBA metrics with construction products manufacturers’ BIM e-Catalogues”

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Executive Summary

This document presents the state of the art and the scope of a project for linking SBA metrics with construction products manufacturers' BIM e-Catalogues. It proposes an approach based on the European generalization of the French INIES database which currently proposes such mechanism for the French construction products manufacturers for the registering of the energy consumption life cycle analysis results of their products. The approach is also based on links with BuildingSmart international organization for the registering of the IFC properties that can be associated to BIM objects for registering this sustainable information and the links with the manufacturer's products.

Glossary

The Proprietary format

A proprietary format is a file format where the mode of presentation of its data is the intellectual property of an individual or organization which asserts ownership over the format. In contrast, a free format is a format that is either not recognized as intellectual property, or has had all claimants to its intellectual property release claims of ownership. Proprietary formats can be either open if they are published, or closed, if they are considered trade secrets. In contrast, a free format is never closed. (Wikipedia, 2011) Example: DXF is an open, but proprietary format for transferring data between applications, whereas DWG is closed, native format of AutoCAD products. (Note: also closed formats may be reverse-engineered in order for third-party applications to read/write these file formats).

Open format

An open file format is a published specification for storing digital data, usually maintained by a standards organization, which can therefore be used and implemented by anyone. For example, an open format can be implementable by both proprietary and free and open source software, using the typical software licenses used by each. In contrast to open formats, closed formats are considered trade secrets. Open formats are also called free file formats if they are not encumbered by any copyrights, patents, trademarks or other restrictions (for example, if they are in the public domain) so that anyone may use it at no monetary cost for any desired purpose. (Wikipedia, 2011) NOTE: e.g. buildingSMART when referring to IFC as "neutral and open format specification" obviously uses the term "open" as synonym to "free"; this is usual the case when discussing "open standards" in broad sense (see e.g. EUROPEAN INTEROPERABILITY FRAMEWORK FOR PANEUROPEAN eGOVERNMENT SERVICES, ISBN 92-894-8389-X, © European Communities, 2004): The following are the minimal characteristics that a specification and its attendant documents must have in order to be considered an open standard: The standard is adopted and will be maintained by a not-for-profit organisation, and its ongoing development occurs on the basis of an open decision-making procedure available to all interested parties (consensus or majority decision etc.). The standard has been published and the standard specification document is available either freely or at a nominal charge. It must be permissible to all to copy, distribute and use it for no fee or at a nominal fee. The intellectual property - i.e. patents possibly present - of (parts of) the standard is made irrevocably available on a royalty free basis. There are no constraints on the re-use of the standard.

IFC File Formats

Industry Foundation Classes (IFC) is a neutral and open format specification, and is currently in the process of becoming the official International Standard ISO 16739. It is an object-based file format with a data model developed by buildingSMART (former known as International Alliance for Interoperability, IAI). IFC was developed to facilitate interoperability in the building industry. It has become a commonly used format for Building Information Modelling (BIM). IFC defines multiple file formats that may be used, and supports various encodings of the same underlying data. (Bentley Systems, 2008) IFC-SPF is a text format defined by ISO 10303-21 ("STEP-File"). IFC-SPF file consists of data strings where each line is a single object record. IFC-SPF file can be recognized by extension ".ifc". IFC-SPF is the most widely used IFC format, due to its advantage of compact size and human interface read-

able text. (Wikipedia, 2011) IFC-XML is an XML format defined by ISO 10303-28 ("STEP-XML"). IFC-XML file can be recognized by extension ".ifcXML". IFC-XML format is interoperable with XML tools and usable for exchanging partial building models. IFC-XML format is less common in practice due to the large size of typical building models. (Wikipedia, 2011) IFC-ZIP is a ZIP compressed format. IFC-ZIP consists of an embedded IFC-SPF file and can be recognized by extension ".ifcZIP". (Wikipedia, 2011).

WEB Services

A Web service is a method of communication between two electronic devices over the World Wide Web. A Web service is a software function provided at a network address over the web or the cloud, it is a service that is "always on" as in the concept of utility computing.

1 Introduction

1.1 Objectives of the study

The objective of this study is to define WEB and BIM based methodology for assisting construction products manufacturers to declare and publish the SBA indicators of their solutions and to allow the retrieving and usage of these indicators in IFC BIM compliant tools for global SB Analysis of the buildings.

This study includes the specifications of IFC Property Sets (in particular for extensions of these properties for Thermal comfort and Indoor air quality) and WEB Services for allowing manufacturers' products SBA indicators archiving and publishing on a SB Alliance linked online facility.

It also prepares future prototyping and demonstration of this facility with the INIES database and the eveBIM and Mbbds software tools.

This research will provide, to building designers (architects, engineers), a better knowledge on the new construction products and systems capabilities in terms of SB and to products manufacturers a better advertising and prescription on their solutions.

It will also potentially bring some new outputs of the SB Alliance, with some rich WEB content, that could be accessed through the sballiance.org site.

1.2 The BuildingSmart international new organization

More and more countries (eg. USA, UK, Scandinavian countries, Singapore, France, Netherlands etc…) are preparing new business rules for public markets in construction projects based on the usage of BIM. BIM will be used for the communication between the designer, constructors and owners, during the development phases and BIM will be required for the data deliveries of these different phases.

Because, these BIM rules cannot be based on a proprietary format, coming from a particular country and one software vendor, the BuildingSmart International organisation, in charge of the development of the IFC standard, which is now ISO, is the only worldwide organisation which is relevant for the scope of this public project.

The BuildingSmart organization as set a new organization:

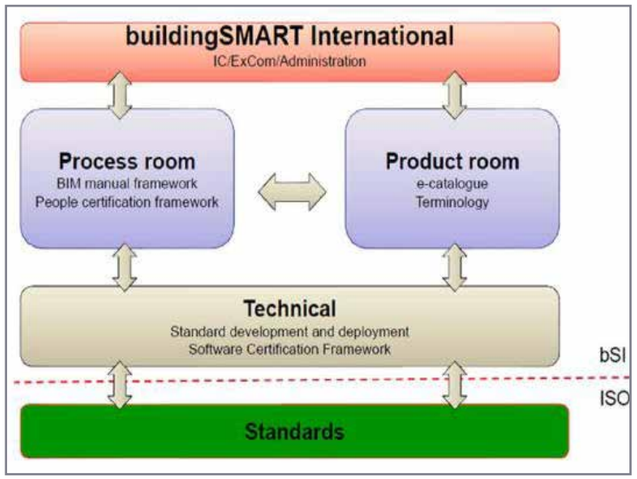


Figure 1 : The BuildingSmart organization

The elements of this new organization are the following:

- The buildingSMART International entity is in charge of the global management of the organisation;

The Process room is in charge of defining and formalising the different use cases and associated exchanges processes between construction actors using IFC standard; In particular, it is in charge of development of IDM and process maps.

- The Product room is in charge of defining the property dictionaries and standard languages for defining construction products e-catalogues; compliant with IFC bases exchanges processes;
- The Technical entity is in charge of the development of the IFC standard and also of the development of the software certification framework, for better quality of the IFC based converters;
- IFC4 standard is now and ISO standard, published with n° ISO 16739.

In particular, in this organization, the Product room, is the place now where new object properties like our SBA metrics will be discussed.

1.2.1 IDM the BuildingSmart recommendation for process formalisation

IDM captures (and progressively integrates) business process whilst at the same time providing detailed specifications of the information that a user fulfilling a particular role would need to provide at a particular point within a project. To further support the user information exchange requirements specification, IDM also proposes a set of modular model functions that can be reused in the development of support for further user requirements. IDM is a guideline, a method for formalising exchange and processes among partners. Therefore, there should be one Interchange Manual per process, which can be seen and considered as the expression of formal requirements for the described process.

From a pragmatic point of view, IDM starts with a high level graphical description of the process. This part is called the "Process Map". The formalism used to translate the process into a drawing (the so called "Process Map") is based on a standard, the BPMN. OMG is maintaining the BPM Notation (Business Process Modelling Notation). The BPMN is the recommended notation for the first part of the IDM methodology (ISO/DIS 29481-1). The goal of BPMN is to provide a standard notation that is readily understandable by all business stakeholders. BPMN is intended to serve as common language to bridge the communication gap that frequently occurs between business process design and implementation by providing a notation that is intuitive to business users yet able to represent complex process semantics.

The second part focus on the description of the exchange (data flow) among the different identified sub-processes. This part has some recommendation in terms of formalism but no specific standard support it. It is recommended that the description of the exchange should be done using natural language in order to be elaborated in conjunction with non technical users.

Third and last part of the IDM is the functional part. This is the most technical one. After the high level analysis of the process (PM) and the description "in natural language" of different exchanges, it is then time to indicate what will be the basic technical elements that will support the data flow, keeping the semantics of the exchange. This part will also identify the common basic blocks that are used at different places all along the process.

It is also very important to stress the fact that BuildingSMART it not promoting "yet another standard". The approach chosen, is to rely on validated and trustable standards tailored for the needs of the Construction Sector.

1.2.2 Process Maps

A process map describes the flow of activities for a particular business process.

It enables the understanding of the configuration and the relationships among of activities that make the whole process work. It also describes the actors involved (according to the roles they are playing in the process), the information required, consumed and produced by these actors.

A process map may capture one or more "events" at which a requirement for the exchange of information is specified.

Process models in general are a great tool to help spot processing gaps and inefficiencies. The benefit of a swim lane process model is that it allows the user to quickly and easily plot and trace processes and, in particular, the interconnections between different process steps. These interconnections, especially when linked to a transfer in responsibility, are the causes for many process problems.

The swim lane technique maps processes linearly as a series of tasks. Lines and arrows between tasks represent the flow of information, goods or work-in-progress. Swim lanes organize process steps by themes, thematically related activities are arranged in one swim lane.

Swim lanes comprise activities bundled according to their thematic cohesion, and are used for the clear demarcation of relationships within the process.

The lanes do not reflect organizational units. It does not matter which organization is responsible for a process step to place it into a certain swim lane. Since the lanes do not reflect organizational units, they are resistant to changes in organization and provide a good foundation for a generic process model.

Below is an example of a process map describing the process of "Energy Analysis" during the design phase. It shows three different levels of details from one simplified high level view (provided with no specific swim-lane) to detailed maps at level 2 and level 3.

At level 2, the task number 2 of the first high level map is decomposed into several subtasks that are placed in different lanes according to the actors concerned by these subtasks.

For level 3, the same approach is applied and the task 2.5 is decomposed in one process with several sub-tasks.

It is worth mentioning that the notation used to represent these Process Maps relies on BPMN (Business Process Model and Notation) which is a standard maintained by the OMG (Object Management Group).

Note: The example is from the IDM for energy analysis, by Jeffrey Wix, AEC3 Ltd.

