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ICT PLATFORM FOR HOLISTIC ENERGY EFFICIENCY SIMULATION AND LIFECYCLE MANAGEMENT OF PUBLIC USE FACILITIES

Deliverable D2.1:

BIM Enhancement Specification

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Executive Summary

The **objective** of the Deliverable 2.1 "BIM Enhancement Specification" is to provide a formal conceptual specification of an open and extensible energy-enhanced BIM framework (eeBIM), to support the data flows for energy efficient design and lifecycle management of complex facilities. It is based upon the HESMOS Deliverable 1.1 "Gap Analysis, Use Case Scenarios and Requirement Specification", which stated eight important data flows for which the user and application viewpoints are considered and the modelling requirements are highlighted.

Deliverable D2.1 is successor of D1.1 and could only be started after completion of D1.1 to warrant a stable specification and an industry focussed solution. This dependency had not been foreseen in the Description of Work. Additional consultation had been sought with buildingSMART, the international organization to promote open BIM use, in order to guarantee that the HESMOS energy enhanced BIM (eeBIM) specification is accepted as a candidate for an official Information Delivery Manual, IDM. Both, the backing in industry-led requirement specifications and standardisation efforts caused a considerable **delay** in completing D2.1.

The Deliverable D2.1 covers the overall work performed within **task** T2.2 “BIM enhancement specification” of WP2.

It is structured into **five parts**.

In **part one**, the conceptual framework of eeBIM is presented. It is based on the important data flows of the TOBE processes being the outcome of Deliverable 1.1.

In **part two**, the overall development roadmap towards the realisation of an industry exploitable eeBIM framework following the Information Delivery Manual [ISO 29481-1] is outlined. This includes the specification of the eeBIM, but also the software architecture of the HESMOS Integrated Virtual Energy Laboratory (IVEL) and its prototype implementation.

In **part three**, the eeBIM kernel and the identified main multi-model links and model transformations are presented. A flexible link model is thereby favoured over a single all-encompassing schema.

Part four comprises the main section of the deliverable report. It focuses on the data requirements imposed by the defined data flows stipulated in part one. For each data flow, the information needs, the data source, the data format and its importance to eeBIM are shown.

Part five provides the resulting specification section explaining the components of the eeBIM framework as elementary models and the overarching link model. The main BIM data schema is based upon the international openBIM standard IFC [ISO 16739], with linked XML schemas to cover device data and other non-BIM information, and XML Meta data to supplement the data flow for external climate and material data bases. Enhancements are proposed to those selected standards and a link schema to combine them as the input for energy simulation, and investment and operational cost calculation. These enhanced and inter-linked formal data schemas constitute the energy enhanced BIM (eeBIM) specification.

All partners were involved and each partner has contributed from their expert viewpoint as follows:

- **AEC3:** Lead, all tasks from contractor and operator point of view, with focus especially on the parts 1, 4 and 5, the technical exchange requirements and the editing of the report.
- **TUD:** All tasks, especially parts 1, 2 and 3, as well as editing.
- **BAM, NEM, OG and OPB** – contributions to parts 3 and 4.

1. Conceptual Schema of the eeBIM Framework

A central issue of the HESMOS platform is the life cycle integration of services and tools based on a consistent model-based approach derived from thoroughly studied end user requirements and existing gaps on the one side, and a preset high-level multi-schema concept on the other side. HESMOS platform supports the main use cases in a building's life cycle where energy performance can be considerably improved via application of an interoperable ICT approach. Based on the overall requirements gathering methodology and results (HESMOS Deliverable 1.1) the conceptual schema of the framework explains the overall concept of an energy enhanced Building Information Model (eeBIM). The conceptual schema of the eeBIM , defined with this deliverable, is the baseline for the eeBIM platform architecture, as specified in HESMOS Deliverable 2.2.

The eeBIM conceptual schema framework consists of a multi-schema architecture with the open Building Information Model (BIM) being the central schema other schemas connect to. The multi-schema concept has been selected for eeBIM because of

- the diversity of data required in the overall life-cycle processes;
- the availability of well-established openBIM schema, ISO16739 (IFC);
- the results of an internal investigation, showing that:
  - IFC can serve as central link model to anchor the additional models,
  - multi-models are more flexible, and easier extensible to adopt for future needs,
  - minimizing changes to IFC is the approach with best chances for industry adoption,

  and that integration with existing software tools already supporting standard is easier.

The requirements for the overall concept for an eeBIM framework were directly taken from the user requirement definition carried out in HESMOS work package 1. The methodology chosen is the Information Delivery Manual (IDM), originally developed within buildingSMART (Wix 2007), and further enhanced as explained in section 2 (see also Figure 2). The main process maps defining the four use cases for the industry-driven holistic approach for sustainable improvement of energy performance in PPP projects identified eight main exchange scenarios. Each is taken into consideration as contributing to the overall eeBIM model scope. Broken down into the exchange requirements and enhanced with the eeBIM schema binding, exemplified in Appendix II, it highlighted exactly the required data elements and structures to be handled by eeBIM framework.

Figure 1 shows the main eeBIM component models and the involved model transformations embedded in the building life cycle. This figure essentially provides an eeBIM-centred perspective of the overall life cycle process identified during the requirement gathering task and documented in BPMN. At the top, the major relevant tasks in the building life cycle are shown, i.e. the Architectural Space Program developed in the early design phase where fundamental energy related decision are taken, the BIM-based Architectural and HVAC design, where decisions on material and component level are taken, and the Monitoring and Control via BAS in the Operation and Maintenance phase. At the bottom, the main related analysis tasks are shown, i.e. Energy Simulation – to forecast or check energy performance, and Life Cycle Costs Calculation – to include energy costs in the total life cycle costs and check eventual redesign, retrofitting or refurbishment decisions against the related investment and operational costs, thereby enabling informed decision-making. In the centre, the eeBIM framework enabling the interoperability and integration of all other components into a consistent platform is shown.

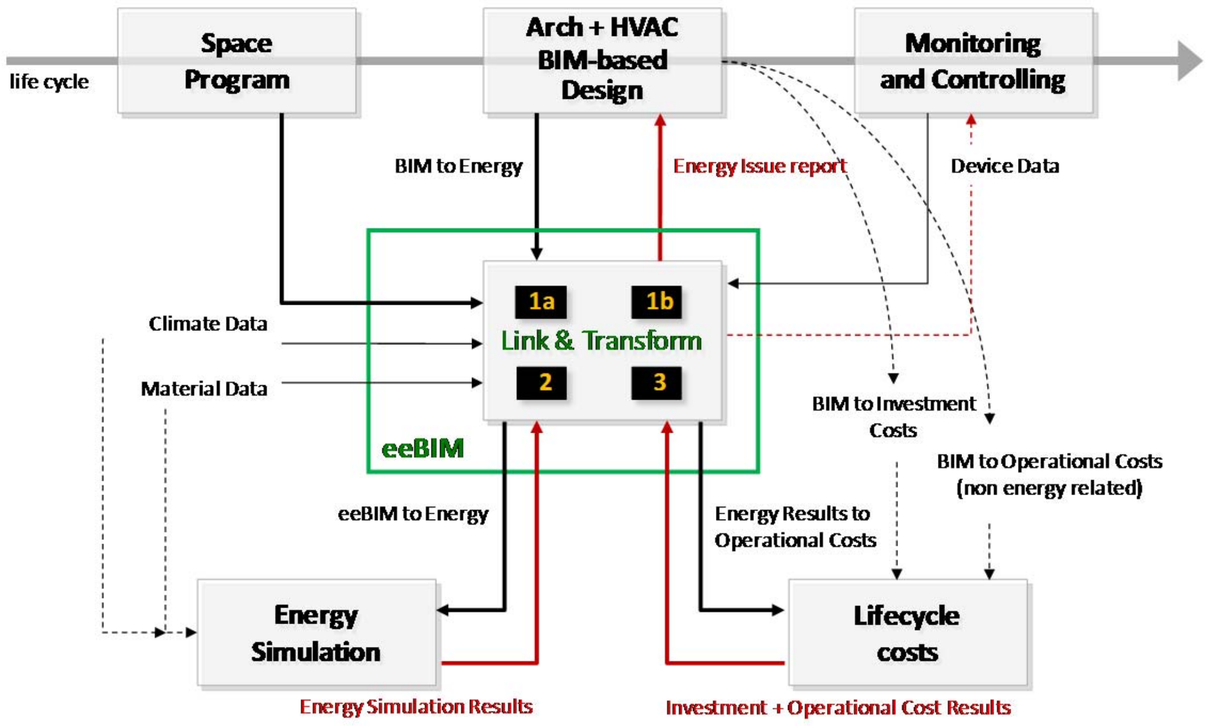

Figure 1: Generalised view of the suggested eeBIM framework

One of the main reasons for choosing the multi-schema approach is diversity of data and data structures. The Figure 1 highlights the various input sources to be dealt with. BIM data comes as partially instantiated model from the space program (mainly spaces with properties capturing space use and related client requirements) and is later completed via architectural and HVAC CAD, adding building elements (walls, slabs, windows, curtain walls, etc.) and equipment elements (heaters, pump, fan, heat recovery units, etc.) to the building model. Those elements represent highly structured data, well covered in the openBIM standard IFC. Climate data originate from weather stations and are provided in weakly standardised form, even though the data structures are not very complex. Material data are also largely in proprietary format, specifically tailored for their use for energy simulation. However, material type names can be used to inter-link BIM-CAD material data and energy-specific material databases. Finally, in a later stage, data from BAS, such as sensor properties, measured values and locations have to be integrated with BIM. Output that needs to be considered includes energy simulation results, cost results and synthetic energy performance indicators. All that information has to be pulled together into a coherent modelling framework. Considering these multiple information sources, the main concept of the eeBIM framework is established. Its essence can be expressed as follows:

- Keep the BIM schema already standardized in the IFC schema virtually unchanged, with only minimal needful extensions on the level of additional attributes to spaces, space boundaries and building elements;
- Interlink BIM to all other information sources via a separate Link Model binding the distributed data sources together and describing the semantics of the established links via added meta data in similar was as RDFS or Dublin Core (Nilsson et al. 2008);
- Use the so assembled BIM-based multi-model for all subsequent model transformations required for achieving service/tool interoperability.

If BIM is to be preserved largely unchanged, thereby facilitating feedback to architectural design after energy and cost analyses are done, adequate links to the needed external data must be established.

In fact, the multi-model concept strongly depends on the quality and convenience of defining such links. In our approach, we use as baseline the specification developed recently in the German lead project Mefisto (Scherer & Schapke 2011). It provides a very efficient method to store and retrieve inter-linked multi-model data, but the creation of such links may vary considerably for different use cases, ranging from fully automated trivial procedures to heavy-duty computational algorithms.

Fortunately, the basic targeted use cases regarding the eeBIM framework can be efficiently tackled with the help of the suggested Link Model. Thus, climate data can be automatically associated to the building's façades, which can be relatively easily determined from the available BIM data. Energy related material properties are linked to respective building element materials in BIM using a mapping table for the material names and associating building element IDs with the primary keys (or IDs) in the material data model. In similar manner, sensor information is linked to spaces or building elements depending on the sensor types, whereby location information can be used to determine the association of each sensor to the appropriate IFC component. Finally, calculated costs can be also associated to the various building components in straightforward manner, which is sufficient for cost estimation, prediction and planning by architects and building owners. Model transformations are inevitable because energy solvers or cost calculation tools normally maintain their own specific data structures and do not "speak" BIM.