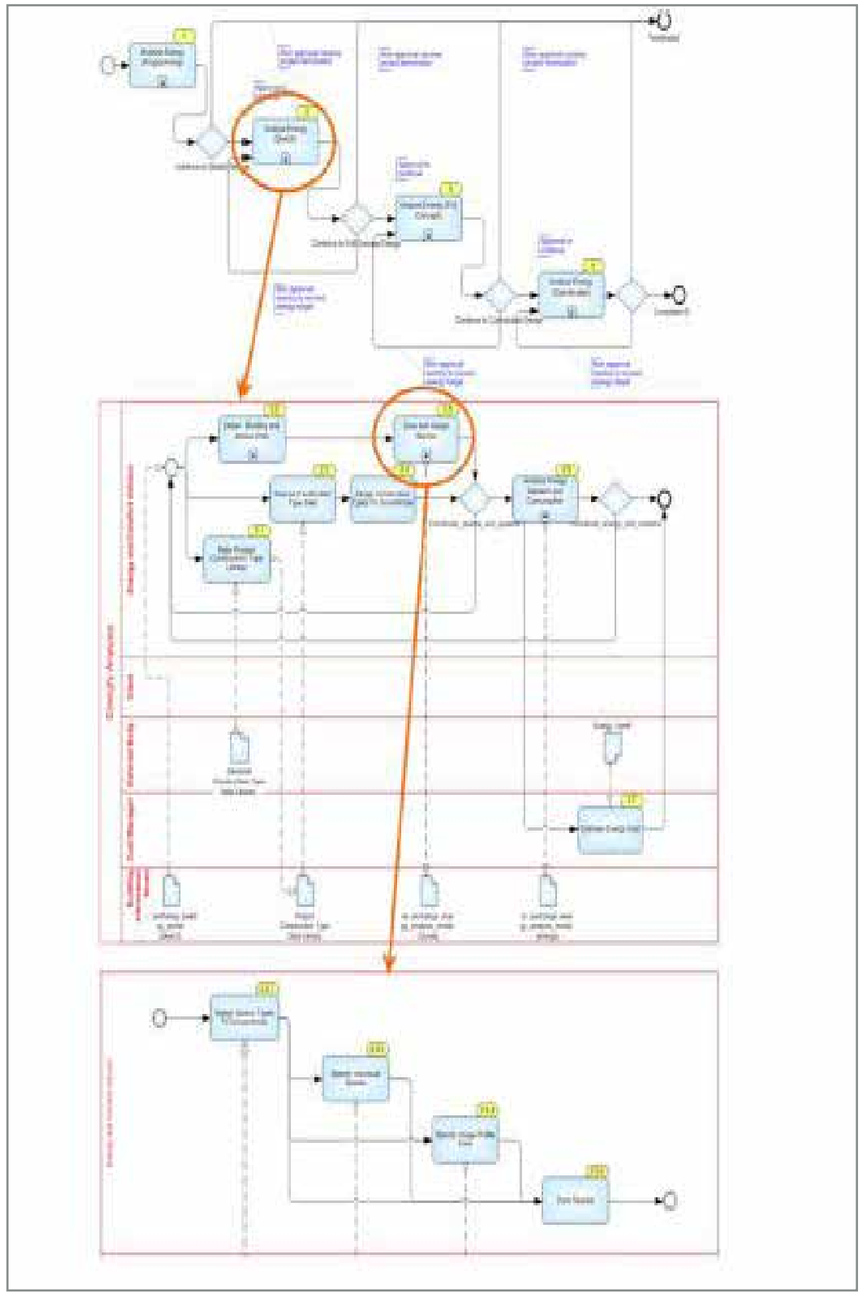


Figure 2 : The IDM multiple level process map syntax.

1.3 Links between BIM tools and BIM-Catalogs

1.3.1 The eveBIM – Elodie Chain

The SBA metrics - BIM software chain could take inspiration from the eveBIM – Elodie, as described below:

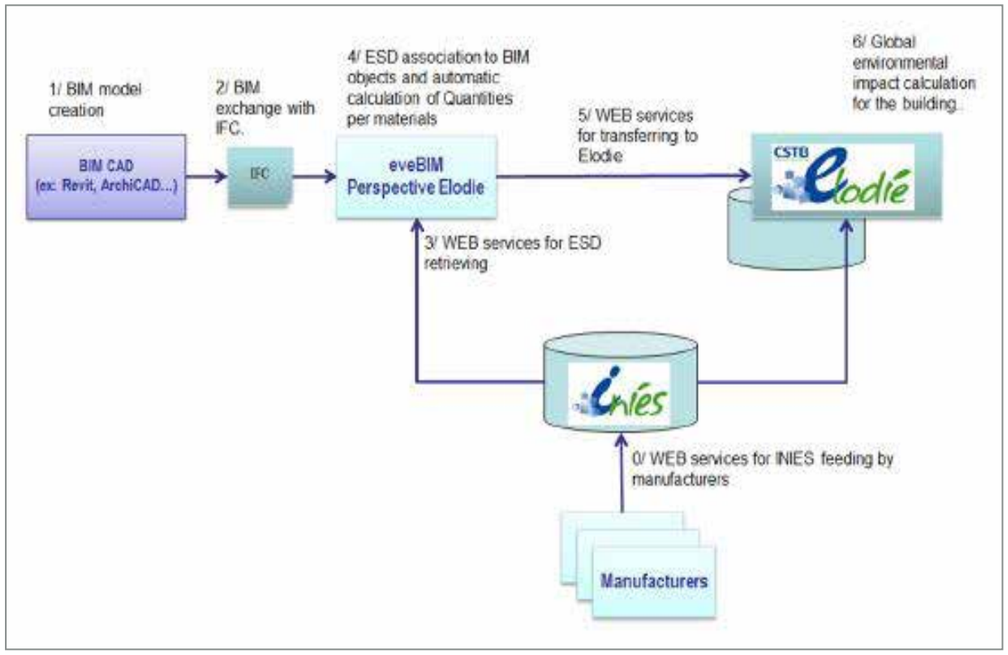


Figure 3 : the eveBIM – Elodie chain

The different steps of the eveBIM – Elodie chain are the following:

0/ Construction product manufacturers can access published authoring WEB services for feeding the INIES database of the Environmental and Sanitary Declarations (ESD) with the life cycle analysis results of their products;

1/ architects or engineers can use BIM CAD tools (ex: Autodesk Revit, Graphisoft ArchiCAD, Nemetscheck Allplan…) for developing their construction models;

2/ these construction models can be exported in IFC format and loaded into eveBIM (IFC viewer en enriching) software

3/ Thanks to published reading WEB services, eveBIM is able to access the INIES database for retrieving the last version of the ESD;

4/ within eveBIM, engineers can associate ESD to BIM objects. eveBIM performs then the automatic calculation of ESD quantities, corresponding to the construction model.

-> Without such BIM association capability, calculation of these quantities is about 80% of the time spent by engineers for building life cycle analysis.

5/ another WEB Service is provided for sending the BIM calculated project to the online Elodie software;

6/ Elodie is then able to perform the life cycle analysis of the complete building.

1.3.2 The IFC Configurators Concept for construction systems

Construction systems correspond to the new approach of manufacturers. It provides multimaterial constructive solution validated by the rules of art or Technical Advice. Systems are composed of set of products with rules for implementing.

The systems approach, integrating all the prefabricated and sustainable capabilities, is the manufacturer's solution for helping the designers in sustainable global design and also speeding up the construction process.

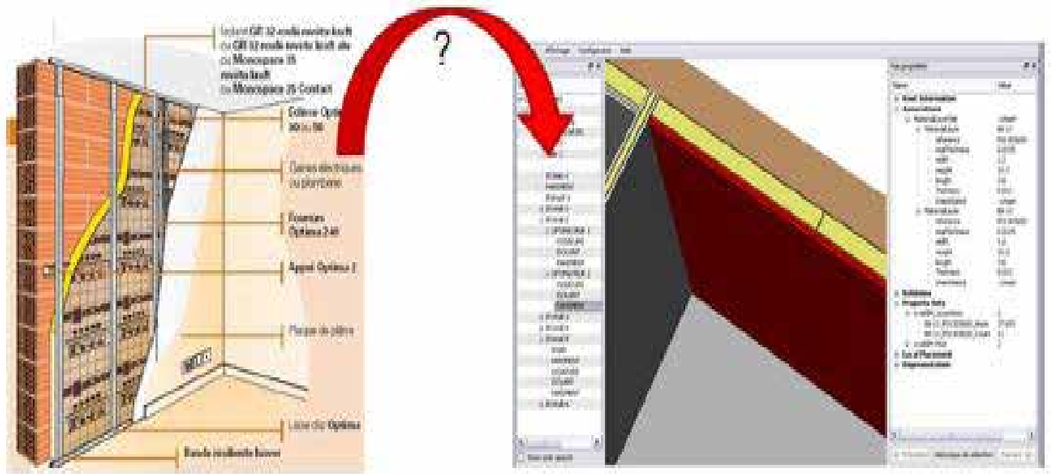


Figure 4 : How defining a parametric construction system in IFC ?

The IFC configurator's concept, as described below, provides a mechanism for defining such multi-products systems with their assembly logic:

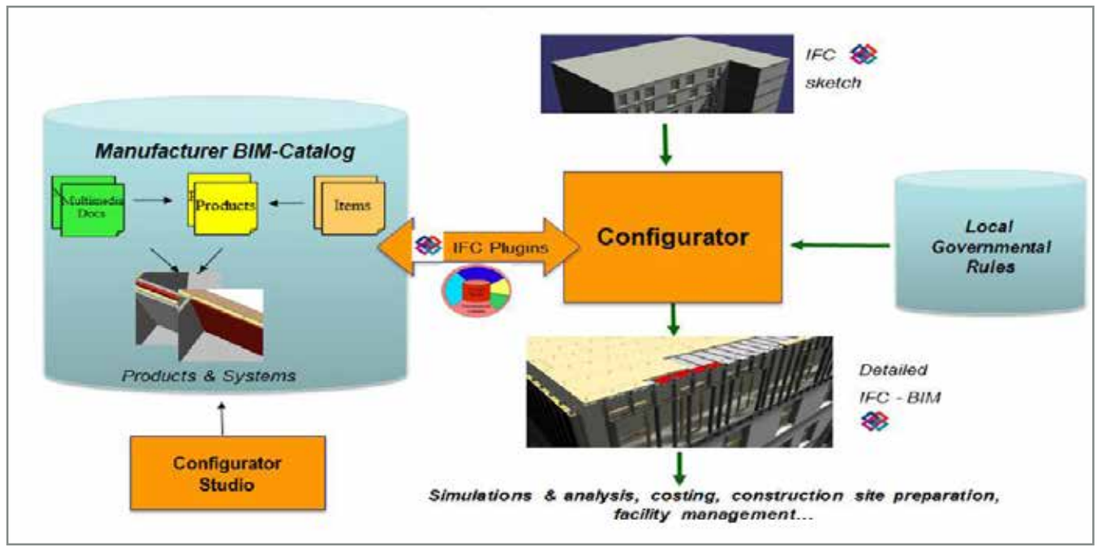


Figure 5 : The IFC Configurators concept for Products & Systems

The different elements of the IFC Configurator's concept are the following:

- First of all, manufacturers have to define their systems as IFC plugins, carrying the assembly logic of the embedded products;
- Architect can produce a first sketch of the building, with giving the main spaces and architectural elements (walls, slabs, openings..) without getting into the details;
- This sketch can be processed by a configurator tool able :
  - To select, into the manufacturer BIM Catalogue, the appropriated system, corresponding to the input sketch and the different relevant local rules;
  - Run the manufacturers IFC Plugins who will automatically create the construction products assembly with geometry and associated properties (including SBA indicators).
- Configurator is then able to generate detailed and manufacturers' properties enriched IFCBIM for very detailed and accurate analysis.

2 Specifications of IFC PropertySets for SBA Metrics indicators integration by BuildingSmart in IFC 4 extensions

2.1 The IFC4, structure of the open language

The building sector's Industry Foundation Classes IFC represent an open specification for Building In-formation Modeling BIM data that is exchanged and shared among the various participants in a building construction or facility management project. IFC's are the international openBIM standard.

The IFCs were originally developed to describe building components in an objectified way (Liebich, 2010). Since the beginning a lot of improvement has been made but the integration of sustainable/ environmental notions is quite new as it has been done in the last release. In this latest version (IFC4) several enhancements have been done. Nevertheless, all notion related to Sustainability are not already taken into account.

Now the IFC counts approximately 800 entities.

Based on STEP principles, the IFC data model is an object oriented model that separates the object identification and the associated properties, including potential different geometric representations and materials association. The following EXPRESS-G diagram (see Figure below) presents the backbone of the IFC data model.

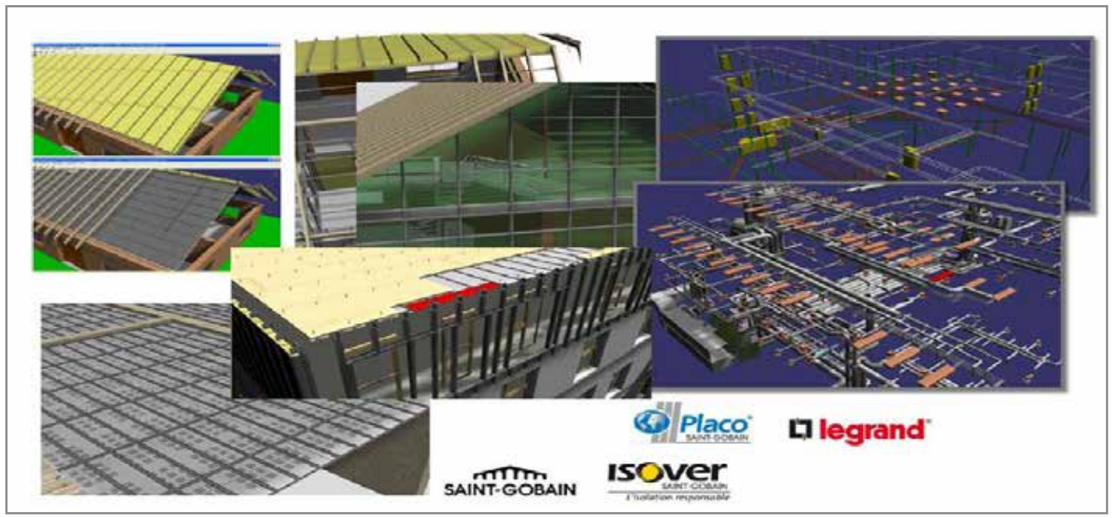


Figure 6 : Examples of IFC Configurators first realizations.

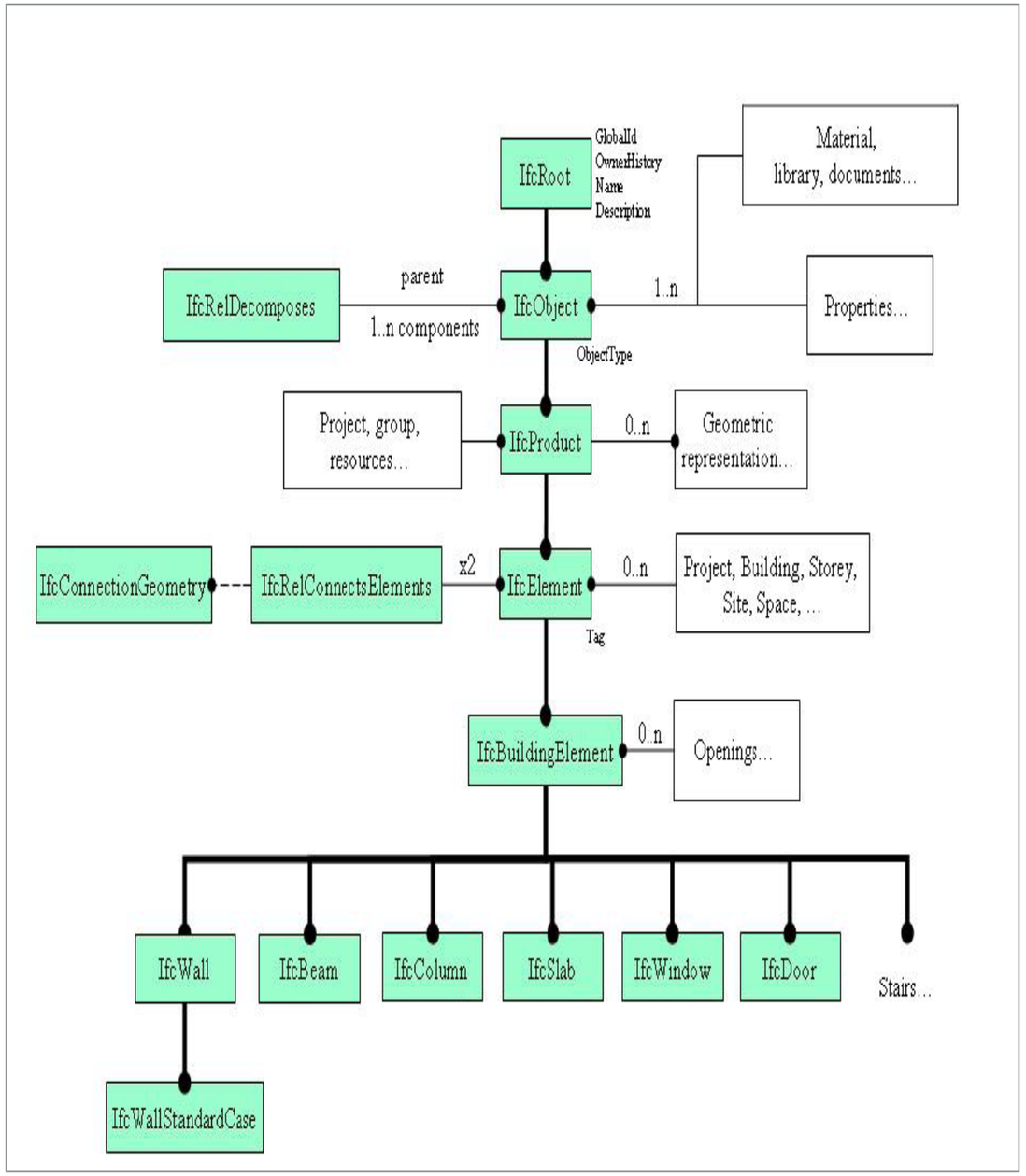


Figure 7: Back bone of the IFC data model (EXPRESS-G diagram)

2.2 The "Property Sets" and "Quantity SETS" mechanisms

2.2.1 Property Sets

In the IFC4 documentation, a Property set is presented as ""any specialization of object can be related to multiple property set occurrences. A property set contains multiple property occurrences. The data type of property occurrence are single value, enumerated value, bounded value, table value, reference value, list value, and combination of property occurrences. "

There is a high demand from manufacturers for solutions allowing better integration of their product libraries in application tools (such as design tools), and supporting automated information exchange and sharing. Several initiatives have been launched to improve the situation by developing semantic links between product libraries and product data models, as well as infrastructures to better support access to product information from design or procurement tools. Generally speaking this raises the problem of convergence between classifications and product modelling.

In the construction domain, for instance, IFC-based implementation of product libraries have good prospect for meeting the industry requirements. Indeed, while IFC classes represent generic categories of element (e.g. wall, beam, space) with very few attributes associated with a class to transfer information relevant to a manufacturer, IFCs incorporate a mechanism called Property Sets (PSets) which allow information publishers to dynamically allocate new properties to an object they wish to describe.

Since there are numerous alphanumeric attribute definitions depending on discipline, life-cycle stage, building regulation and region, there will never be a complete set of internationally standardized attributes.

Therefore, IFC defined property sets intent to standardize a basic set of properties, whereas other property sets can be regionally defined, or agreed upon in projects.

The current drawback, however, is that there is no specification of the semantics of PSet information outside that published in the IFC distribution (PSD - Property Set Definition - Schema for the definition of property sets and properties).

As an example, below is the list of properties defined in the PSet attached to the common entity IfcBoilerType:

- PressureRating
- OperatingMode
- Material
- HeatTransferSurfaceArea
- NominalPartLoadRatio
- WaterInletTemperatureRange
- WaterStorageCapacity
- IsWaterStorageHeater
- Weight
- PartialLoadEfficiencyCurves
- NominalEfficiency
- HeatOutput
- OutletTemperatureRange
- NominalEnergyConsumption

It is important to stress the assets of such mechanism. IFC objects can have properties attached to them. The IFC model differentiates between attributes that are directly attached to the object as attribute of the entity, and properties, group in a property set and assigned to the object by a relationship. The latter is the more flexible way to extent applicable properties.

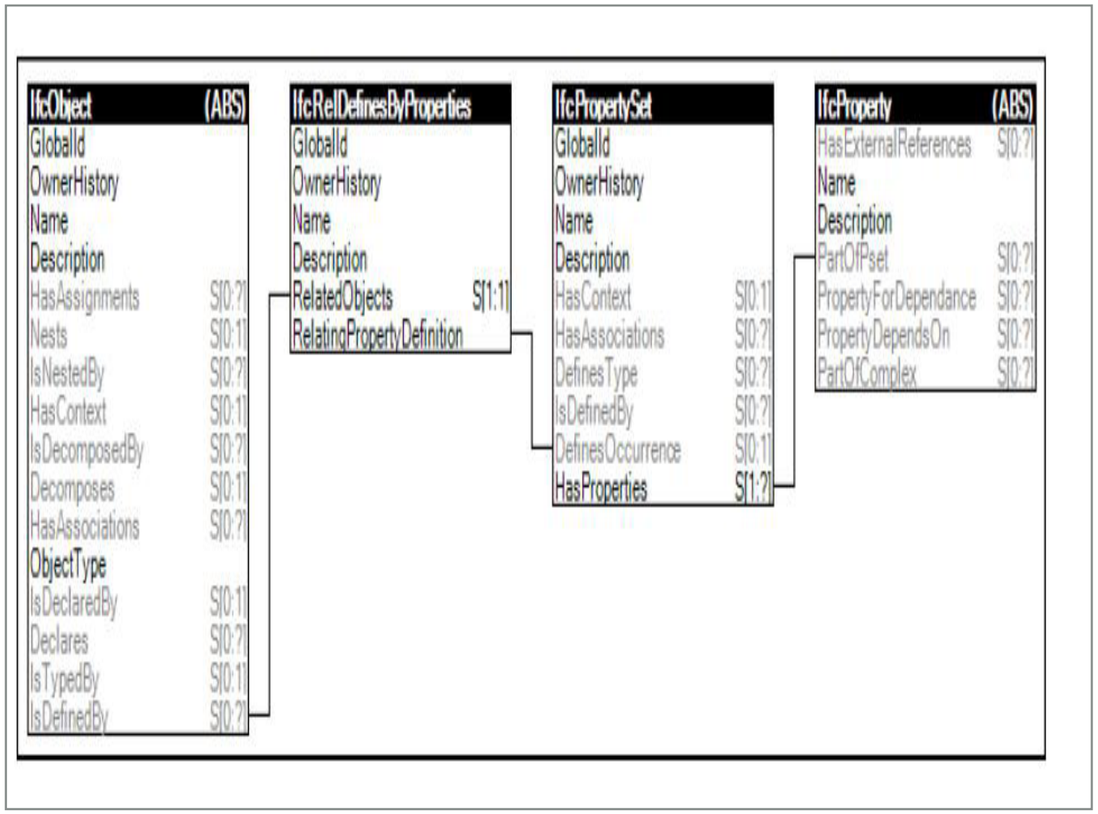


Figure 8 : Linking mechanism between an IfcObject and a Property Sets

Furthermore these properties may be specific to particular regions, projects or process. The IFC schema supports storing and transmitting these properties in named sets (so called "IfcPropertySet"). Therefore, a property set is a collection of properties that can be declared outside of the IFC schema but that can as-signed to all objects defined within the IFC schema.

In the case of a BIM way of working and a process lead approach, It is worth defining well-suited property sets commonly agreed by parties as the right structure to convey the domain specific information between BIM and this specific activity.

In the current version IFC4, there are more than 400 property sets already defined.

2.2.2 Quantity Sets

A quantity set contains multiple quantity occurrences. The data type of quantity occurrence values are count, length, area, volume, weight, time, or a combination of quantities. Each quantity is defined by its name, value, and optionally a description and a formula.

The quantity set is expressed by instances of IfcElementQuantity, where the Name attribute determines the common designator of the quantity set. This specification contains a number of predefined quantity sets, a template definition is provided for each of them in the documentation.

The name of the template has to be used as the value of the Name attribute. The MethodOfMeasurement attribute specifies the method, by which the values of the individual quantities are calculated. For the quantity set templates included in this specification, the value of MethodOfMeasurement shall be "BaseQuantities".

The figure below illustrates an instance diagram.

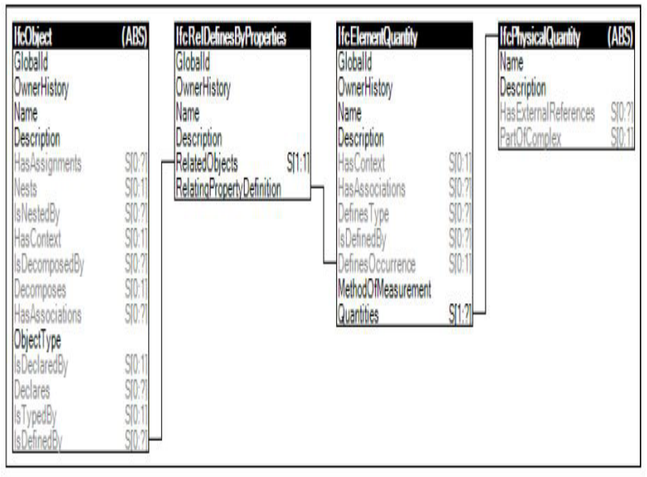


Figure 9 : Linking mechanism between an IfcObject and a Quantity Set

There are currently 91 quantity sets defined in the IFC4.

2.3 Environmental Property sets and their connections with Building elements

In the scope of this deliverable it is worth mentioning again two property sets that have just been introduced in this recent version of the IFC.

The first one is the property set "Pset_EnvironmentalImpactIndicators" which official definition is "Environmental impact indicators are related to a given "functional unit" (ISO 14040 concept). An Example of functional unit is a "Double glazing window with PVC frame" and the unit to consider is "one square meter of opening elements filled by this product". Indicators values are valid for the whole life cycle or only a specific phase (see LifeCyclePhase property). Values of all the indicators are expressed per year according to the expected service life. The first five properties capture the characteristics of the functional unit. The following properties are related to environmental indicators. There is a consensus agreement international for the five one. Last ones are not yet fully and formally agreed at the international level".