2. Overall Development Roadmap

Development of the efficient HESMOS eeBIM framework, reusable and adaptable for different practical configurations, entails:

- Proper definition of the involved actors and the roles they play in the overall process (HESMOS Deliverable D 1.1);
- Specification of typical use cases and user scenarios (Deliverable D 1.1);
- Determining the respective information exchange requirements, (Deliverables D 1.1/ D2.1);
- Development of the eeBIM concepts, schemas and supporting methods and services (this Deliverable D 2.1),
- Specification of the platform architecture (Deliverable D2.2)
- Elaboration of the eeBMI and implementation in CAD software (WP3 / WP8, with input from WP 4-7)

This complex sequence of tasks is typically handled in cooperation of end-users, modellers and software developers who all have different background and expertise. Therefore, a grounded methodology that can bring together such multifaceted teams was necessary.

The methodology selected is the Information Delivery Manual (IDM) developed within the buildingSMART initiative for that purpose (Wix 2007) and later standardized in ISO 29481-1 "Building information modelling -- Information delivery manual -- Part 1: Methodology and format". It is extended and adapted for the specific objectives of life cycle modelling, the definition of a generalised multi-model framework based on, but not limited to, a single standardised BIM (currently IFC2x3), and the derivation of information and processing (workflow) requirements for the components of an integrated virtual energy laboratory (IVEL).

This information needs to represent requirements to the conceptual schemas that are to be selected and enhanced for the purpose of an energy-efficient BIM. Therefore the exchange requirements were further specified and developed as Exchange Requirement Models (ERM) and published in Appendix II. The ERM is an enhancement of the Exchange Requirement ER from a software point of view as and it provides in addition:

- The data source: the application, service or data base where the information is typically stored and to be made available;
- The data format: the data schema, exchange standard or transaction protocol that is typically used to exchange the information;
- The mapping to the data format: the mapping of the required information to the exact data field (class/element and characteristic/attribute) within the chosen data format.

Thus the exchanges were sorted, specified and mapped to the data exchange formats as shown in Figure 2.

The work on an improved methodology for IDM (ISO 29481-1) is now contributed back to the international standardization community, ISO Technical Committee 59 (building construction), Sub Committee 13 (Organization of information about construction works). The actual IDM for energy enhanced BIM is going to be submitted for consideration as an international template for similar exchange scenarios to buildingSMART International.

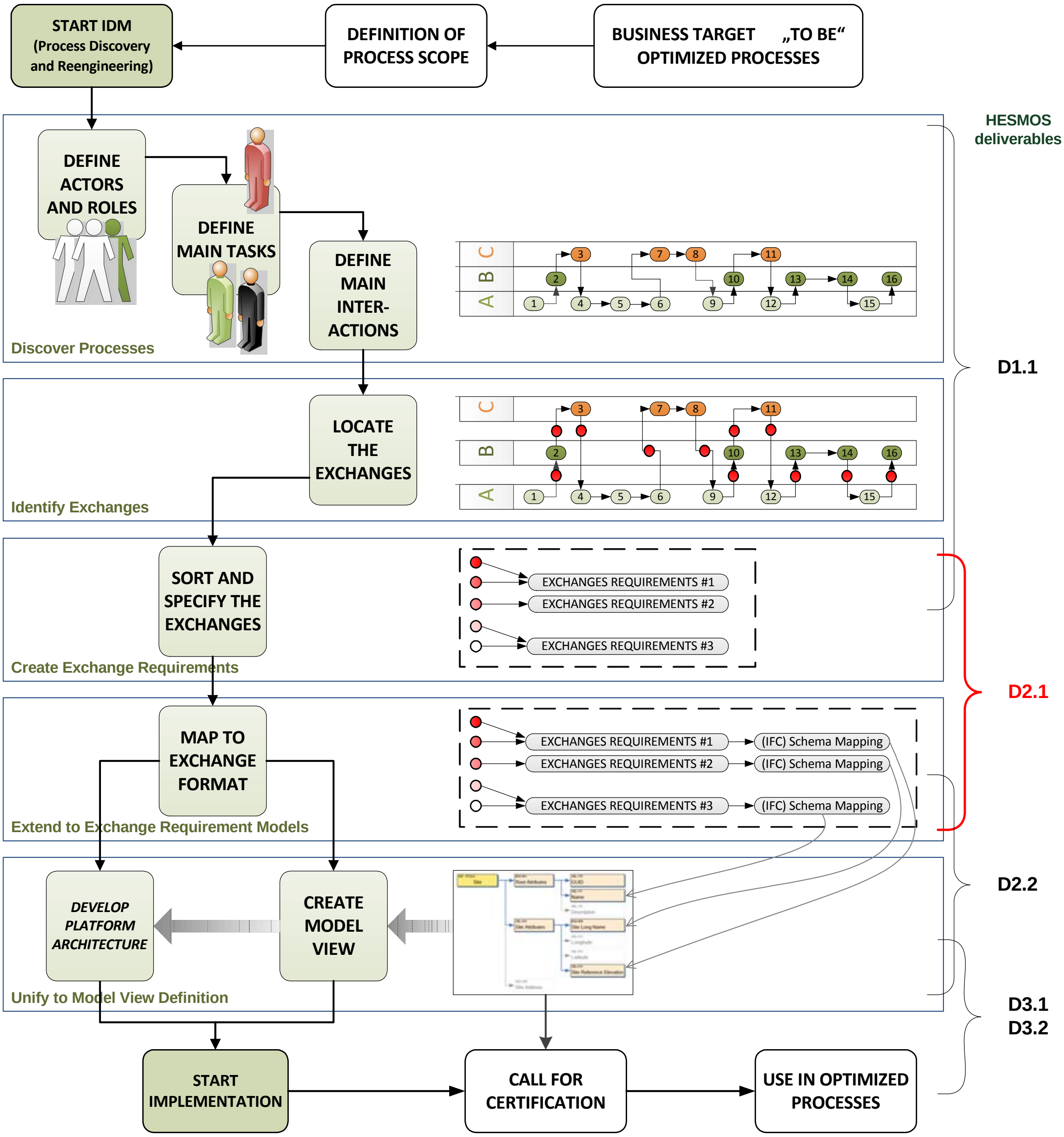

Figure 2: IDM-based development process – specifying eeBIM

3. Major Multi-Model Links and Model Transformations

As introduced in Section 1, the eeBIM specification is based on a link model of confederated data schemas with the IFC data schema as the main underlying schema[1].

The data elements of the other highly specialized schemas (climate data, material data, device data, occupancy schedules, etc.) are linked to components of the IFC data schema using the link model approach (cf. Scherer & Schapke 2011). On Figure 3 below, the principal bidirectional data flows within the eeBIM framework and the involved model transformation types are shown.

The **model links**, binding all elementary models with IFC data schema, comprise:

- **BIM ↔ Climate data**
  Link to IFC data schema via high-level spatial structure objects site or building, represented by the classes *IfcSite* and *IfcBuilding*
- **BIM ↔ Material data**
  Link to IFC data schema via each corresponding material name provided as material characteristic to relevant building elements that bound a thermal zone, represented by classes *IfcMaterial* associated to an *IfcBuildingElement*
- **BIM ↔ Device data**
  Link to IFC data schema via each corresponding sensor element, provided that a detailed building service information model is available, or via the space object in which the device is located, represented by the classes *IfcDistributionControlElement* or *IfcSpace*
- **eeBIM ↔ Energy reports**
  Link to IFC data schema via high-level spatial structure objects building, space to reports, depending on the context
- **eeBIM ↔ Cost reports**
  Link to IFC data schema via high-level spatial structure objects building, space, or construction elements or aggregates to reports, depending on the context

The **main model transformations** that need to be supported are:

- **Spatial requirements to eeBIM**
  Early energy-related requirements are typically provided in form of a spatial requirements definition listing the spatial, functional, comfort and equipment requirements for each functional area. Such spatial requirements form a very early, conceptual building information model and are also available as IFC data models. Particularly the comfort and equipment requirement information is needed by eeBIM for early phases.
- **BIM (CAD or FM) to eeBIM**
  Typically, architectural or MEF CAD and FM systems provide BIM data that is lacking many energy relevant features. Except for the external sources mentioned (climate, material characteristics and so on) the exported BIM data generally does not include space boundaries or at most defines them on what is known as *Level 1* representation (Weise & Liebich 2008). However, energy solvers require at least *Level 2a or 2b*, which in turn leads to complex geometry computations and subsequent restructuring of existing BIM data.

[1] The choice of IFC (more precisely the IFC2x3 Coordination View V2.0) as the open, standardized data schema for BIM has been made for reasons detailed in section 5.

- **Monitoring to eeBIM**
  As indicated above, BAS data can be linked to BIM on the basis of the provided locational and typological information. However, the difficulty is to first provide a suitable BAS description, containing the needed meta data in neutral format. This requires a BIM-BAS ontology that defines concepts generalizing the data from the various used BAS standards today (LON, KNX, BacNet, EnOcean etc.).
- **eeBIM to Energy Solver**
  Energy simulation models essentially employ the same data as already contained in the eeBIM, but structured completely differently. Therefore here a typical mapping transformation as used e.g. in federated databases is required. Due to the large range of available solvers, each having its own dedicated data input model, two possible approaches can be envisaged: (1) customary one step mappings to each solver integrated in the eeBIM-based virtual laboratory platform, and (2) the more difficult but also more promising two step approach involving development of a harmonised simulation model and first mapping eeBIM to it, thereby achieving higher level of interoperability on medium term.
- **eeBIM to Costs**
  This transformation is in spirit the same as the described transformation of eeBIM to Energy Simulation Models above. However, the IFC model already contains definitions of various cost elements, which greatly facilitates the mapping process.

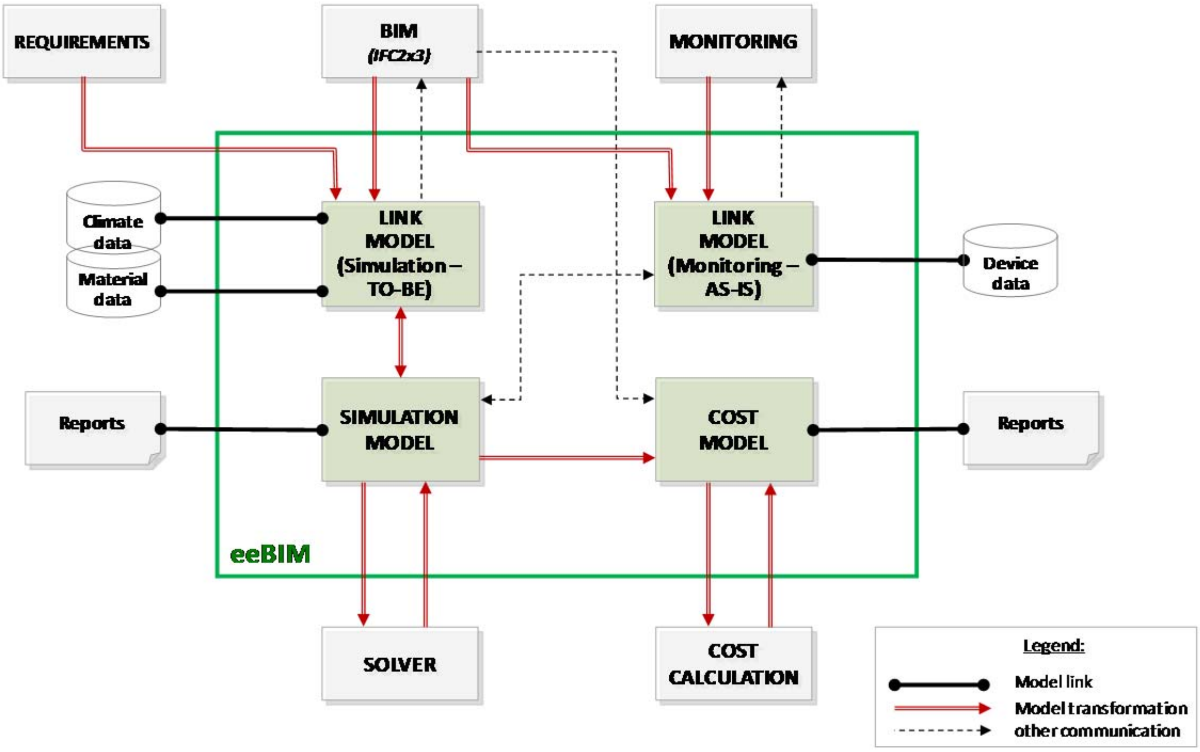

Figure 3: principal model links and transformations in eeBIM

Based on these principal links and transformations, closing the eeBIM life cycle circle, detailed modelling issues can be further defined and partial model views can be specified as necessary. Moreover, support ICT services and their interfaces can be more easily and clearly identified, and workflows providing for efficient service/tool orchestration of various sub-processes in the overall life cycle business process can be worked out, such as the automated creation of single-zone energy simulation models from architectural BIM.