The second one is the property set "Pset_EnvironmentalImpactValues" which official definition is "the following properties capture environmental impact values of an element.

They corre-spond to the indicators defined into Pset_EnvironmentalImpactIndicators. Environmental impact values are obtained multiplying indicator value per unit by the relevant quantity of the element".

These two property sets are strongly interrelated as the first one is dedicated to the definition of the considered indicator(s) along with its unit(s) and validity domain(s). The table below details the different properties of the two property sets.

Table 1 : List of properties for the two environmental property sets

Pset_EnvironmentalImpact Indicators	Pset_EnvironmentalImpact Values
• EutrophicationPerUnit	• AtmosphericAcidification
• WaterConsumptionPerUnit	• NonRenewableEnergyConsumption
• PhotochemicalOzoneFormationPerUnit	• InertWaste
• NonRenewableEnergyConsumptionPerUnit	• PhotochemicalOzoneFormation
• ExpectedServiceLife	• RadioactiveWaste
• RadioactiveWastePerUnit	• NonHazardousWaste
• Unit	• ResourceDepletion
• NonHazardousWastePerUnit	• WaterConsumption ·
• LifeCyclePhase	• RenewableEnergyConsumption
• RenewableEnergyConsumptionPerUnit	• StratosphericOzoneLayerDestruction
• Reference	• HazardousWaste
• ResourceDepletionPerUnit	• ClimateChange
• StratosphericOzoneLayerDestructionPerUnit	• Eutrophication
• HazardousWastePerUnit	• TotalPrimaryEnergyConsumption
• ClimateChangePerUnit	
• AtmosphericAcidificationPerUnit	
• TotalPrimaryEnergyConsumptionPerUnit	
• InertWastePerUnit	
• FunctionalUnitReference	

They are commonly attached to the notion of IfcElement which is an abstract concept in the IFC ontology (see detailed description of the IfcElement in the paragraph below).

2.4 The IfcElement and its relations with environmental properties

2.4.1 Description of the IfcElement Structure and connexions

An IfcElement is a generalization of all components that make up an AEC product. Those elements can be logically contained by a spatial structure element that constitutes a certain level within a project structure hierarchy (site, building, storey or space).

In the documentation, the connection between an IfcElement and a property set is illustrated as follows :

The only property sets allowed to be attached to the IfcElement are:

- Pset_Condition
- Pset_EnvironmentalImpactIndicators
- Pset_EnvironmentalImpactValues
- Pset_ManufacturerOccurrence
- Pset_ManufacturerTypeInformation
- Pset_PackingInstructions
- Pset_ServiceLifePset_Warranty

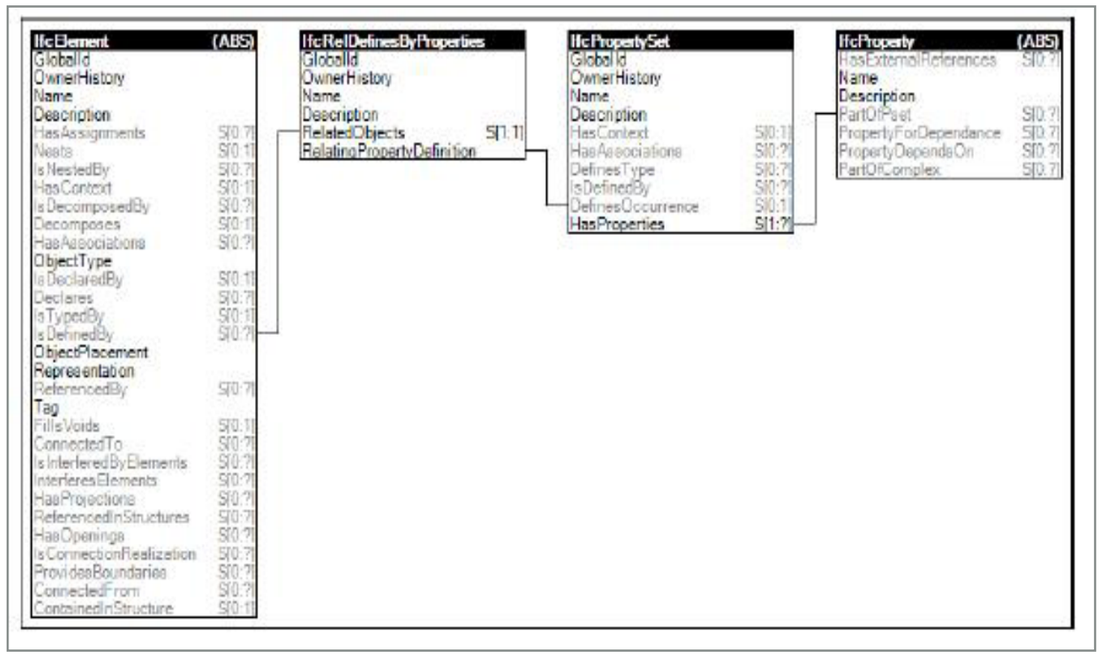


Figure 10 : definition of the IfcElement concept and its connection with property sets.

In other words, there is a hierarchy of concepts and according to the IFC ontology model, the only way to bind the environmental property sets described above to an IFC consist in attaching these "P_Sets" to the IfcElement as illustrated below.

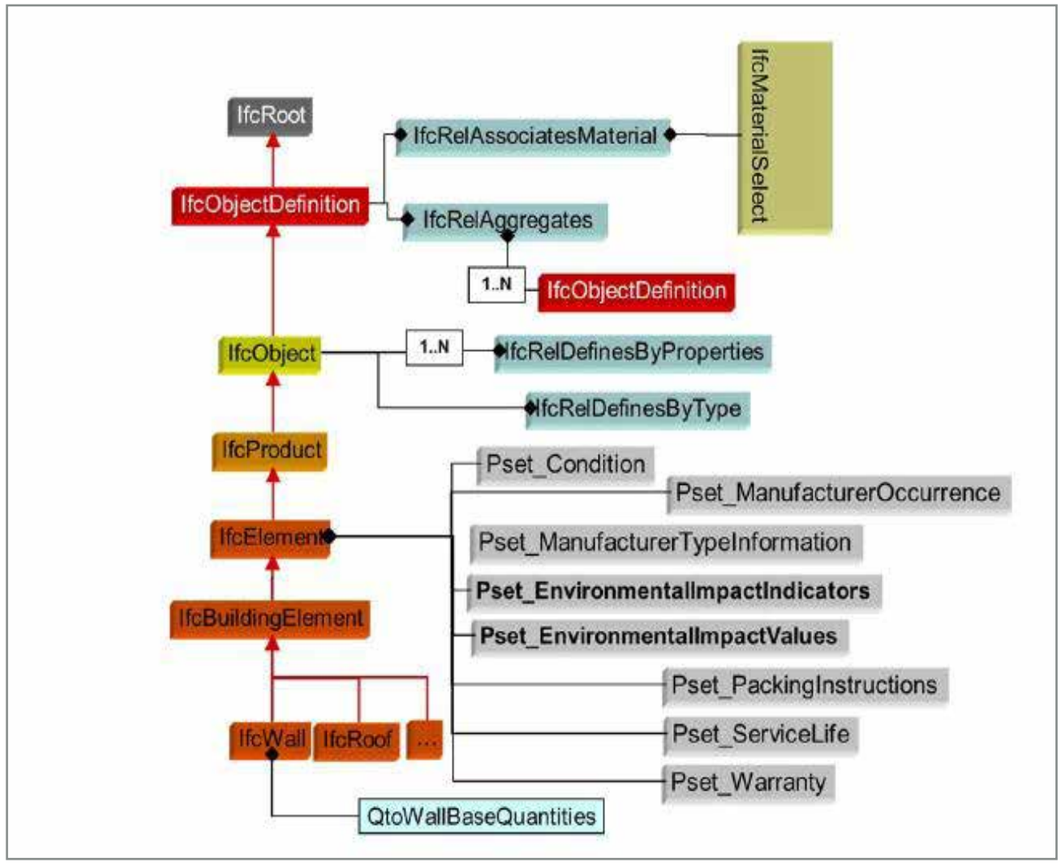


Figure 11 : Taxonomy of concepts below the IfcObject

At the lower level of the figure above are represented various concepts that are directly referring to building component (or building elements). All these objects that can be described as « child objects » in the current representation are inheriting from their « fathers » their different properties. Therefore, it is possible to « attach » the property sets available at the IfcElement or IfcObject level to an « IfcBeam », an « IfcWall » or similar.

2.4.2 Link between building elements, quantities and materials

IfcMaterial

The different elements listed below the concept of IfcBuildingElement like IfcWall, IfcDoor, IfcBeam, etc… are related to the concept of material (named « IfcMaterial ») which allows to express what the considered element is made of. IfcMaterial is the basic entity for material designation and definition; this includes identification by name and classification (via reference to an external classification), as well as association of material properties (isotropic or anisotropic) defined by (subtypes of) IfcMaterialProperties. The different Qto_xxxBaseQuantities

As introduced earlier, there are several quantity sets specifically defined to express the quantities that are common to the definition of all occurrences of a sub-element of IfcBuildingElement. For instance, there are the correspondences shown in the table below.

Sub element of IfcBuildingElement	Corresponding Quantity Sets
IfcBeam	Qto_BeamBaseQuantities
IfcChimney	IfcQto_ChimneyBaseQuantities
IfcColumn	Qto_ColumnBaseQuantities
IfcDoor	Qto_DoorBaseQuantities
IfcRoof	Qto_RoofBaseQuantities
IfcSlab	Qto_SlabBaseQuantities
IfcWall	Qto_WallBaseQuantities
IfcWindows	Qto_WindowBaseQuantities

Table 2 : Examples of IfcBuildingElements and their corresponding quantity sets

These sets are provided in order to define in an accurate and non-ambiguous way the meanings of the values attached to each of these building elements. · Example of the « Qto_WallBaseQuantities »

The table below illustrates how these Qtos are structured in order to define with a contextual and accurate semantic meaning the different quantities that are usually attached to the mentioned building elements.

Property	Definition
Length	Total nominal length of the wall along the wall center line (even if different to the wall path).
Width	Total nominal width (or thickness) of the wall measured perpendicular to the wall path. It should only be provided, if it is constant along the wall path
Height	Total nominal height of the wall. It should only be provided, if it is constant along the wall path.
GrossFootprintArea	Area of the wall as viewed by a ground floor view, not taking any wall modifications (like recesses) into account. It is also referred to as the foot print of the wall.
NetFootprintArea	Area of the wall as viewed by a ground floor view, taking all wall modifications (like recesses) into account. It is also referred to as the foot print of the wall.
GrossSideArea	Area of the wall as viewed by an elevation view of the middle plane of the wall. It does not take into account any wall modifications (such as openings).
NetSideArea	Area of the wall as viewed by an elevation view of the middle plane. It does take into account all wall modifications (such as openings).
GrossVolume	Volume of the wall, without taking into account the openings and the connection geometry
NetVolume	Volume of the wall, after subtracting the openings and after considering the connection geometry.
GrossWeight	Total gross weight of the wall, without add-on parts, not taking into account possible processing features (cut-out's, etc.) or openings and recesses.
NetWeight	Total net weight of the wall, without add-on parts, taking into account possible processing features (cut-out's, etc.) or openings and recesses.