4. ICT requirements to the detailed eeBIM specification

4.1 Basic Issues

The main task for identifying the schema and general ICT requirements is to built upon the work done in HESMOS Deliverable D1.1 (Bort et al., 2011), where the user requirements are stipulated. According to Figure 2, the Deliverable D1.1 comprises the results of the following steps: "Gap Analysis, Use Case Scenarios and Requirements Specification", including the issues "define actor roles", "define main tasks", "define main interactions", "locate the exchanges", and partially "sort and specify the exchanges". The delivery format for "sort and specify the exchanges" is the Exchange Requirement (ER) table. This format is shown in Figure 4 below. The intellectual source for filling the ER table is the domain expert knowing about the data needed.

Element / Property concept / Property group / Property name	Definition	Examples and further explanatior	Data Source	BIM Export
Construction				
Building Structure				
Building general				
geographical position - latitude		**47° 25′ N** / 010° 59′ E	BIM	M
geographical position - longitude		47° 25′ N / **010° 59′ E**	BIM	M
High above sea level		113 m over sea level Amsterdam	BIM	M
Orientation	north arrow		BIM	M
Type of use	Name of the type for the building	"Office", "School"	BIM	M
Location description	Textual description of construction / buildings / landscape nearby	city center, field	BIM	O
Air tightness (infiltration rate)			*BIM*	-

Figure 4: Exchange Requirement tables as defined in deliverable 1.1

In order to be used as part of the ICT requirements for the conceptual schema and later the platform architecture of eeBIM, the user driven ER table needs to be reviewed and enhanced. The task is, by iterating within the step "sort and specify the exchanges", to add a schema and ICT expert point of view to the exchange requirements. This involves:

- Identifying data source format and applications through which data is transmitted;
- Separating informal data from structured (computer readable and interpretable) data;
- Splitting general data requirements into its individual (and structured) parts.

The outcome is an improved ER table. This involved an iterative procedure within which, along with general improvements of the ER table, additional review sessions with the domain experts had been held. Being a means of communication between domain experts and modelling / ICT experts, the ER tables also required improvements in the definition and examples and further explanation columns.

The next step according to the overall roadmap (Figure 2) is "map to exchange format". After identifying the data source format, usually an exchange file format, or transaction format, the format is analysed and the sub-sections (or data fields) are identified that can handle the required data content. This step may also reveal that the chosen data format has limitations and is not suitable.

Both steps led to the enhanced requirement table, called an **Exchange Requirement Model (ERM).** The ERM table structure is shown in Figure 5.

[ER 2] Exchange Requirements for BIM to Energy						*Exchange Requirement Model*
Element Property concept Property group Property name	Definition	Examples and further explanations	Data Source	IFC2x3 Export	additional data	IFC2x3 Schema Representation
Construction						
Building Structure						
Building general						
geographical position - latitude	World Latitude at reference point	**47° 25' N** / 010° 59' E	IFC	M		IfcSite.RefLatitude
geographical position - longitude	World Longitude at reference point	47° 25' N / **010° 59' E**	IFC	M		IfcSite.RefLongitude
High above sea level	Datum elevation relative to sea level	113 m over sea level Amsterdam	IFC	M		IfcSite.RefElevation
Orientation	North arrow, true north direction relative to the bulding model y axis	+30° (true north is +30 degree from project y-axis)	IFC	M		IfcGeometricRepresentationContext.TrueNorth
Type of use	Name of the type for the building	"Office", "School"	IFC	M		IfcBuilding + IfcPropertySingleValue (Pset_BuildingCommon, OccupancyType)
Location description	*Textual description of constructions, buildings, landscape, nearby this facility*	*A selection from a catalogue with predescribed text, e.g.: city center, field*	eeBIM		ee	
Air tightness (infiltration rate)	*Normalized air infiltration rate on a normalized air pressure setpoint - 'blower door' result*	*Information typically not available to the designer - to be added in the eeBIM enrichment process.*	eeBIM		ee	

Data Source	IFC2x3 Export	additional data	IFC2x3 Schema Representation
IFC	M		IfcSite.RefLatitude
IFC	M		IfcSite.RefLongitude
IFC	M		IfcSite.RefElevation
IFC	M		IfcGeometricRepresentationContext.TrueNorth
IFC	M		IfcBuilding + IfcPropertySingleValue (Pset_BuildingCommon, OccupancyType)
eeBIM		ee	
eeBIM		ee	

Figure 5: Exchange Requirement Model tables as outcome of this deliverable

The "Data Source" column shows the origin, or place of creation of the data, and it is now specific to the data format. The next column identifies whether the data has to be included in each transaction when such a data file or data stream is received, and the column titled "IFC2x3 export" is specific to the data format chosen. The following column shows where additional data, not being contained in the data format, is created, transformed or received.

The main new column is the data format mapping column, here specifically shown as "IFC2x3 Schema Representation". It identifies the data field, where this data item can be addressed. This provides exact guidance for the eeBIM database and software development work. The following steps according to Figure 2, "Develop platform architecture" and "create model view" are based on the ERM tables.

4.2 Energy-related Client Requirements [2]

The Exchange Requirements (ER) “Energy-related Client Requirements” contain e.g. the room book (space program), room type book (thermal requirements or system requirements) and the energy requirements regarding the building and its systems.

In the Design and Tendering Phase they are used to specify the project, in the Retrofitting and Refurbishment Phase to add a new space program and energy requirements.

Being based on the initially specified ER ‘Clients Requirements’ as described in D1.1 (Bort et. al., 2011), sect. 1.4.1 and Appendix II, respectively, the ER “Energy-related Client Requirements were updated, extended and newly structured. The table below provides an outline of the detailed ER.

REQUIREMENTS	DETAILED DESCRIPTION
PROPERTIES (USER INPUT):	• Building Use Information • Building program: • Energy requirements Spaces • Space group program: • General space group requirements • Space program: • General space requirements • Thermal comfort requirements • Visual Comfort requirements • Indoor Air Quality Requirements • Quality Requirements
DATA SOURCE:	A tool for managing spatial requirements like a ‘space programme’. Within HESMOS, an extended version of the OG tool **RoomEx** will be used to this end.
DATA FORMAT:	To make the Energy-related Client Requirements available via the aforementioned tool the **IFC2x3 data format** was chosen.[3]
REMARKS:	The spaces are imported into the tool RoomEx™ mainly from the architectural BIM model using IFC. The HVAC requirements will then be added to the spaces. The output is an IFC file.

[2] The complete Exchange Requirements for ‘Energy-related Client Requirements’ and all subsequent parts can be found in HESMOS Deliverable D1.1, Appendix I [ER 1] – cf. (Bort et al. 2011).

[3] Section 4.3.1 of this report provides more information on this open standard.

4.3 BIM to Energy

The ER "BIM to Energy" contain the geometry. After adding other relevant data like client requirements (s. 4.2 oben) location and climate data (s. 4.10 below) as well as material data (s. 4.11 unterhalb) the ER "eeBIM to Energy" prepare the BIM for Energy Analysis and Comfort Simulation.

They are used in the Design and Tendering Phase as well as in the Retrofitting and Refurbishment Phase.

Being based on the initially specified ER 'BIM to Energy' as described in Deliverable D1.1, sect. 1.4.2 and Appendix II, respectively (cf. Bort et. al., 2011), the ER "BIM to Energy" were updated, extended and newly structured. The table below provides an outline of the detailed ER.

REQUIREMENTS	DETAILED DESCRIPTION
PROPERTIES (USER INPUT):	Due to the large amount of relevant data and data types contained in a BIM model, the user input is subdivided into several subsections, namely: Building Structure, Energy-related Technical Equipment, Space-related user behaviour data and Site data.

BUILDING STRUCTURE:	Building simulations focusing on energy aspects are mostly space related. Therefore it is essential to describe the spaces inside a building in a detailed manner. Hence, for the HESMOS IVEL an IFC file has to include, in addition to the usual building elements data:
	• Spaces:
	   • Geometry
	   • Space quantities, such as volume, area, semantic description etc.
	   • Thermal requirements
	   • Lighting requirements
	   • Air quality requirements
	   • Space occupancy and usage requirements
	   • Technical Equipment of the Room (not HVAC) – data for each piece (internal gain)
	   • Opaque components and transparent components
	   • Shading
	• 2nd level Space Boundaries (SB)
	• Order and material data of each layer in the opaque space envelope
	• Detailed description of the inner structure for transparent parts of the space envelope

ENERGY-RELATED TECHNICAL EQUIPMENT:	For thermal conditioning not only exterior factors causing heat gains or losses have to be taken into account. Interior heat gains caused by technical equipment in conjunction with time schedules have to be considered as well. This equipment data can also be used to calculate the demand of electrical energy or other consumption-related media. Costs and the financial effort for maintaining and replacing this equipment should also be considered.

	The relevant BIM data of the HVAC equipment are: (1) Mechanical ventilation, (2) Heating system, (3) Hot water system, (4) Cooling system, (5) Lighting system, and (6) Renewable resources & low carbon measures equipment. However, detailed energy analyses of these systems incl. their mechanical components are beyond the scope of HESMOS.
SPACE RELATED USER BEHAVIOUR:	Except for the building envelope the use of the spaces is the main factor for energy consumption. Set point temperatures, (outside) air flow rates, occupancy rates, activities – all related with time schedules – are the main factors which have a significant influence on the thermal and electrical energy demand and the effort for related resources and media.
SITE:	Information about the building's location is essential for choosing weather data. Information about the surrounding area of the site affects the calculation of solar radiation on the exposed envelope of the building and is needed as well.
DATA SOURCE:	3D-design software for architects (CAAD) supporting BIM. In HESMOS Allplan (Nemetschek) is used to this end.
DATA FORMAT:	To make the exchange requirements 'BIM to Energy' available via the aforementioned tool the **IFC2x3 data format** was chosen.
REMARKS:	Within the 3D-design software a BIM is created. The output is an **IFC file** [with 1st level space boundaries[4] (SB)]. Within the HESMOS Integrated Virtual Energy Laboratory (IVEL) **these files have be enriched (including 1st to 2nd level SB)**.

[4] More information on Space Boundaries can be found in D1.1 (Bort et. al., 2011)

4.4 BIM to Investment Costs

The ER "BIM to Investment Costs" contain all required data for investment cost calculation.

They are used in the Design and Tendering Phase as well as in the Retrofitting and Refurbishment Phase for quantity take-off, LCC and 2D.

Being based on the more general ER 'BIM to Cost' described in D1.1 (Bort et. al., 2011), sect. 1.4.3 and Appendix III, respectively, they were updated and newly structured. The table below provides an outline of the detailed ER.

REQUIREMENTS	DETAILED DESCRIPTION

PROPERTIES (USER INPUT):	• Space
	• Construction:
	  • Foundation
	  • Beam
	  • Column
	  • Slab
	  • Stair flight
	  • Wall (Concrete, Brickwork)
	• Façade:
	  • Curtain Wall
	  • Doors
	  • Windows
	• Fit-Out:
	  • Wall claddings
	  • Non load bearing walls
	  • Indoor doors
	  • Ceiling and roof finishes
	  • Roof coverings
	• HVAC equipment:
	  • Sewage, Water, Gas Plants
	  • Heating Systems
	  • Mechanical Ventilation System
	  • Electrical System
	  • Mechanical Ventilation System
	  • Electrical System
	  • Telecommunication and Information Technology Equipment
	  • Conveyors e.g. elevators
	  • Specific use equipment
	• Building Automation System
	• Cost data

DATA SOURCE:	Program for tendering, awarding and invoicing. Within HESMOS **Allplan Building Cost Management (BCM)** is used for quantity take-off.
DATA FORMAT:	To make the 'BIM to Investment Costs' exchange requirements available via the aforementioned tool an **Allplan internal exchange format** can be used.
REMARKS:	Even though Investment costs are an important part, they are realized outside the IVEL core. Therefore the format is not further evaluated. A complete bill of quantities is generated within **Allplan BCM Quantities**. Hence, on the one side, there is the possibility to calculate the investment costs in Allplan BCM Construction Costs with standard prices from a data base or, on the other side, to export the bill of quantities to another cost estimation tool over the standardized GAEB-interface and import it into BCM after cost estimation.

4.5 BIM to Operational Costs (non-energy-related)

The ER "BIM to Operational Costs (non-energy-related)" contain components linked with specific service lives, cleaning areas etc. and additional cost data from data bases to calculate the non-energy related operational costs like cleaning, maintenance etc.

They are used in the Design and Tendering Phase as well as in the Retrofitting and Refurbishment Phase.

Being based on the more general ER 'BIM to Cost' described in D1.1 (Bort et. al., 2011), sect. 1.4.3 and Appendix III, respectively, they were updated and newly structured. The table below provides an outline of the detailed ER.

REQUIREMENTS	DETAILED DESCRIPTION

PROPERTIES (USER INPUT):	• Maintenance
	• Renewal & Decorative Repair
	• Cleaning Areas
	• Key figures for Cleaning
	• Cost data
	  • Maintenance Costs;
	  • Renewal & Decorative Repair Costs;
	  • Cleaning Costs Stair flight
	• Analysis Method: Net present value

REMARKS:	Even though Operational costs are an important part, they are realized outside the IVEL core. Therefore the format is not further evaluated.

4.6 Energy Simulation Results

The ER "Energy Simulation Results" contain the results of the energy analysis (heating, cooling and airflow demand, the as-analyzed thermal performance and the annual energy consumption results for heating, cooling and electricity).

They are used in the Design and Tendering Phase, the Commissioning and Operation Phase as well as the Retrofitting and Refurbishment Phase.

Based on the initially specified ER "Thermal Analysis Results" described in D1.1 (Bort et al., 2011) sect. 1.4.5 and Appendix III, respectively, they were updated and newly structured. The table below provides an outline of the detailed ER.

REQUIREMENTS	**DETAILED DESCRIPTION**
PROPERTIES (USER INPUT):	• Space • Energy consumption • Thermal comfort
Structuring:	The results provided by the advised energy simulation can be separated into four main parts: • Air flow rates • Demand of thermal conditioning of the building/spaces • Parts from total demand of electrical energy • Water demand • Thermal comfort measured by the operational room temperature The energy simulation provides values with a scaling of one hour or smaller for the parts. There are several benchmarks for comparison of energy and water demand depending on the type of building, e.g. demand per office worker / hospital bed / schoolchildren / working hour.
Air flow rates:	Based on the predefined user requirements and the time schedule of using the spaces the calculation of space related airflow rates are processed. The results lead to the evaluation of thermal and electrical energy for air conditioning and heating. Airflow rate is a real value with the unit '1/hour' or 'm^3/hour'.
Energy Demand of Thermal Conditioning:	The energy for thermal conditioning is divided into three parts: • Heating • Cooling Depending on users input data, e.g. activity level, operational temperature set points, and time schedules the results relates to a single space, a group of spaces or the building and to the time range specified by the user. Typical time ranges are one heating or cooling period or one year. The energy demand is a real value applied to a time interval e.g. 'MWh/year', 'kWh/year' or 'kWh/heating period'.

Demand of Electrical Energy:	The calculation of electrical energy used for lighting and peripheral components of HVAC systems is based on time schedule and user requirements. The results are closely connected with energy demand of heating, cooling and air conditioning too. The energy demand is a real value applied to a time interval e.g. 'MWh/year', 'kWh/year' or 'kWh/heating period'
Water Demand:	The water demand caused by users and HVAC equipment is estimated according to advised type of use in conjunction with the type and amount of the technical equipment. The water demand is given as real value expressed as volume per time interval, e.g. 'm^3/year'
Thermal Comfort:	Thermal comfort inside a single space is estimated by operational temperature and the difference between actual value and set point value according to a predefined time schedule. Analysis of this data during every time step inside a simulation run provides the possibility to a simplified evaluation of the thermal comfort a by means of lower deviation or overrun the set point. Both values are real numbers expressed as time period per time interval, e.g. 'hour/year'. The simulated maximal and minimal values for the operational temperature during period provides second criteria for evaluating thermal comfort. Minimum and maximum values are real numbers with the unit 'Kelvin'.
DATA SOURCE:	Has to be a tool for flexible navigation in the nD information space, thereby enabling presentation of simulation results not only in detailed engineering representation forms but also – at least for preliminary design and overview inspection – in intuitive manner based on perception aspects and criteria. Within the HESMOS project the new tool ***'nD Navigator'*** (to be developed in WP7) will be used to this end.
DATA FORMAT:	To make the 'Energy Simulation Results' exchange requirements available via the aforementioned tool an **enriched IFC format** can be used.
REMARKS:	Energy simulation results emerge from the information export from energy simulation runs. They are needed for: • Requirements management during design • HVAC technical requirements for HVAC design • Estimating life cycle costs in during design • Performance monitoring in operation phase • The nD Navigator, to visualize results in the energy cockpit. Energy-related requirements management verifies client requirements against as-analysed thermal performance from energy simulation. It includes also performance verification to other design alternatives/versions. The information exchange demands are following: • As-analysed spatial temperature performance (simul. max/min temp.) • As-analysed energy consumption prediction (heating, cooling, electricity, water).

	Energy simulation results support also HVAC design by defining technical requirements based on client requirements. The definition of technical requirements for HVAC design is done by sizing air-conditioning needs: • Airflow demand • Heating demand (heat losses) • Cooling demand. To estimate life cycle costs during design needs information about investment and operational costs. Energy simulation results support estimating of the energy-related operational costs. The information exchange demand is the following: • As-analysed energy consumption prediction (heating, cooling, electricity, water). Energy simulation results support additionally continuous performance monitoring during operation, where energy simulation creates targets for energy consumption. The information exchange demands include: • As-analysed energy consumption prediction (heating, cooling, electricity, water). The 'nD Navigator' is used to visualise results in the energy cockpit. The user specific charts of external energy results require numerical sequences of calculated energy data and life cycle costs to be displayed in the nD Navigator. The Import to the nD Navigator is a sequence of values (type: strings, Real type, Integer). Additional information concerning the data stream could be added, e.g. data description, unit name, etc. The visualization form is selected in the nD Navigator (column chart, line chart, bar chart, 3D chart, pie chart, etc.). Information exchange needs from energy simulation results cover at least the following: • As-analysed spatial temperature performance (simulated max/min temperatures) • As-analysed spatial air-conditioning needs (air flow, heating, cooling) • As-analysed energy consumption prediction (heating, cooling, electricity, water).

4.7 Energy Results to Operational Costs

The ER “Energy Results to Operational Costs” contain the results of the energy analysis (energy consumption for heating and cooling as well as electricity consumption) and additional cost data (energy tariffs) to calculate the energy-related operational costs.

They are used in the Design and Tendering Phase as well as the Retrofitting and Refurbishment Phase.

Based on the more general ER ‘BIM to Operational Costs’ described in D1.1 (Bort et. al., 2011), sect. 1.4.4 and Appendix III, respectively, they were updated and newly structured. The table below provides an outline of the detailed ER.

REQUIREMENTS	DETAILED DESCRIPTION

PROPERTIES (USER INPUT):	• General
	• Use Information
	• Energy Analysis Results
	• Cost data
	    • Energy Costs
	    • Electricity Costs
	• Analysis Method - Net present value.

DATA SOURCE:	Energy cockpit (generalizing results from energy solvers)
DATA FORMAT:	Internal format of IVEL
REMARKS:	Energy simulation generates the basis for calculating life cycle costs in conjunction with a given price model of an (local) energy supplier. Each kind of media demand, e. g. water or energy consumption e.g. combustible gas, fuel, heat provided by district heating, electricity is combined with an individual price model divided into an part related to the installed maximum thermal or electrical load, a second part containing consumption based prices and a third part describing cost for measurement and service. According to the energy demand the final conditions for energy and media supply are results of a negotiation between the PPP partner and the supplier. Based on the fact that there is no international standard defining a price model in this context storing price model data inside IFC is not worthwhile.

4.8 Investment and Operational Cost Results

The ER “Investment and Operational Cost Results” contain the results of the LCC calculation as a graphical interpretation of different alternatives.

They are used in the Design and Tendering Phase as well as the Retrofitting and Refurbishment Phase.

Based on the more general ER ‘Cost Results’ described in D1.1 (Bort et al., 2011), sect. 1.4.7 and Appendix III, respectively they were updated and newly structured. The table below provides an outline of the detailed ER.

REQUIREMENTS	DETAILED DESCRIPTION

PROPERTIES (USER INPUT):	• Building program:
	  • General Investment Costs
	  • Investment Costs Construction
	  • Investment Costs fit-out
	  • Investment Costs HVAC
	• Operational Costs:
	  • Energy-related Operational Costs
	  • Non Energy-related Operational Costs
	  • Parameter
	• Life Cycle Costs:
	  • Investment Costs
	  • Operational Costs

DATA SOURCE:	Investment cost calculation is done inside the Allplan tool. Operational cost calculation is processed combining the simulation results with individual price models of suppliers of energy and water inside ***IVEL***.
DATA FORMAT:	The results of investment and operational cost calculation could presented to architects, designers, or project managers supporting their different point of view and level of detail via individual reports divided into energy / media consumption, energy / media costs and thermal comfort indicators. Access to the reports is provided via **nD-Navigator**.
REMARKS:	Only a combination of operational costs, investment costs and thermal comfort provides a complete picture about the (financial) situation in a project. Especially during the design and tendering phase the energy simulation results and derived cost results support financial and design related decisions.

4.9 Energy Issue Reports

The ER "Energy Issue Reports" contain changes derived from the Energy and Cost analysis back into the design.

They are used in the Design and Tendering Phase as well as in the Retrofitting and Refurbishment Phase.

The ER 'Energy Issue Report' are based on the initial ER 'Cost Results' described in D1.1 (Bort et. al., 2011), sect. 1.4.7 and Appendix III, respectively. Due to the diversity of relevant result data, depending on the specific context and tasks, further detailing of the exchange requirements in this regard will be done in WP5. The table below outlines the overall concept.

REQUIREMENTS	DETAILED DESCRIPTION
PROPERTIES (USER INPUT):	Investment Costs
DATA SOURCE:	Various energy solvers (existing such as EnergyPlus, or new tools that will be extended or developed anew in HESMOS).
DATA FORMAT:	Typically text data or proprietary formats that are not readily computer-interpretable. However, for certain tasks, formal result description is possible and will be provided using XML. HESMOS will exploit the BIM Collaboration Format (BCF), currently being assessed for adoption as an associated buildingSMART standard, as part of eeBIM (see sect. 4.9 below).
REMARKS:	1) Those issues detected should be flagged up for attention. Comments may therefore be generated in three distinct ways: • By the analysis application detecting violation of predefined expectations • By the domain analyst raising violations from the deployment of his experience and expertise • By services run on the central model on dispatch or receipt of data packages when validating against the exchange requirements. 2) A number of formats used to hold design review issues have been evaluated, most of which are currently proprietary formats, including Solibri ModelChecker XML, US NIBS Projnet XML, Autodesk Navisworks XML, and others.