Table 3 : List of the properties of the Qto_WallBaseQuantities

2.5 The remaining environmental indicators

2.5.1 The metrics taken into account and results from previous study

The SBA Core Indicators considered since the last study (carried out in 2011) are the followings (10 individual indicators, in 6 sub-categories of 3 main categories):

1. Resource depletion

    1.1. Use of non-renewable primary energy in [kWh/m2]

    1.2. Water consumption in [m3/time period]

2. Indoor environment quality

    2.1. Thermal comfort: For summer and winter settings [% time out of range] of minimum and maximum temperature

3. Indoor air quality

    3.1. Concentration of CO_2 [ppm] during the occupied period

    3.2. Formaldehyde concentration [µg/m3]

4. Building emissions

    4.1. Global Warming Potential: Global Warming Potential (GWP100) [kg CO2 eq/<unit>] (according to IPCC 2001)

5. Solid wastes production

    5.1. [Tonnes Hazardous waste]

    5.2. [Tonnes non-Hazardous waste]

    5.3. [Tonnes Inert waste]

    5.4. [Tonnes Nuclear waste]

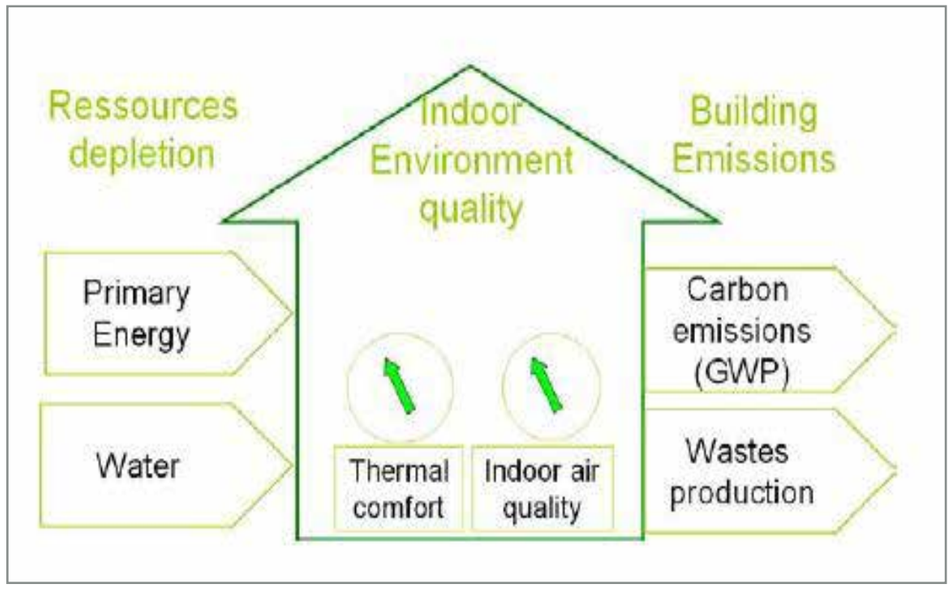


Figure 12 : The six SBA Core Indicators described in the 2009 version (SBA, 2010)

The table below shows when these indicators should be considered according to the considered life cycle of the building.

Indicator	Before use stage					Use Stage				End of Life Stage			
	Product Stage			Construction Stage							Disposal Stage		
	Raw Material Process	Transport	Manufacturing	Transport	Construction Installation Process	Operation of building-incorporated services	Operation of non building- incorporated appliances	Maintenance, repair and refurbishment	Transport (of people)	Deconstruction	Transport	Recycling, reuse and energy recovery	Waste Disposal
GWP													
Energy													
Water													
Waste						*	*						
IEQ													

Stages included for each indicator				
		Required in 2009 version		Optional in 2009 version
		Not included in 2009 version		Not relevant

Table 4 : Life cycle stages included in the 2009 version (SBA, 2010).

* The 2009 version only includes for the operational stage the nuclear wastes linked to energy production The detailed description of the indicators, the data needed to their calculation and the requirements and limitations of their calculation according to SBA can be found in (SBA, 2010). The main outcomes of the previous study with respect to the support by the IFC of these indicators was the following:

How SBA metrics fit into IFC ?

The following table establishes a mapping between SBA core metrics (version 2009 validated beginning 2010) and the environmental property sets proposal in IFC4 standard. There are already some gaps identified at that level.

As said previously, even the new 2X4 version provides with a better support of sustainable/ environmental notions, there is still room for improvement. For example, the notion of Life cycle stage still applies at the project level (via the use of the ifcContext" entity) as it should be also available at the product level when coupled with the SBA core indicators.

Another gap is the lack of support of some SBA core indicators like the Indoor Environmental Quality indicators. This point is detailed in next page.

As defined by SBA, the notion of "IEQ" (Indoor Environmental Quality) counts two major indicators that are namly:

- The thermal comfort:

For summer and winter settings [% time out of range] of minimum and maximum temperature

- The Indoor air quality (IAQ):

The IAQ is composed of two metrics:

- The Concentration of CO2 [ppm] during the occupied period;
- Formaldehyde concentration [µg/m3]

It worth noticing here that these indicators are defined for the "Use stage" and are considered as "not relevant" for the 2 other stages considered by SBA ("Before use stage" and "End of life stage").

IEQ and IAQ:

Looking at the existing and already defined Property Sets in the IFC, there are no specific pset dedicated to these indicators (something like "pset_IEQ_space") and looking at IAQ leads to the same conclusion: No specific already predefined structure to express and convey such information or measurement.

Thermal Comfort:

In the IFC4, several Property sets are already dealing with the notion of Thermal comfort. (from the Core Data Schema)

- Pset_SpaceThermalDesign: Space or zone HVAC design requirements. It's a new property set corresponding to the previous "Pset_SpaceHvacInformation";
- Pset_SpaceThermalLoad: The space thermal load defines all thermal losses and gains occurring within a space or zone. The thermal load source attribute defines an enumeration of possible sources of the thermal load. The maximum, minimum, time series and app;
- Pset_SpaceThermalLoadPHistory: WThe space thermal load IfcSpaceThermalLoadProperties defines actual measured thermal losses and gains occurring within a space or zone. The thermal load source attribute defines an enumeration of possible sources of the thermal load;
- Pset_SpaceThermalPHistory: Thermal and air flow conditions of a space or zone;
- Pset_SpaceThermalRequirements: Properties related to the comfort requirements for thermal and other thermal related performances of spaces that apply to the occurrences of IfcSpace or IfcZone. This includes the required design temperature, humidity, and air conditioning;
- Pset_ThermalLoadAggregate: The aggregated thermal loads experienced by one or many spaces, zones, or buildings. This aggregate thermal load information is typically addressed by a system or plant;
- Pset_ThermalLoadDesignCriteria: Building thermal load design data that are used for calculating thermal loads in a space or building. It's a new property set corresponding to the previous " Pset_LoadDesignCriteria".

SBA metric	IFC4 corresponding property*	Comments
IEQ:	*See the details in the paragraph above.*	*Only notions related to thermal comfort are well covered. IAQ is not already taken into account explicitly (it could be proposed but there is not yet an agreed way of doing it).*
Global warming potential (GWP)	*ClimateChange* : Quantity of greenhouse gases emitted	in kg eq CO2/m^2
Use of non renewable primary Energy	*NonRenewableEnergyConsumption* : Quantity of non-renewable energy used	in kWh/m^2
Water consumption	*WaterConsumption* : Quantity of water used expressed	in m^3/time unit
hazardous Waste	*HasardousWaste* : Quantity of hazardous waste generated	in t/m^2
Non hazardous	*NonHasardousWaste* : Quantity of non hazardous waste generated	in t/m^2
Inert waste	*InertWaste* : Quantity of inert waste generated	in t/m^2
Nuclear waste	*RadioactiveWaste* : Quantity of radioactive waste generated	in t/m^2

Table 5 : IFC4 environmental property set suitability for SBA Environmental metrics calculation

*All these properties can be given in the model for the whole life cycle or only for a given phase.

2.5.2 IFC4 support for IEQ and IAQ – Proposal for support

The IFC4 version remains the same and a demand to integrate the support of the IAQ sub indicators (metrics) has been prepared.

From a technical point of view, these two metrics are:

- The Concentration of CO2 [ppm] during the occupied period;
- Formaldehyde concentration [µg/m3].

It is related to a zone / a space were occupants are living and thus must be related to an IfcSpace / IfcZone and thus it seems relevant to adopt a similar approach than the one followed for the definition of the "Pset_SpaceThermalRequirements" which definition is "Properties related to the comfort requirements for thermal and other thermal related performance properties of spaces that apply to the occurrences of IfcSpace, IfcSpatialZone or IfcZone. It can also be used to capture requirements for IfcSpaceType's. This includes the required design temperature, humidity, ventilation, and air conditioning".

Our proposal will be to suggest a "Pset_SpaceIndoorAirQualityRequirements" which definition will be "Properties related to the indoor air quality requirements for concentration of CO2 and 29 concentration of Formaldehyde in spaces that apply to the occurrences of IfcSpace, IfcSpatialZone or IfcZone".

Note: So far the notion of IEQ sems not well defined as an indicator in itself. It is a composition of two indicators (IAQ and thermal comfort). In order to keep the consistency with the already existing property set "Pset_SpaceThermalRequirements", our proposition will be in favour of a Pset_SpaceIndoorAirQualityRequirements and not a "Pset_SpaceIndoorEnvironmentalQualityRequirements".

2.5.3 Further needs – the formalisation of the Assessment Processes

Actually, to use Building Information Modelling effectively and for benefit to be unlocked, the level of understanding among partners involved in the same construction process and project needs significant improvement. For this to happen, there must be a common understanding of the building processes and of the information that is needed for and results from their execution.

In order to do that, these practices have to be turned into shared/agreed processes. The first step is to define the different processes that are relevant in the sustainable building assessment across life cycle building.

The aim is to have a set of processes described in a uniform way, to be used for sustainable assessment. Actors, sequence of actions, type of data and checks on data should become visible to support the sustainable building assessment practices.

There are several tools and approaches providing method for formalising exchange and processes among partners. IDM (Information Delivery Manual) is one of these solutions that allow the formal and accurate description of processes among actors and tools interacting around a BIM.

The IDM will target both BIM users and solution providers. For BIM users, it will provide a simple to understand, plain language description of building construction processes, the requirements for information to be provided to enable the process to be carried out successfully, additional information that may need to be provided by the user and the expected end results of the process. For BIM solution providers, it will identify and describe the detailed functional breakdown of the process and the IFC capabilities needing to be supported for each functional part in terms of the entities, attributes, property sets and properties required.

2.5.4 Exchange requirements

An Exchange Requirement (ER) can be seen as the description of the information that needs to be exchanged between the sub tasks (or events) of the process described by the Process Map.

An ER supports a particular business requirement at a particular stage of a project. It provides a description of the information in non-technical terms.

They are general statements of requirement and they are expressed in natural language, which means the statements expressed are not specific to any IFC solution at that stage.

2.5.5 Functional parts

A description of the technical actions within the process mainly targeted towards the SW implementers. This again leads to the specific IFC capabilities supporting the actions and prescribed values of attributes where appropriate. The FP can be supported by an IFC schema view for the process (in EXPRESS, ifcXML and other formats). For solution providers, descriptions of IFC capabilities will also be developed for reusable 'functional parts' which are commonly occurring sets of data that may be used by any number of processes/ER's. FP gives the background for answering the questions of what data that is needed in a specific case for generating Model View Definition. On the basis of this, SW will certify to provide content that is captured using the model view definition format.

2.6 Relevance for Sustainable Assessment

When relaying on integrated way of working / on ICT based ways of working, there is a mandatory need to ensure the quality all along the whole process and among the list of key issues for the successful implementation of integrated design for instance; the one of particular interest with respect to the BIM is the formalisation of process via the IDM.

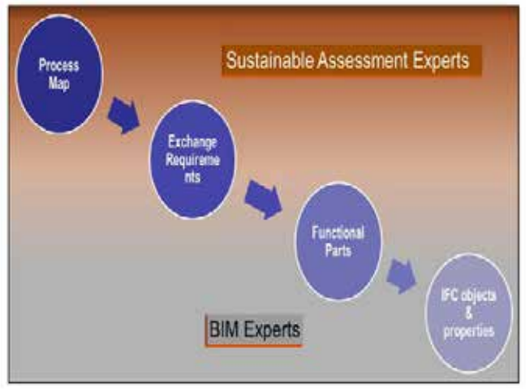
The need for a better communication is identified as a crucial point especially the need for a "clear and well-defined communication structure". The BIM is seen as essential as a supporting tool for integrated design.

The formalisation of the different sub-processes that are under the "integrated design" overall process will lead to the production of one Interchange Manual per sub-process and thus to the harmonisation of practices and lead also to a common sharing of the underlying IFC ontology that is implemented in order to support the various information exchanged.

This formal description will also ease the work of software developers that will be able to provide with solutions compliant with the processes described.

Formalising the way information is described / supported by IFC will also disambiguate some situations and clarifies the level of quality the BIM should reach before performing an sustainable assessment.

If the needs and the responsibilities of the different parties involved are well documented and easy to understand by all because of the use of a common method to describe common implementation then it provides more guarantee to have this semantic continuity coupled with the technical interoperability all along the overall process. But this is only feasible because of the use of a common language (IFC) and a common method to describe the exchange processes (IDM and more specifically the FP aspects of IDM which is the more technical part making the link between the process data and IFC).



From high level process to technical implementation

This last figure illustrates also that this formalisation process needs to be applied the collaboration at least of one Sustainable assessment experts who knows well the current practices and BIM experts who are able to identify in the model the appropriate objects and mechanism to support the exchange.