4.10 Climate Data

Climate Data is used in the Design and Tendering Phase as well as in the Retrofitting and Refurbishment Phase to simulate the thermal comfort, to size the HVAC systems or to obtain the annual energy consumption.

In the Operation Phase Actual Climate Data is used to be able to compare the actual state with the simulations.

Based on the library "Climate Data" described in D1.1 (Bort et al., 2011), z. B. sect. 1.3.3, it was updated. The table below provides an outline of the library data.

REQUIREMENTS	DETAILED DESCRIPTION
PROPERTIES	Data Structure: The data schema for describing weather data used for energy simulation in conjunction with software tools from TUD-IBK is divided into two parts. The first part contains all metadata and the second part holds the data itself. Every part is stored in one single file (Kupfer & Nicolai, 2010). Part 1 – metadata – contains the following items: • Site address; • Textual description; • Information about availability and user rights of the data; • Geographical position; • Data quality; • Available climate elements; • Available time periods; • Information about data manipulation. Part 2 – Standard climate element data with standardized names and units: • Temperature [°C]; • RelativeHumidity [%]; • LongWaveSkyRadiation [W/m²]; • WindDirection [°]; • WindVelocity [m/s]; • AirPressure [hPa]; • WindDrivenRain [kg/(m²s)]; • ShortWaveDirectRadiation [W/m²]; • ShortWaveDiffuseRadiation [W/m²]; • Azimuth [°]; • Elevation [°]; • ShortWaveGlobalRadiation [W/m²].

	Part 3 – Extended climate element data with standardized names and units: • CloudCoverage [1/8]; • DewPoint [°C]; • Precipitation [mm/h].
DATA SOURCE:	Weather stations and weather service
DATA FORMAT:	The metadata are stored in a XML format inside a directory structure depending on the geographical location. A unique ID identifies the metadata and the related climate element date.
REMARKS:	Design of the Weather Data Repository: "Data Model Development for THERAKLES and CAMPS Simulation Code" (Nicolai, 2011) and "Climate Calculation Module – Concept and Specifications" (Kupfer, Nicolai, 2010) give a more detailed description about the weather data repository model developed by TUD-IBK. The main facts related to weather data access in HESMOS are given consecutively. The weather data repository from TUD-IBK is a file-based structure. There are several reasons for this: • Compatible with in-house software tools using the same weather information like HESMOS; • Easy to set up; • Easy to maintain via a simple ASCII editor; • Independent from software operating system and special software application.

4.11 Material Data

Material Data is used in the Design and Tendering Phase as well as in the Retrofitting and Refurbishment Phase to simulate the thermal comfort, to size the HVAC systems or to obtain the annual energy consumption.

Based on the library "Material Data" described in D1.1 (Bort et al., 2011), z. B. sect. 1.3.2, it was updated. The table below provides an outline of the library data.

REQUIREMENTS	DETAILED DESCRIPTION
PROPERTIES	Material Information: The Material Data comes from external Databases or Tables. Usually every Material is identified by a unique ID-Code. Allplan Objects like Wall, Floor, etc. are storing these ID-Codes in the Object Parameter list. Other physical material properties, which are important for the energy calculation, are identified in the Material Database itself by the aid of the material ID-Code. However, it is also possible to attach additional parameters directly to Allplan (CAD) objects. The material ID-codes or names are strings of type character. The object information (material, geometry etc.) is exported via IFC interface or other formats to external applications.
DATA SOURCE:	Material libraries and databases.
DATA FORMAT:	All information about one material is stored in a single XML file. The identification of a material is done by the file name, which contains a unique identification number. For keeping data integrity and reproducibility of a simulation run every change inside a material description produces a new material data file named with a new identification number.
REMARKS:	In the current time there are no general data repositories or special standardized data protocols or information exchanging of physical data of construction material between software applications available on the market. For fulfilling this gap TUD-IBK developed an in house standard to exchange material data from different resources including the in house material laboratory to different own software applications during the last few years. The description for a material is formulated in a hierarchical structure using the XML language in a proprietary way. The internal structure of the model schema for material description that is used in HESMOS is divided into three main parts. The first part contains material name and material category, the second part provides constant scalar values, and the third part describes functional relationships between two physical values as data tuples as a pre-stage for generating spline functions for approximation intermediate values. The number of functions inside a material description is not restricted. So the third part can contain more than one function described with several data tuples (Nicolai, 2011).

	Design of the Material Repository: The material repository from TUD-IBK that will be used in HESMOS is a file-based structure. There are several reasons for that: • Compatible with in-house software tools using the same material information like HESMOS • Easy to set up • Easy to maintain via a simple ASCII editor • Independence from the software operating system and any specific software application.

4.12 Device Data to eeBIM

This part of the eeBIM framework comprises the information related to the Building Automation Systems (BAS). Knowledge about BAS is necessary for comparing the simulated energy consumption with the real situation. It is not intended to store the whole measurement data in the eeBIM; that may easily be Gigabytes of data only part of which is really relevant and needs to be directly addressed. Instead, this data is stored either locally in a database at the building or centrally in a database of the IVEL, depending on the needs of each specific PPP project However, information about the available sensors, their positions and functionality must be stored in the eeBIM.

Based on the ER 'Sensor Data' described in D1.1 (Bort et. al., 2011), sect. 1.4.3 and Appendix III, respectively, the ER "Device Data to eeBIM" were updated. The table below provides an outline of the detailed ER.

REQUIREMENTS	DETAILED DESCRIPTION
PROPERTIES (USER INPUT):	• Space • Room temperature, humidity, lighting • Room Occupancy • System • Alarms • Heating • Ventilation • Cooling • Lighting • Consumption (Heating, Cooling, Water, Electricity, Fuels) • Weather Data • Device Information
DATA SOURCE:	A user client to the BAS. In HESMOS, a specialised web application will be developed to this end.
DATA FORMAT:	Specific XML schema
REMARKS:	Not only sensors are needed for evaluation, but also information about the state of actuators and controllers. Therefore the more general term "device" is used. A device may be a sensor, controller, actuator or even a combination of them. One device can also include several sensors. For example, one physical device may be able to measure both room temperature and room humidity. For this complexity, an ontology is to be developed in WP 4. This ontology enables the eeBIM to be independent of network technologies like BACnet, LonWorks, KNX, EnOcean or ZigBee. The connection between the building geometry and the BAS devices have be established by linking devices to spaces and elements (IfcSpace and IfcBuildingElement). This gives the possibility to link e.g. temperature sensors to rooms (spaces) and surface temperature sensors to walls.

5. Information Exchange in the eeBIM Framework

One of the most important criteria for selecting the most suitable exchange formats is the availability of open standard interfaces. Especially for public authorities it is very important to be able to tender (BIM) services without being forced to specify one proprietary software solution.

Therefore, the availability of the standardised interface IFC (ISO 16739) implemented in the appropriate software applications plays such a major role.

Recognizing this fact, the public authorities in Finland - Senate Properties, in Norway - Statsbygg, in Denmark – DECA, and in the USA - GSA, jointly gave a statement of Intention to Support Open Standards for Building Information Modelling.[5]

Following these considerations, IFC as on open standard was chosen to be **the main data format** for exchanging building information within the HESMOS IVEL.

5.1 Basic issues

Based on the fact that not all relevant data can be structured in a single super schema, our approach is to take existing models as they are and treat them as one interoperable multi-model space. Advantages of that approach are as follows:

1. Existing and accepted data models can be used further without modification
2. According to a given task or process, information can be assembled in a straightforward way by composing relevant model data
3. IT coverage of building process information can be extended by alternative data models, as suggested or by data models created in future.

This shifts the paradigm from BIM-centred information management to a federation of coequal multi-models. Multi-models aggregate model instances of unmodified existing data schemes of possibly orthogonal domains and allow explicit relations between the instances by linking their elements. In the same way they aim at achieving instant adoption for prevalent and legacy construction software applications.

The generic multi-model approach aims at exchanging linked domain models relevant to a particular task of the entire information process. Producing those links as described formerly is seen as a complex and expensive work, hence the results represent high domain knowledge and should be accessible for further information processes. So the approach is not intended to give a single central access to a construction project´s complete information resources. Therefore it is not necessary to exchange data between different domain models, avoiding the need for implementers to develop preferable complete mappings on schema level. Rather than that, linking is intended to work on instance level, expressing the user´s ambition to describe a relation between some real world objects which are represented by different data models. As such relations have a task-specific semantic and allow a different interpretation without further context information, the sender´s original intention must be recognizable by a multi-model receiver to facilitate correct further processing. Hence the concept is seen as a temporary and loose coupling of elementary models. Therefore the approach also does not provide change management. Like the underlying domain models, the multi-model is only capable of representing one static information state.

[5] http://www.gsa.gov/graphics/pbs/Statement_of_Intention-BIM_FINAL.pdf (last visited: 2011-08-14)

Initiatory, a definition of the concepts of *Elementary Model, Link Model and Multi-Model* is essential.

An ***Elementary Model*** is an exchangeable instance of a data model with a delimited domain and an appointed semantic.

That means an Elementary Model does not require a corresponding explicit schema - e.g. XML-documents without XSD - but the semantic of the data must be known.

A ***Link Model*** is a serializable instance of a data model with a schema that stores references between elements of different Elementary Models.

A ***Multi-Model*** is a serializable composite of a set of Elementary Models **EM** and a possibly empty set of Link Models having elements of **EM** as subject.

5.2 Link model

Links are the explicit externalization of references between EMs. As most of the existing construction information models have identifiers for their elements, the authors chose an ID-based linking. That way links can be held outside of the domain models. Here the class *LinkModel* represents the idea of task-specific linking - each instance stands for a distinct combination of some of the EMs. Each contained link is expressed by an instance of class Link where the n-arity of a requirement as well as the ability to have a higher cardinality is implemented by a collection of contained *LinkedElements*. Each instance of that class represents one EM-element by using its ID in the attribute *elementID*. For further convenience the class *LinkModel* provides a reference to *ElementaryModel* having all the EMs which are subjects of the contained Links. Therefore a user or application does not have to inspect all *LinkedElement* instances to discover whether a *LinkModel* is relevant to it.