3 State-of-the-Art on Product Manufacturers' Catalogues

This chapter reports state-of-the-art of product manufacturers catalogues and data definitions for building information model (BIM) based sustainability assessment: technologies and available content. It includes both the technologies currently in use or emerging (such as IFD or ISO 16 757) for data definitions and delivery (set up of catalogues) as well as the availability of such data (content).

This chapter reports state-of-the-art of product manufacturers catalogues and data definitions for building information model (BIM) based sustainability assessment: technologies and available content. It includes both the technologies currently in use or emerging (such as IFD or ISO 16 757) for data definitions and delivery (set up of catalogues) as well as the availability of such data (content).

Product catalogues are needed because a supplier's catalogues contain central data referenced by business processes within the organisation (Australian Government Department of Communications, Information Technology and the Arts, 2004). A company selling building parts would find it difficult to operate without a list of different products. If a supplier's catalogue data is not available in electronic format it will be impossible to link the catalogue products with any external systems, for example a contractor's procurement system. The contractor has to enter the manufacturer's product data manually into the procurement system. This is very time-consuming given the amount of products in catalogues and the number of suppliers that a contractor typically does business with.

Core data management is a major aspect in electronic trading (Australian Government Department of Communications, Information Technology and the Arts, 2004). National and international standards are central to the process. Standards allow less flexibility in catalogues, therefore making them more usable and flexible in usage: Manufacturer specific product data is better structured, thus more easily transformed into other formats and read into other systems by the numerous e-procurement technologies. Use of standards enables the use of same data in different systems by buyers, resellers and e-marketplaces.

3.1 Product Manufacturers' BIM e-Catalogues

Traditionally, building product information has been acquired from printed product catalogues, product manufacturer's distributors, professional magazines, and word of mouth. Internet search engines and web based product information providers have rapidly replaced these traditional methods. The BIM e-catalogues offer benefits to both specifiers and building product manufacturers. These benefits include one-stop access to various product information, comparison of different products of the same function, quick updates on information about new and existing products and the availability of statistics about the visitors of each product information page (Lee, et al., 2011).

3.1.1 Manufacturers' interests in providing BIM e-catalogues

Designers using various design software are replacing traditional 2D CAD with BIM. They model the building and from that model they edit design documents: plans, cut sections, elevations, 3D renderings, building description, take-offs, specifications etc. More and more products and 34 product data is sought online. Designers go online to choose and specify a building product in their BIM. Even though designers will search for available products that could be used in their projects, in most cases they still model using generic objects and specify in generic terms. The actual product selection remains open for the contractor to conclude the procurement of materials and supplies according to their contracts.

It is an objective of the near future that the software vendors and 3rd parties provide generic design objects with standardised property fields. The specifiers can then populate the product data according to product requirements and contractors then exchange the generic virtual product with manufacturer specific virtual product.

BIM object e-catalogues are in demand for the following reasons:

- digital products represent real life products
- digital products minimise design lead time as designers do not have to spend time to model geometry of "something that's going to look like" the product
- designers can check the product aspects and different variations before downloading the digital product
- digital product geometry and data content is authored by the manufacturer
- digital products make project more accurate in 2D and 3D
- 3D renderings look more realistic with digital products that represent real manufacturer products

Product manufacturers are beginning to output e-catalogues and BIM-object libraries due to companies' sustainability objectives and increasing usage of BIM. If a product is modelled in BIM, there is a good chance that the product will be chosen during the procurement process and then implemented on the construction site. As design technology and construction transfers to 3D/BIM the supply for 3D components and product data content becomes vital. There are hundreds of manufacturers and suppliers on the market. Manufacturers and suppliers that are most likely to be specified provide high standard 3D digital products.

A pool of 282 companies was chosen based on company size, availability of BIM compatible content, and collaboration with the 3rd parties that publish quality products for architects, engineers and specifiers or create BIM objects and content for manufacturers. A total of 32 manufacturers listed in Table 6 were selected from the pool of 282 companies based on the availability of BIM object libraries and company's published sustainability objectives. The rest of the companies had BIM libraries, e-catalogues etc. but no established sustainability objectives which is why they were ruled out. Building product giant Saint-Gobain group announced their first BIM objects (11 in total) from Saint-Gobain Weber, developed in Sweden and published by BIMobject® on March 1st 2013 for Swedish and Norwegian markets. Many European companies have extensive sustainability and green building strategies but the companies do not provide digital product catalogues or BIM content as their North American competitors do. The chosen companies represent products that impact a variety of SBA indicators:

A Resource depletion

- Use of non-renewable primary energy
- Water consumption

B Indoor environment quality

- Thermal comfort
- Indoor air quality

C Building emissions

- Global Warming Potential
- Solid wastes production.

Manufacturer	SBA Indicator	Sustainability Input	Industry Field
Airolite	Indoor environment quality	LEED, Green building council member	Louvers, grilles, louver screens and sun controls
All-Lite	Indoor environment quality	LEED	Louvers, grilles, louver screens and sun controls
American Standard	Resource depletion	EPA Water Sense Partner	Plumbing fixtures and washroom accessories
Boral Bricks Inc.	Resource depletion	LEED	Clay brick products
Brizo	Resource depletion	EPA Water Sense Partner	Plumbing fixtures and washroom accessories
CertainTeed Corporation	Building emissions	Sustainable Building Products	Building products
Construction Specialties	Building emissions	Greenbuild Expo exhibitor	Building products
DELTA® Faucet Company	Resource depletion	EPA Water Sense Partner, Water savings calculator	Plumbing fixtures and washroom accessories
Englert, Inc.	Resource depletion	LEED	Metal roofing
greenscreen	Building emissions	Green product	Green building
Hunter Douglas Contract	Indoor environment quality	Indoor environmental quality (IEQ)	Window Coverings, Ceilings, Solar Control, Facades
Hunter Panels	Resource depletion	LEED	Roof insulation panels
International Environmental Corporation (IEC)	Indoor environment quality	Green building council member	Air conditioning equipment, fan coil, conditioning contractors
Legrand	Indoor environment quality	Several sustainability inputs	Electrical equipment
LiveRoof	Building emissions	LEED	Hybrid Green Roof System
Major Industries, Inc.	Indoor environment quality	LEED	Curtain walls and skylights
National Gypsum Co.	Resource depletion	LEED, GPS	Gypsum board
Nystrom Building Products	Building emissions	Green building council member	Building Products
Pella Corporation	Indoor environment quality	Green building council member, etc.	Windows and doors
Pottorff	Indoor environment quality	LEED	Dampers and louvers
RedBuilt™	Resource depletion	LEED	Engineered wood products, structural components and construction systems
Ruskin	Indoor environment quality	LEED	Air and sound control
Saint-Gobain and sub-companies (ISOVER, WEBER, CORAMINES...)	Resource depletion, Indoor environment quality Building emissions	Several sustainability inputs	Building materials
Schneider-Electric	Resource depletion, Indoor environment quality Building emissions	Several sustainability inputs	Electrical equipment
Sherwin-Williams	Resource depletion	LEED	Paint
Surface America, Inc.	Building emissions	LEED	Playground surfaces
T&S Brass & Bronze Works, Inc.	Resource depletion	LEED	Plumbing fixtures and washroom accessories
Taco	Resource depletion	Green building council member	Hydronic systems
Technical Glass Products (TGP)	Indoor environment quality	LEED, Green building council member	Glazing
Watts	Resource depletion	LEED, MasterSpec	Water technologies
Weyerhaeuser	Resource depletion	Green building	Timber products
Zurn Industries	Resource depletion	Lead-Free Initiative, green	Water technologies

Table 6 : A list of product manufacturers that have sustainability objectives and BIM libraries.

roof drains

Many of the product manufacturers collaborate with third party web service providers that enable product manufacturers to share BIM models, drawings, and specifications to designers and contractors who recommend or specify building products. Some manufacturers provide electronic products on their websites as Revit families or ArchiCAD objects. In addition to the BIM formats, product data is generally available in .txt files or PDF documents. The electronic products include manufacturer metadata, material data, parameters, and links to online documents. The online documents provide e.g. product sheets, specifications, product options, and installation instructions.

Product manufacturers online product catalogues are organised into categories from which a designer can search or pick product. Some companies have gathered all their sustainable and green products into matrix charts, which enable a designer to view suitable products at a glance. For example, Ruskin Company has gathered all their LEED certified products under category "Green products and Literature", from which a designer can continue to products, literature or company's LEED matrix of certified product families as illustrated in Figure 14 (Ruskin Company, 2012). Saint-Gobain CertainTeed has Green Building Products At-A-Glance chart, illustrated in Figure 15, with detailed information on which Green Building Standards the product contributes to (Saint-Gobain CertainTeed, 2012).

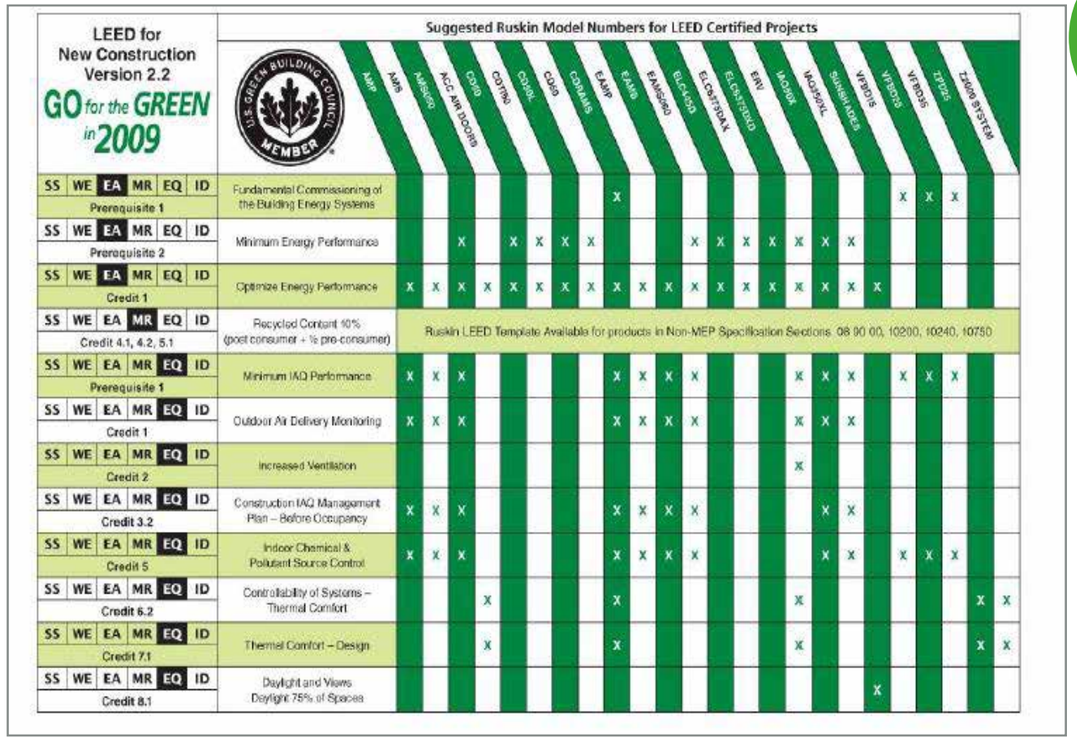
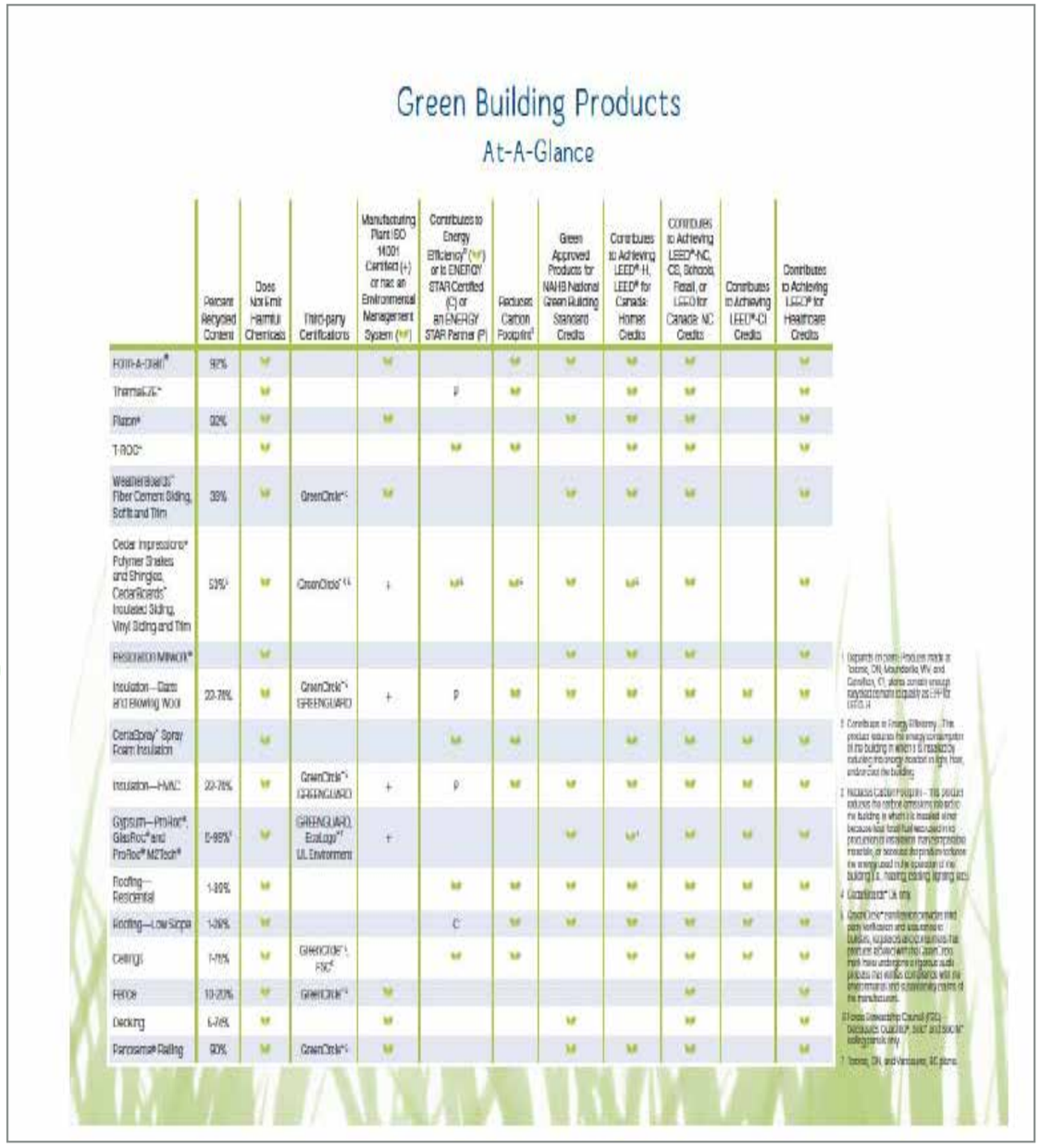