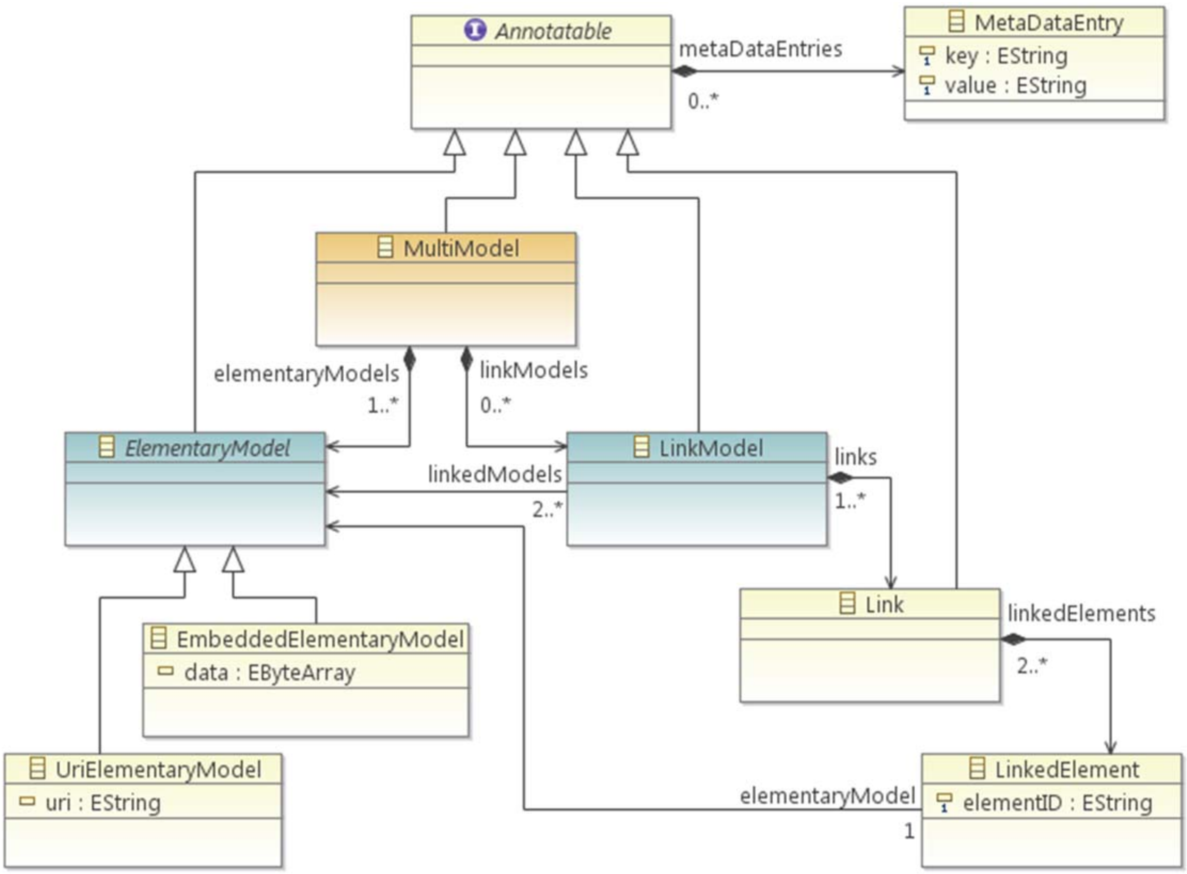

Figure 4: Class diagram of the generic multi-model schema

5.3 Elementary Models

After taking the different criteria such as format availability and openness into account, the following formats were selected for the specific exchanges within the HESMOS data flow.

The preferred format for exchanging data derived from an architectural building model is the current state-of-the-art ***IFC 2x3 format*** and for extensions the soon to be published IFC4 (s. 4.3.1)

Climate and Material Data (s. 4.10 and 4.11) transport is realized via HTTP using the transport/exchange layer TCP/IP. For writing the corresponding messages SOAP was selected, and for the interface WSDL.

For Device Data an approach independently of existing technologies like BACnet, KNX or LonWorks was seen to be suitable for evaluation purposes (s. 4.12).

5.3.1 BIM Data - ISO 16739 Industry Foundation Classes (IFC)

The base schema for BIM data is the IFC schema, the only comprehensive open BIM data specification that is currently undergoing its acceptance as a full ISO standard.

> *"ISO 16739 is an International Standard for the computer-interpretable representation of construction and facility management information and for the exchange of building data. The objective is to provide a neutral mechanism capable of describing buildings and similar facilities in the built environment throughout their life cycle. This mechanism is suitable not only for neutral file exchange, but also as a basis for implementing and sharing product databases, and as a basis for archiving." (Introduction, ISO/CD 16739:2011)*

BIM data input – state-of-the-art IFC2x3

As IFC2x3 is the current release[6] and all applications have implemented this interface, the prototypes within HESMOS shall be based on IFC2x3.

The official buildingSMART IFC Software Certification procedure, which is intended to promote consistent and reliable implementations of the IFC specification, is also based on IFC2x3 [7]

Coordination View Version 2.0 (CV2.0)

As a building is a very complex structure, a format covering all of its different aspects has to be very complex as well. IFC offers a vast array of information that is only partly needed at different stages in a building's lifecycle. That is why *"IFC data exchange is achieved with subsets -called views- of the whole IFC specification"* [8].

> *"The Coordination View targets the coordination between the architectural, mechanical and structural engineering tasks during the design phase. It has been the first view definition developed by buildingSMART International and is currently the most implemented view of the IFC schema." (See: http://buildingsmart-tech.org/specifications/ifc-view-definition/coordination-view-v2.0)*

One of the main targets of CV2.0 is to *"provide a full and syntactically complete and correct sub model of the IFC2x3 […] schema"*

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6 IFC2x4, or IFC4 respectively, hasn't been released, but is expected to be published in the 1st half of 2012.

7 More information on the official buildingSMART Certification Program can be found at: http://buildingsmart-tech.org/certification/details (last visited: 2011-06-30)

8 See: http://www.ifcwiki.org/index.php/IFC-Developers

> *The shared building information model […] includes the definition for spatial structure, building, and building service elements with shape representations, including both, parametric shapes for a limited range of standard elements, and the ability to also include non-parametric shape for all other elements. Property sets, material definitions and other alphanumeric information can be assigned to those elements. (http://buildingsmart-tech.org/specifications/ifc-view-definition/coordination-view-v2.0)*

These qualities make IFC2x3 CV2.0 the right format for exchanging the information defined in ER "BIM to Energy" (see also section 4.3).

BIM data output to energy solvers – upcoming IFC4

IFC2x3 was a stability release with no scope change. This autumn (2011), after 8 years, IFC4 – *the final and marketing name of IFC2x4* (cf. Liebich et al, 2011) –, will most likely be published, thereby providing:

- The next step to openBIM
- More and better support for interoperability in construction
- Full EXPRESS and XML schema specifications.

IFC4 will be submitted for a full ISO Standard 16739. First implementations are expected at the end of 2011 (Liebich, 2010).

Within HESMOS, all software prototypes will be based on the current and well-implemented release IFC2x3. However, extensions – brought about by future work in the HESMOS project, especially with regard to energy analyses and simulations –, will be based on IFC4.

5.3.2 BIM Collaboration Format (BCF)

While not being an official standard of buildingSMART International yet, the BCF – externally developed – has been endorsed by buildingSMART and is under review to become one of the buildingSMART standards. By using BCF, information on changes in a BIM can be exchanged between parties without having to exchange the whole BIM (Jan Karlshøj, 2011).

- The BCF format is extremely simple and easy to implement
- The basic content is that you create an issue, add comment and refer that to the object(s) in question (using IFC mechanisms for Global Unique Identifiers (GUIDs)).
- The format also supports comments and status as this issue may be referred to and answers/suggestions added by receiving applications
- In addition to text can be included
  - Comments
  - Lists of objects
  - Attached camera and viewport
  - Snapshot(s) of how the model looked in the application where the issue was last addressed.

For practicability reasons the BCF will be used in HESMOS to transfer the necessary changes caused by the calculations and simulations back to the original architectural BIM.

5.3.3 Device Data

As stated in section 4.12, not the measurement data itself but data about the BAS devices has to be stored in the eeBIM. Basic information about these things is already available in IFC2x4 (e.g. *IfcSensor*), but this is not enough for evaluation purposes. Real devices are complex objects, which can combine functionality of several sensors. Also existing device description languages like EDDL, GSDML and FDCML cannot be used because of their insufficient semantically defined vocabulary for automatic evaluation, which is necessary in HESMOS to clear the users of BAS knowledge. Instead, an ontology-based approach is used in HESMOS. The basic structure of the device information structure is shown below.

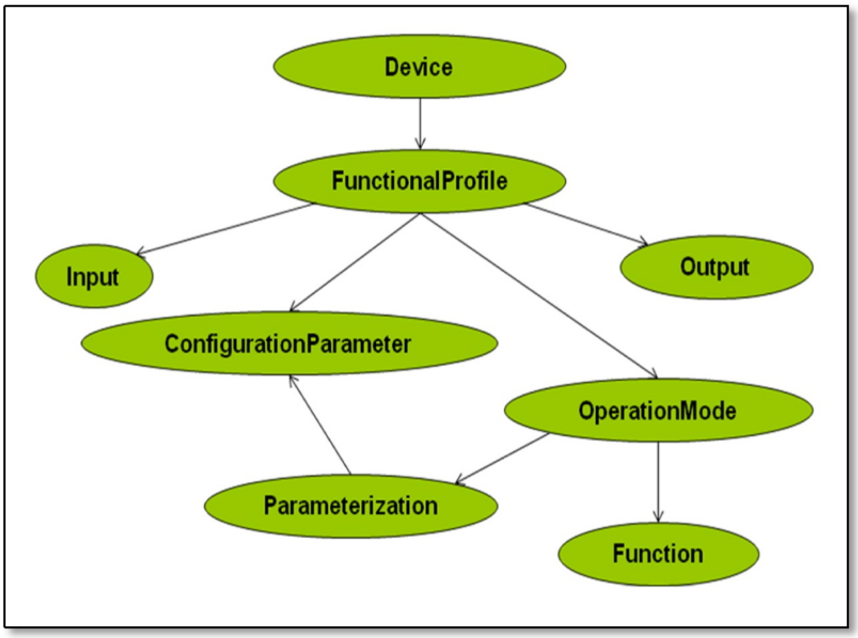

Figure 6: Basic structure device information

One device can contain several functional profiles, each having own inputs, outputs and configuration parameters. Sets of parameters for a given operation mode are united into parameterizations. This approach is independent of concrete technologies like BACnet, KNX or LonWorks. This allows to be prepared for upcoming BAS technologies in the future. Additionally to the data shown above, information about the access to the measurement data (a reference parameter) is stored, containing information about the network and the "way" to get the information. The details of the information to be stored in the eeBIM are to be developed in WP 4, closely related to the ontology to be created there. The device information is given in form of XML. The linkage between the building geometry data (IFC) and the BAS devices is given by connecting BAS devices to spaces or building elements, enriched by their exact position (coordinates). This information is needed for exact evaluation of the meaning of measurement data and easy, even automatic finding of appropriate sensors for a given purpose.

5.3.4 Climate Data

Protocol

Web service data transport will be realized via HTTP using the transport/exchange layer TCP/IP. SOAP will be used for format description of the messages. The language for interface description is WSDL.

Format - Data Schema

The data schema for describing weather data used for energy simulation in conjunction with software tools from TUD-IBK is divided into two parts. The first part contains all metadata and the second part holds the data itself. Every part is stored in one single file. (Nicolai, 2011; Kupfer & Nicolai, 2010).

The division into metadata and climate element data allows a reduction of data traffic between the weather data repository and the 'IVEL core' respectively the GUI because mostly the user needs only the metadata in the GUI to choose a weather data set, which fits his needs.

Content

Part 1 – metadata – contains the following items:

- Site address;
- Textual description;
- Information about availability and user rights of the data;
- Geographical position;
- Data quality;
- Available climate elements;
- Available time periods;
- Information about data manipulation

Part 2 contains the actual stored climate data.

5.3.5 Material Data

Protocol

For web service data transport is realized via HTTP using the transport/exchange layer TCP/IP. SOAP is used for format description of the messages. The language for interface description is WSDL.

Format - Data Schema

The description for a material is formulated in a hierarchical structure using XML in a proprietary way. An example of one material description is given in (Nicolai, 2011).

All information about one material is stored in a single XML file. The identification of a material is done by the file name, which contains a unique identification number. For keeping data integrity and reproducibility of a simulation run every change inside a material description produces a new material data file named with a new identification number.

Content

The material metadata section contains the following items:

- Part 1 –material name (and material category if present);
- Part 2 – scalar material property values.

6. Conclusions and Outlook

In this Deliverable we specified all major aspects of the energy enhanced building information modelling framework (eeBIM) that is being developed for the HESMOS Integrated Virtual Energy Laboratory (IVEL), but can also be used in other systems beyond HESMOS and is intended to be forwarded for standardisation. The framework is based on an innovative multi-model concept comprising a consistent set of elementary models, with IFC-BIM as central integrating part and a Link Model to bind the distributed model data together. In addition, the adopted IDM development approach was extended and adapted for the needs of energy efficient ICT support in the whole building life cycle. In particular, a clear development roadmap was worked out that can not only serve HESMOS, but many related research areas and application domains as well. The IDM approach was made more slender and easier to understand by practitioners, but it was at the same time extended in the specification part for implementers (introducing a new exchange requirements model, ERM). Thus, a sound basis for technical formulation of the eeBIM in WP3 and the software implementations in WPs 3-8 was set.