Figure 14 : Ruskin Company's LEED Matrix of Certified Products.



Green Building Products

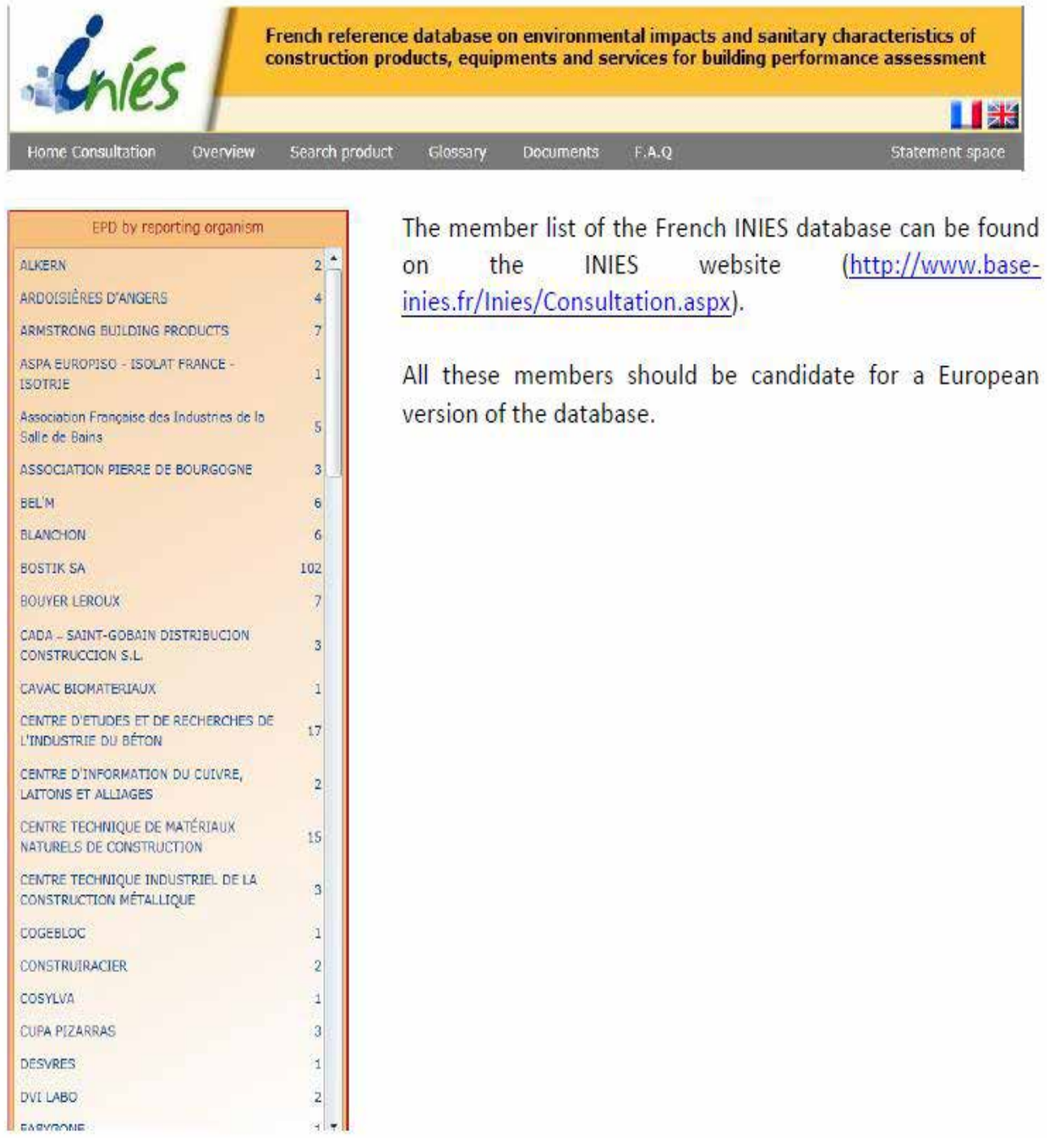
At-A-Glance

	Percent Recycled Content	Does Not Emit Harmful Chemicals	Third-party Certifications	Manufacturing Plant ISO 14001 Certified (+) or has an Environmental Management System (✓)	Contributes to Energy Efficiency[2] (✓) or is ENERGY STAR Certified (C) or an ENERGY STAR Partner (P)	Reduces Carbon Footprint[3]	Green Approved Products for NAHB National Green Building Standard Credits	Contributes to Achieving LEED® H, LEED® for Canada Homes Credits	Contributes to Achieving LEED®-NC, CS, Schools, Retail, or LEED for Canada NC Credits	Contributes to Achieving LEED®-CI Credits	Contributes to Achieving LEED® for Healthcare Credits
FOIL-A-Dam®	92%	✓		✓		✓	✓	✓	✓		✓
Thermalok®		✓			P	✓		✓	✓		✓
Flexon®	92%	✓		✓			✓	✓	✓		✓
T-ROC®		✓			✓	✓		✓	✓		✓
WeatherBoards® Fiber Cement Siding, Soffit and Trim	38%	✓	GreenCircle®	✓			✓	✓	✓		✓
Cedar Impressions® Polymer Shakes and Shingles, CedarAcents® Insulated Siding, Vinyl Siding and Trim	53%[1]	✓	GreenCircle®[4]	+	✓[5]	✓[6]	✓	✓[5]	✓		✓
RESISTANT MINUS®		✓					✓	✓	✓		✓
Insulation—Glass Wool Blowing Wool	22-78%	✓	GreenCircle®[4] GREENGUARD	+	P	✓	✓	✓	✓	✓	✓
CertaSpray® Spray Foam Insulation		✓			✓	✓		✓	✓	✓	✓
Insulation—HVAC	22-78%	✓	GreenCircle®[4] GREENGUARD	+	P	✓	✓	✓	✓	✓	✓
Gypsum—ProRoc®, GlasRoc® and ProRoc® METech®	0-95%[1]	✓	GREENGUARD, EcoLogo®[7] UL Environment	+			✓	✓[5]	✓	✓	✓
Roofing—Residential	1-89%	✓			✓	✓	✓	✓	✓	✓	✓
Roofing—Low Slope	1-36%	✓			C	✓	✓	✓	✓	✓	✓
Ceilings	1-71%	✓	GREENCIRCLE®[4] FSC®		✓	✓		✓	✓	✓	✓
Fence	10-20%	✓	GreenCircle®[4]	✓					✓		✓
Decking	6-74%	✓		✓			✓		✓		✓
Panoramic® Railing	80%	✓	GreenCircle®[4]	✓			✓	✓	✓		✓

Figure 15 : Saint-Gobain CertainTeed's Green Building Products At-A-Glance Chart.

Product manufacturers' e-catalogues contain information about product data, installation instructions, technical information, accessories, specifications, CAD-drawings and BIM-objects. BIM-compliant content for building products, materials and finishes is increasingly critical to the successful future expansion of BIM (Jones, 2011).

Product manufacturers member list of the French INIES database



The member list of the French INIES database can be found on the INIES website (http://www.base-inies.fr/Inies/Consultation.aspx).

All these members should be candidate for a European version of the database.

Figure 16: Product manufacturers member list of the French INIES database

The member list of the French INIES database can be found on the INIES website (http://www.baseinies. fr/Inies/Consultation.aspx). All these members should be candidate for a European version of the database.

3.2 Data Definitions for BIM Based Sustainability Assessment

3.2.1 Technologies

IFD data definitions

The IFD standard resembles the EPISTLE standard for the Oil and Gas industry. The IFD standard describes what the objects are, and what properties, units and values they can have (buildingSMART, 2012), and thus enriches to the IFC standard that describes objects, how they are connected, and how the information should be exchanged and stored (buildingSMART, 2012).

IFD provides the dictionary, the definitions of concepts, the relationships between them and the common understanding necessary for the communication to flow smoothly (buildingSMART, 2012). BuildingSMART Data Dictionary (bSDD) - International Framework for Dictionaries (IFD) is a dictionary based on a framework compatible with the ISO 12006-3 standard (Watson, 2008). IFD is a very comprehensive solution, which aims to provide open complementary product data definitions, identification and distribution methods. It is a unified reference library of terms and properties, intended to support improved interoperability in the building and construction industry. Data dictionary will be an open, shared, international terminology library for structuring object-oriented information exchange. It is an object-oriented database, programmed with EXPRESS data modelling language. The library classifies and defines properties for structured identification of commonly used terms and concepts. The system assigns a Global Unique Identifier (GUID) for all defined terms entered into the system in order to enable data utilization in variety of structured documents and applications.

IFD Library provides benefits for the exchange of model information between software applications and between languages. IFD is primarily designed to improve reliable exchange of BIM data between similar or dissimilar applications. Similar applications are e.g. two geometric modelling software and dissimilar applications are e.g. costing software and specification software (Watson, 2008). In applications where terms are used to identify concepts, IFD Library provides an automatic translation service for those terms.

The largest BIM software vendors support buildingSMART IFC exchange standard. IFD Library support will enable these applications to generate geometric models containing objects which are much more "rich" in data than is possible with IFC classes alone (Watson, 2008).

From the application point of view, when a BIM application receives rich, non-geometric data from another application, the geometric modelling software will be capable of storing, retrieving, displaying, and re-transmitting exchanged data (Watson, 2008).

ISO 16757 data definitions

The subject of ISO 16757 data definitions standard is modelling of data in technical Building Services product catalogues. The Building Services products include the product categories for heating, ventilation and air-conditioning (HVAC) (Standards Norway, 2012).

The catalogues carry information about Building Services products from manufacturers to users – respectively to the users' software systems. The information described by this standard is targeted 41 to allow a software supported search and selection of components as well as the integration of product data into CAD/CAE tools for designing Building Services systems. The information about the products has to be suitable for the layout, the calculation and the simulation of Building Services systems in CAD/CAE systems. (Standards Norway, 2012).

To provide for such a deep description of the Building Services products, a number of resources are required, including:

- product classes and product properties for the appliance in the field of building services
- geometric representations of products
- description of operating characteristics and algorithms for the design of building services systems.

The proposed standard will make use of existing elements of IFC and IFD and other buildingSMART standards, wherever possible, and where required, it will define additional resources (Standards Norway, 2012).

3.2.2 Content

Manufacturer provided product catalogues and BIM library contents differ from each other. The online catalogues have greater information content than the BIM objects they provide for design purposes. The challenge in offering product data, installation instructions, technical information, accessories, specifications etc. via BIM objects is the amount of data per product, and the fact that the deliverable data content is not standardized (Palos, 2012; Nummelin, et al., 2011; Karstila & Seren, 2005). It is easier for the product manufacturer to provide all product information on ebrochures than struggle with BIM objects and different software. The data content and the data format that manufacturers use to provide information about their products vary as listed in Table 7. In general, content is provided in proprietary formats, CAD/BIM formats, and document file formats but not for example in IFC due to issues related with data exchange in IFC. 2D-formats are provided due to tha transision the industry is going through at the moment – BIM is becoming more popular every day, but it is not yet the industry practice.

Table 7 : File formats that manufacturers use for exchanging data in design files or documents.

Design Files	Application	File Extension
	Autodesk 3ds Max Design	3ds, .max
	Autodesk Design Review	.dwf
	AutoCAD	.dwg, .dxf
	Autodesk Maya	.mb
	Autodesk Revit	.rfa, .rvg, .rvt, .mlib, .txt, .csv
	Bentley Microstation	.dgn
	Graphisoft ArchiCAD	.gsm, .ies
	Vectorworks	.mcd
	Google SketchUp	.skp, .skm
	Xfrog	.xfr

Document Files	Application	File Extension
	Microsoft® Word	.doc, .docx
	Adobe Acrobat	.pdf
	WordPerfect	.wpd
	Microsoft® Excel	.xls, .xlsx

The advent of IFC-based collaboration has made the exchange and library content limitations critical as comprehensive material, structural, thermal behaviour and acoustic performance attributes are missing to support their corresponding disciplinary analyses (Cooperative Research Centre for Construction Innovation (CRC), 2009). In addition, use of a BIM neutral file format like the IFC could potentially serve a wider scope of designers and contractors seeking data from manufacturers' product catalogues.

3.2.3 Delivery

Most manufacturers on the list presented in Table 6 provide their online catalogues under link Literature on their website. The literature section lists all product catalogues in alphabetical order. Additional literature can be e.g. case studies, flyers/brochures, mechanical specifications, installation or owner's manuals, or technical catalogues. What is common in all online catalogue cases is that all data is provided in text format via e-publications or PDFs. None of the information can be downloaded into BIM and certainly not all of the data provided in the catalogues is integrated into manufacturer's BIM objects.

4 Specifications of SBA metrics Web Server

This chapter proposes a server data model and associated WEB Services for SBA metrics management, feeding by the construction products manufacturers and using by Product Model Based Building Design Software.

4.1 Data model of the SBA metrics web server

The following schema presents a possible data model for the SBA metrics Web server.

This organization is equivalent to the existing one available in France for the INIES database, which can be accessed in feeding by construction products manufacturers and in reading by life cycle analysis tools like ELODIE.

In order to declare an SBA Impact Declaration (SBAID) the manufacturer should apply for an account and provide the required information: Name, address, contact, website, single product manufacturer or professional organization…

When the apply form is validated, the SBA platform Administrator creates a user's account for the product manufacturer.

SBAID templates and families are implemented in the platform by the administrator. The SBAID forms are classified by families, we propose to range the SBAID by use function (cf. INIES French database for example): insulation, structural elements…

The product manufacturer fills the (SBAID). Each SBAID template contain general information of the product, for example (cf. INIES French database): product's name, product's classification, version date, date of last update, Number of products covered by the SBAID, trade reference of the products, ability of the product to meet requirements (CE marking for example) …

Also, the product manufacturer has to provide all the required SBAID Description elements: Impact indicators, Life cycle stage, functional unit, proof of conformity documents, optional documents.

The SBAID is reviewed and assessed by a technical committee, further discussions and information exchanges with the manufacturer may be required. After the validation of the SBAID by the committee, the SBAID can be published on the SBA platform.

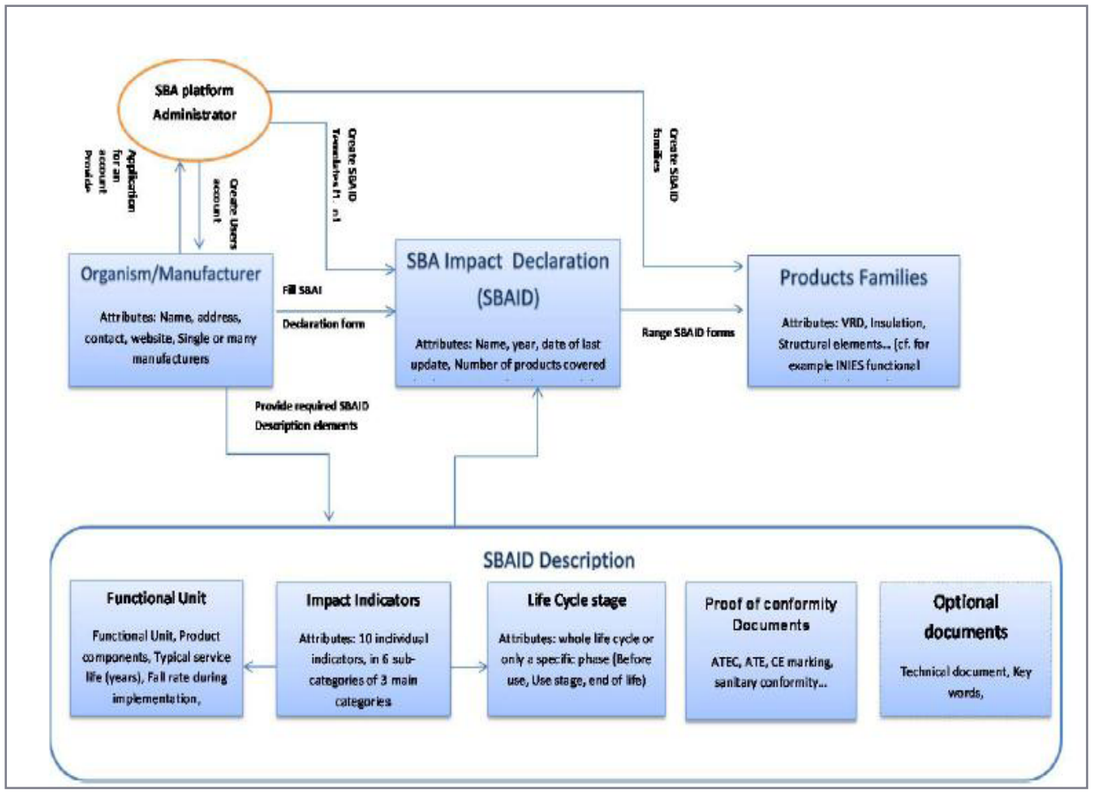


Figure 17 : data model for the SBA metrics Web server

4.2 Specifications of WEB Services for SBA Metrics declaration usage by the platform Administrator

The following WEB services shall be developed for and be used by the SBA metrics server administrator.

4.2.1 Create user (Organisms/Manufacturers) account

Function: create an organism or manufacturer account.

Attributes: Name, address, contact, website, Single or many manufacturers.

4.2.2 Create SBAID Template

Function: create SBA Impact Declaration (SBAID) template.

Attributes: Name, year, date of last update, Number of products covered by the SBAID, trade reference of the products.

4.2.3 Get SBAID

Function: get SBA Impact Declaration (SBAID) form filled by the organism/manufacturer.

Attributes: Name, year, date of last update, Number of products covered by the SBAID, trade reference of the products.

4.2.4 Create SBAID families/nomenclature

Function: create SBAID families/nomenclature, using for example the INIES functional classification.

Attributes: Insulation, Structural elements...

4.2.5 Get SBAID families/nomenclature

Function: get SBAID nomenclature list filed by the organism/manufacturer

Attributes: Insulation, Structural elements,…

4.2.6 Create SBAID Description Templates

Function: Create SBAID Description Templates

4.2.6.1 Create "Functional Unit" template

Function: Create SBAI Definition Templates

Attributes: Functional Unit, Product components, Typical service life (years), Fall rate during implementation.

4.2.6.2 Create "Impact Indicators" template

Function: Create SBA Impact Indicators template

Attributes: impact indicators.

Resource depletion

Use of non-renewable primary energy in [kWh/m2]

Water consumption in [m3/time period]

Indoor environment quality

Thermal comfort: For summer and winter settings [% time out of range] of minimum and maximum temperature

Indoor air quality

Concentration of CO2 [ppm] during the occupied period

Formaldehyde concentration [µg/m3]

Building emissions

Global Warming Potential: Global Warming Potential (GWP100) [kg CO2 eq/<unit>] (according to IPCC 2001)

Solid wastes production

[Tonnes Hazardous waste]

[Tonnes non-Hazardous waste]

[Tonnes Inert waste]

[Tonnes Nuclear waste]

4.2.6.3 Create "Life Cycle stages" template

Function: Create "Life Cycle stages" template

Attributes: Before use, Use stage, end of life

4.2.6.4 Create "Proof of conformity Documents" template

Function: Create "Proof of conformity Documents" template

Attributes: ATEC, ATE, CE marking, sanitary conformity…

4.2.6.5 Create "Optional documents" template

Function: Create "Optional documents" template

Attributes: Technical document, keywords.

4.2.7 Get SBAID

Function: Get SBAI Declaration list filled by the organism/manufacturer

4.2.8 Get SBAID description

Function: Get SBAID description list filled by the organism/manufacturer SBAI description forms: impact indicators, Life Cycle stages", "Proof of conformity Documents", "Optional documents".

4.3 Specifications of WEB Services for SBA Metrics declaration usage by organisms/ Manufacturers

4.3.1 Login

Function: Login to SBA platform

Attributes: username, password

4.3.2 Fill organism information

Function: Fill organism/manufacturers information

Attributes: Name, address, contact, website, Single or many manufacturers

4.3.3 Fill SBAID Template

Function: Fill SBAID Template

Attributes: Name, year, date of last update, Number of products covered by the SBAID, trade reference of the products.

4.3.4 Fill SBAID Description Templates

Function: Fill the following SBAID Description Templates

4.3.4.1 Fill "Functional Unit" template

Function: Fill "Functional Unit" template

Attributes: Functional Unit, Product components, Typical service life (years), Fall rate during implementation,

4.3.4.2 Fill "Impact Indicators" template

Function: Fill "Impact Indicators" template

Attributes: 10 individual indicators,

4.3.4.3 Fill "Life Cycle stages" template

Function: Fill "Life Cycle stages" template

Attributes: Before use, Use stage, end of life

4.3.4.4 Fill "Proof of conformity Documents" template

Function: Fill "Proof of conformity Documents" template

Attributes: ATEC, ATE, CE marking, sanitary conformity…

4.3.4.5 Fill "Optional documents" template

Function: Fill "Optional documents" template

Attributes: Technical document, keywords

4.3.5 Fill SBAID families/nomenclature

Function: Fill SBAID families/nomenclature

Attributes: Insulation, Structural elements…

4.3.6 Close Session

Function: close manufacturer session

4.4 Specification of WEB Services for SBA Metrics usage by Product Model Based Building Design Software

This section presents WEB Services proposal for SBA Metrics usage by Model Based Building Design Software (MBBDS).

4.4.1 Login

Function: Login to SBA platform

Attributes: username, password

4.4.2 Create MBBDS SBA Project

Function: create Model Based Building Design Software SBA Project

4.4.3 Get SBAID

Function: get SBAI Declaration

4.4.4 Get Products Families Items

Function: get Products Families list,

4.4.5 Get SBAID Description

Function: Get SBAID description forms filled by the organism/manufacturer SBAI description forms: impact indicators, Life Cycle stages", "Proof of conformity Documents", "Optional documents",

4.4.6 Get SBA Impact Indicators Items

Function: get SBA Impact Indicators list

Attributes: 10 individual indicators,

4.4.7 Get Life cycle stage Items

Function: get Life cycle stage Items list

Attributes: Before use, Use stage, end of life

4.4.8 Get "Functional Unit" items

Function: get "Functional Unit" items

Attributes: Functional Unit, Product components, Typical service life (years), Fall rate during implementation,

4.4.9 Get Proof of conformity Documents list

Function: get Proof of conformity Documents list Attributes: ATEC, ATE, CE marking, sanitary conformity…

4.4.10 Get Optional Documents

Function: get Optional Documents list

4.4.11 Close Session

Function: close MBBDS session

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