Further work regarding eeBIM includes:

- Harmonization of the eeBIM framework and the established overall software architecture of the IVEL platform (cf. Deliverable D2.2) to technical specifications for the implementations – WP3;
- Feedback with as-needed revision and extensions of eeBIM details with regard to energy simulation (WP4), device data from BAS (WP5) and FM (WP6), as well as viewing, inspection and navigation (WP7);
- Full integration and testing of the framework on the IVEL (WP8) and its validation in real-life pilots (WP9).

The eeBIM realisation will be shown in these work packages in accordance to the project schedule.

Literature Sources

Bort, B., Geißler M.-C., Guruz R. (2011): *HESMOS Deliverable D1.1: Gap Analysis, Use Case Scenarios and Requirements Specification*, © HESMOS Consortium, Brussels.

buildingSMART (2011): *Coordination View Version 2.0 Summary*, http://buildingsmart-tech.org/specifications/ifc-view-definition/coordination-view-v2.0

Fuchs, S., Kadolsky, M., Scherer, R. J. (2011): *Formal Description of a Generic Multi-Model*, IEEE WETICE 2011, Paris, 27-29 June 2011.

Fuchs, S., Katranuschkov, P., Scherer, R. J. (2010): *A framework for multi-model collaboration and visualisation*, European Conference on Product and Process Modelling (ECPPM) 2010, Cork, Republic of Ireland, 14-16 September 2010.

GSA (2009): *GSA BIM Guide for Energy Performance*, United States General Services Administration (GSA), Public Buildings Service (PBS), Office of the Chief Architect and Capital Construction Programs (OCA-CCP).

Hietanen, J. (2006): *IFC Model View Definition Format*, International Alliance for Interoperability, http://www.secondschool.net/one/IAI_IFC_framework.pdf (last visited 2011-07-05)

IFC-Developers (last visited: 2011-06-30): http://www.ifcwiki.org/index.php/IFC-Developers

ISO 29481-1 (2010): *Building information modelling -- Information delivery manual -- Part 1: Methodology and format*, © ISO, Geneva

ISO/CD 16739 (2011): *Industry Foundation Classes for AEC/FM data sharing*, © ISO, Geneva

Karlshøj, J. (2011): *Standardized User requirements and new technical development*, buildingSMART IUG Meeting, Abu Dhabi, 30-31 March 2011.

Katranuschkov, P., Weise, M., Windisch, R., Fuchs, S., Scherer, R.J. (2010): *BIM-based Generation of Multi-Model Views*, CIB W078 2010, Cairo, 27-29 November 2010.

Kupfer, H., Nicolai A. (2010): *Climate Calculation Module – Concept and Specifications* (internal report), Dresden Univ. of Technology, Faculty of Architecture, Institute of Building Climatology.

Nicolai, A., Vogelsang S. (2011): *An Extensible Calculation Framework for Climate Data and Boundary Conditions*, NSB 2011, 9th Nordic Symposium on Building Physics, Tampere, Finland, Vol. 1 (3).

Nicolai, A. (2011): *Data Model Development for THERAKLES and CAMPS Simulation Code* (internal report), Dresden Univ. of Technology, Faculty of Architecture, Institute of Building Climatology.

Liebich, T. (2010): *Unveiling IFC2x4*, buildingSMART International.

Liebich, T. (Ed.) Stangeland B., Karlshøj, J., Steinmann, R. (2011): *Compatibility Issues with IFC4,* buildingSMART Model Support Group, buildingSMART Int. Meetings, Abu Dhabi, March 2011.

Scherer, R. J., Schapke, S.-E. (2011): *A distributed model-based management information system for construction projects*, to appear in: Journal of Advanced Engineering Informatics, Elsevier.

Statement of Intention to Support Building Information Modeling with Open Standards (last visited: 2011-06-29), http://www.gsa.gov/graphics/pbs/Statement_of_Intention-BIM_FINAL.pdf

Wix J. (2007): *Information Delivery Manual: Guide to Components and Development Methods*, © BuildingSMART Norway, http://idm.buildingsmart.no, 82 p.

Appendix I: Acronyms

AEC:	**A**rchitecture, **E**ngineering, and **C**onstruction
ASCII:	**A**merican **S**tandard **C**ode for **I**nformation **I**nterchange
BAS:	**B**uilding **A**utomation **S**ystems
BCF:	**B**IM **C**ollaboration **F**ormat
BCM:	**B**uilding **C**ost **M**anagement
BIM:	**B**uilding **I**nformation **M**odel/**M**odelling
CV:	**C**oordination **V**iew
eeBIM:	**e**nergy **e**nhanced **BIM**
ER:	**E**xchange **R**equirement
ERM:	**E**xchange **R**equirement **M**odel
FM:	**F**acility **M**anagement
GAEB:	**G**emeinsamer **A**usschuss **E**lektronik im **B**auwesen *(Joint Committee on Information Technology in the Construction Industry)*
GUID:	**G**lobal **U**nique **I**dentifier
HTTP:	**H**yper**T**ext **T**ransfer **P**rotocol
HVAC:	**H**eating, **V**entilation, and **A**ir **C**onditioning
IDM:	**I**nformation **D**elivery **M**anual (ISO 29481)
IFC:	**I**ndustry **F**oundation **C**lasses (ISO 16739)
IVEL:	**I**ntegrated **V**irtual **E**nergy **L**aboratory
LCC:	**L**ife-**C**ycle **C**osting
SB:	**S**pace **B**oundaries
SOAP:	**S**imple **O**bject **A**ccess **P**rotocol
TCP/IP:	**T**ransmission **C**ontrol **P**rotocol/**I**nternet **P**rotocol
WSDL:	**W**eb **S**ervice **D**efinition **L**anguage
XML:	e**X**tendable **M**ark-up **L**anguage

Appendix II: BIM to eeBIM Exchange Requirements Table

[ER 2] Exchange Requirements for BIM to Energy						*Exchange Requirement Model*
Element / Property concept / Property group / Property name	Definition	Examples and further explanations	Data Source	IFC2x3 Export	Additional data	IFC2x3 Schema Representation
Construction						
Building Structure						
Building general						
geographical position - latitude	World Latitude at reference point	47° 25' N / 010° 59' E	IFC	M		IfcSite.RefLatitude
geographical position - longitude	World Longitude at reference point	47° 25' N / 010° 59' E	IFC	M		IfcSite.RefLongitude
High above sea level	Datum elevation relative to sea level	113 m over sea level Amsterdam	IFC	M		IfcSite.RefElevation
Orientation	North arrow, true north direction relative to the building model y axis	+30° (true north is +30 degree from project y-axis)	IFC	M		IfcGeometricRepresentationContext.TrueNorth
Type of use	Name of the type for the building	"Office", "School"	IFC	M		IfcBuilding + IfcPropertySingleValue (Pset_BuildingCommon, OccupancyType)
Location description	*Textual description of constructions, buildings, landscape, nearby this facility*	*A selection from a catalogue with prescribed text, e.g.: city center, field*	eeBIM		ee	
Air tightness (infiltration rate)	*Normalized air infiltration rate on a normalized air pressure set point - 'blower door' result*	*Information typically not available to the designer - to be added in the eeBIM enrichment process.*	eeBIM		ee	
Spaces						
Spaces general						
Space number	Unique number of the space (e.g. in context of the building or story)	"EG-001"	IFC	M		IfcSpace.Name
Space name	Descriptive name of the space	"Foyer"	IFC	M		IfcSpace.LongName

[ER 2] Exchange Requirements for BIM to Energy						Exchange Requirement Model
Element / Property concept / Property group / Property name	Definition	Examples and further explanations	Data Source	IFC2x3 Export	Additional data	IFC2x3 Schema Representation
Space quantities						
Space area	Area as stated in ÖNORM B 1800, SIA 416, SN 504416 or DIN 277	Net area as covered by base quantities	IFC	M		IfcQuantityArea (BaseQuantities, NetFloorArea)
Space volume	Volume as stated in ÖNORM B 1800, SIA 416, SN 504416, DIN 277	Net area as covered by base quantities	IFC	M		IfcQuantityVolume (BaseQuantities, NetVolume)
Thermal requirements						
Design temperature maximum	Temperature of the space or zone, that is required from user/designer view point.	[°C]	IFC	M		IfcPropertySingleValue (Pset_SpaceThermalRequirements, SpaceTemperatureMax)
Design temperature minimum	Temperature of the space or zone, that is required from user/designer view point.	[°C]	IFC	M		IfcPropertySingleValue (Pset_SpaceThermalRequirements, SpaceTemperatureMin)
Humidity, summer	Humidity of the space or zone that is required from user/designer view point.	[% relative humidity]	IFC	M		IfcPropertySingleValue (Pset_SpaceThermalRequirements, SpaceHumiditySummer)
Humidity, winter	Humidity of the space or zone that is required from user/designer view point.	[% relative humidity]	IFC	M		IfcPropertySingleValue (Pset_SpaceThermalRequirements, SpaceHumidityWinter)
Lighting requirements						
Luminance level	Required average luminance value for this space.	[lux]	IFC	O		IfcPropertySingleValue (Pset_SpaceLightingRequirements, Illuminance)
Direct or indirect lighting	Indication whether this space requires artificial lighting or not.	True/False	IFC	O		IfcPropertySingleValue (Pset_SpaceLightingRequirements, ArtificialLighting)

[ER 2] Exchange Requirements for BIM to Energy						*Exchange Requirement Model*
Element Property concept Property group Property name	Definition	Examples and further explanations	Data Source	IFC2x3 Export	Additional data	IFC2x3 Schema Representation
Air quality requirements						
Natural Ventilation	Indication whether the space is required to have natural ventilation (TRUE) or mechanical ventilation (FALSE).	True/False	IFC	M		ifcPropertySingleValue (Pset_SpaceThermalRequirements, NaturalVentilation)
Natural Ventilation Rate	Indication of the requirement of a particular natural air ventilation rate	[l/h] general rate of replacing the air volume of the space per hour	IFC	O		ifcPropertySingleValue (Pset_SpaceThermalRequirements, NaturalVentilationRate)
Mechanical Ventilation Rate	Indication of the requirement of a particular mechanical air ventilation rate	[l/h] general rate of replacing the air volume of the space per hour	IFC	O		ifcPropertySingleValue (Pset_SpaceThermalRequirements, MechanicalVentilationRate)
Fresh air requirement	Outside air exchange rate in volume per hour and person or volume per hour per square metre	[l/s/person] - to be calculated for eeBIM enrichment from basic values above.	eeBIM		ee	
Space occupancy and use requirements						
Type of the room	Occupancy type (often according to a space naming classification)	a link to a catalogue of predefined names (in germany for instance DIN 276): "meeting room"	IFC	M		IfcPropertySingleValue (Pset_SpaceOccupancyRequirements, OccupancyType)
Number of users	Number of people expected for the activity assigned to this space.	10	IFC	M		IfcPropertySingleValue (Pset_SpaceOccupancyRequirements, OccupancyNumber)
Maximal number of users	Maximal number of people expected for the activity assigned to this space in peak time.	15	IFC	O		IfcPropertySingleValue (Pset_SpaceOccupancyRequirements, OccupancyNumberPeak)
Type of activity of the user	*Activities as stated in standards like DIN EN ISO 7730, DIN 1946, VDI 2078*	*sitting, standing with light work, heavy demanding work*	eeBIM		ee	
Time period of activity per day	Daily and weekly schedule	Monday, Friday from 7:00 to 9:00	eeBIM	ee		

[ER 2] Exchange Requirements for BIM to Energy						*Exchange Requirement Model*
Element / Property concept / Property group / Property name	Definition	Examples and further explanations	Data Source	IFC2x3 Export	Additional data	IFC2x3 Schema Representation
Technical Equipment of the Room (not HVAC) - data for each piece (internal gain)						
Heat gain from equipment	Heat gains and losses from equipment.	[W] total thermal load per room, e.g. 200W (as sum of all equipment)	IFC	O		IfcPropertySingleValue (Pset_SpaceThermalLoad, EquipmentSensible
Heat gain from equipment per area	Heat gains and losses from equipment as design value per area (per square meter)	[W/m2] total thermal load per square meter, e.g. 20W/m2 (as sum of all equipment)	eeBIM		ee	
Number of equipment which produces heat gains	Number of the equipment depending on the type of room	one pc+tft per person, meeting room with one beamer and one laptop per person	eeBIM		ee	
Type of equipment which produces heat gains	Type of the equipment depending on the type of room	one pc+tft per person, meeting room with one beamer and one laptop per person	eeBIM		ee	
Time period using the equipment	Daily and weekly schedule.	Monday, Friday from 7:00 to 9:00. Default values can be used depending on the type of room and the number of occupants	eeBIM		ee	
Opaque components						
Building element type	Classification of element (wall, roof, slab, etc.)	Selection of correct element type for the opaque component (BIM object oriented structure)	IFC	M		IfcWall, IfcSlab, IfcRoof, IfcColumn, IfcBeam, IfcRamp, IfcStair
Construction type	Identification code for this type of element within the project	OW1 (outside wall type 1)	IFC	M		e.g. IfcWall + IfcPropertySingleValue (Pset_WallCommon, Reference)
Internal or external element	Indication whether the building element is part of the outer envelope (facade) or not	True/False	IFC	M		e.g. IfcWall + IfcPropertySingleValue (Pset_WallCommon, IsExternal)

[ER 2] Exchange Requirements for BIM to Energy						*Exchange Requirement Model*
Element / Property concept / Property group / Property name	Definition	Examples and further explanations	Data Source	IFC2x3 Export	Additional data	IFC2x3 Schema Representation
Building element material	Reference to the material information for this element, can be a single material, or a material layer set	either "brick", or 3 layer wall with layer[1] 365mm 'brick', layer[2] with 40mm isulation, layer[3] 20mm external plaster	IFC	M		e.g. IfcWall + IfcRelAssociatesMaterial + (SELECT) IfcMaterialSelect
Material layer set - Name of the layer	Material information provided as material layer set - Name of the material per layer	brickwall (outer leaf) [-]	IFC	M		e.g. IfcWall + IfcRelAssociatesMaterial + IfcMaterialLayerSet + IfcMaterialLayer + IfcMaterial.Name
Material layer set - Position of the layer	Material information provided as material layer set - Identification of the position of the layer inside the wall	second from outside [-]	IFC	M		e.g. IfcWall + IfcRelAssociatesMaterial + IfcMaterialLayerSet + IfcMaterialLayer (position with the list of IfcMaterialLayerSet)
Material layer set - Thickness of the layer	Material information provided as material layer set -Thickness of each layer	[m]	IFC	M		e.g. IfcWall + IfcRelAssociatesMaterial + IfcMaterialLayerSet + IfcMaterialLayer.LayerThickness
Density of the layer material	*Material mass density.*	*rho [kg/m³] Retrieved from a material database with the material's unique ID*	*eeBIM*		ee	[IFC4] IfcMaterial.HasProperties + IfcExtendedMaterialProperties(Pset_GeneralMaterialProperties, MassDensity)
Thermal conductivity	*Property of a material's ability to conduct heat*	*[W/(m K)] Retrieved from a material database with the material's unique ID*	*eeBIM*		ee	[IFC4] IfcMaterial.HasProperties + IfcExtendedMaterialProperties(Pset_ThermalProperties, ThermalConductivity)
Specific heat capacity of the layer material	*Defines the specific heat of the material: heat energy absorbed per temperature unit.*	*c [J/kgK] Retrieved from a material database with the material's unique ID*	*eeBIM*		ee	[IFC4] IfcMaterial.HasProperties + IfcExtendedMaterialProperties(Pset_ThermalProperties, SpecificHeatCapacity)
Transparent components						
Building element type	Classification of element (window, door (with glazing), roof light, curtain wall, etc.)	Selection of correct element type for the transparent component (BIM object oriented structure)	IFC	M		IfcDoor, IfcWindow, IfcCurtainWall

[ER 2] Exchange Requirements for BIM to Energy						Exchange Requirement Model
Element / Property concept / Property group / Property name	Definition	Examples and further explanations	Data Source	IFC2x3 Export	Additional data	IFC2x3 Schema Representation
Construction type	Identification code for this type of element within the project	W1 (window type 1)	IFC	M		e.g. IfcWindow + IfcPropertySingleValue (Pset_WindowCommon, Reference)
Internal or external element	Indication whether the building element is part of the outer envelope (facade) or not	True/False	IFC	M		e.g. IfcWindow + IfcPropertySingleValue (Pset_WindowCommon, IsExternal)
Ratio of glazing per transparent element	Ratio of glazing relative to the side (or elevation) area of the transparent element (e.g. ratio of glazing of a window)	0.8 = 80% [-] - i.e. 80% glazing, 20% framing for a window.	IFC	M		e.g. IfcWindow + IfcPropertySingleValue (Pset_WindowCommon, GlazingAreaFraction)
Proportion of glass on the whole area	Ratio of glazing relative to the space	0.2= 20% [-] - i.e. 20% glazing per space floor area	eeBIM		ee	
Type of glass	Heat protection glass / sun protection glass	[-] Retrieved from component database with window construction type id	eeBIM		ee	
Number of window panes	Number of glass layers	3 [-] Retrieved from component database with window construction type id	eeBIM		ee	e.g. IfcWindow + IfcPropertySingleValue (Pset_DoorWindowGlazingType, GlassLayers)
Thickness of every pane	Thickness of each glass layers	[m] Retrieved from component database with window construction type id	eeBIM		ee	e.g. IfcWindow + IfcPropertySingleValue (Pset_DoorWindowGlazingType, GlassThickness1/2/3)
Thickness of every spacing between panes		[m] Retrieved from component database with window construction type id	eeBIM		ee	
Position and number of thermal and optical coatings	Name of the position of glass coatings - direction from outside to inside (exterior glass pane / spacing / interior glass pane)	Data type INTEGER (=position number). Retrieved from component database with window construction type id	eeBIM		ee	
Type and mixture of gas between the panes		[-] Air(10%)/Argon(90%);	eeBIM		ee	e.g. IfcWindow + IfcPropertySingleValue (Pset_DoorWindowGlazingType, FillGas)
Overall energy transmittance Solar Heat Gain Transmittance		data type REAL. Retrieved from component database with window construction type id	eeBIM		ee	

[ER 2] Exchange Requirements for BIM to Energy						Exchange Requirement Model
Element / Property concept / Property group / Property name	Definition	Examples and further explanations	Data Source	IFC2x3 Export	Additional data	IFC2x3 Schema Representation
Thermal transmittance resistance of the glass	Thermal transmittance Summer/-Winter only for glazing system (without frame!);	U [W/m²K] data type REAL. Retrieved from component database with window construction type id	eeBIM		ee	
Material of the window frame		[-] Retrieved from component database with window construction type id	eeBIM		ee	[IFC2x3] e.g. IfcWindow + IfcWindowStyle.IfcWindowStyleConstructionEnum [IFC4] e.g. IfcWindow + IfcMaterialConstituentSet + IfcMaterialConstituent
Thickness of the window frame	Lining thickness	[m] data type REAL. Retrieved from component database with window construction type id	eeBIM		ee	IfcWindowLiningProperties.LiningDepth/ LiningThickness
Thermal transmittance resistance of the window frame	Thermal transmittance Summer/-Winter only for window frame (without glazing!)	U [W/m²K] Data type REAL. Retrieved from component database with window construction type id	eeBIM		ee	
Air transmissivity of the joint in the window frame	Joint permeability coefficient. The airflow, which is exchanged between the interior and exterior per meter joint length at a reference barometric pressure difference of 10 Pa.	[m³/(h * m * daPa²/³)] data type REAL. Retrieved from component database with window construction type id	eeBIM		ee	
Shading	Divided as shading being part of doors windows and curtain walls, and additional shading devices that protrude out of the facade					
Type of shading		*Textile lamella / aluminium lamella / textile blind - no pervious to light / textile blind - dimming light. [-]. data type STRING.*	*eeBIM*		ee	
Location of shading		*inside, outside; data type: STRING*	*eeBIM*		ee	
Shading coefficient	*Ratio of solar gain (due to direct sunlight) passing through a glass unit to the solar energy which passes through 3mm Clear Float Glass*	*0,3 [-]. Data type: REAL*	*eeBIM*		ee	IfcPropertySingleValue (Pset_DoorWindowShadingType, ExternalShadingCoefficient)

[ER 2] Exchange Requirements for BIM to Energy						Exchange Requirement Model
Element / Property concept / Property group / Property name	Definition	Examples and further explanations	Data Source	IFC2x3 Export	Additional data	IFC2x3 Schema Representation
Geometry of inner shading		*data type INTEGER (e.g. 0… horizontal; 1…vertical)*	*eeBIM*		ee	
Control mode of the outer shading	*Manually operated by people depending on their personal behaviour or automatically operated via electric engine by BAS based on measured solar radiation, wind velocity and/or time;*	*Data type could be INTEGER (e.g. 0... manually controlled; or 1... BAS controlled)*	*eeBIM*		ee	
HVAC equipment	-					
Mechanical ventilation						
Ventilation system service zone	Group of spaces, served by the ventilation system.		IFC-HVAC	hvac		[IFC2x3] IfcZone + IfcPropertySingleValue (Pset_ZoneCommon, Category) [IFC4] IfcSpatialZone.PredefinedType + .ServicedBySystems (link to ventilation system)
Type of system	Category "Ventilation", additional name of system		IFC-HVAC	hvac		[IFC4] IfcDistributionSystem.PredefinedType = VENTILATION + IfcDistributionSystem.Name
Outside air	The value describes how many times the air inside a space volume will be exchanged hourly by outside air.	Closely connected with "Fresh air require-ment", because "Fresh air requirement" describes a specific value depending on e.g. the persons in the space or other underlying values. Outside air (change) is based on the volume of the space.	IFC-HVAC	hvac		
Natural ventilation		yes / no [-]	IFC-HVAC	hvac		
Schedule	Daily operating time, start and finish time	daily, 6:30 - 22:30	IFC-HVAC	hvac		

[ER 2] Exchange Requirements for BIM to Energy						Exchange Requirement Model
Element / Property concept / Property group / Property name	Definition	Examples and further explanations	Data Source	IFC2x3 Export	Additional data	IFC2x3 Schema Representation
Fan power	Installed electrical power of the fan in the air/climate system	data type REAL, unit [W]	IFC-HVAC	hvac		
Heat recovery %	Ratio between the difference of the inlet air and outlet air temperature on the hot/worm side of a heat recovery device to the temperature difference between inlet air temperature on the warm an inlet air temperature on the cold side of the heat recovery device	data type REAL, without unit	IFC-HVAC	hvac		
Return air %	Ratio between the difference of outgoing exhaust air and exhaust air	data type REAL, without unit	IFC-HVAC	hvac		
Heating system						
Heating system service zone	Group of spaces, served by the heating system		IFC-HVAC	hvac		[IFC2x3] IfcZone + IfcPropertySingleValue (Pset_ZoneCommon, Category) [IFC4] IfcSpatialZone.PredefinedType + .ServicedBySystems (link to ventilation system)
Type of system	Category "Heating", additional name of system	e.g district heating, boiler, solar system, combined heat and power unit.	IFC-HVAC	hvac		[IFC4] IfcDistributionSystem.PredefinedType = HEATING + IfcDistributionSystem.Name
Energy source/ fuel type		e.g. Heating oil, natural gas, biomass, timber, coal. data type STRING	IFC-HVAC	hvac		
Flow temperature	Set Point Temperature for the water inside the pipe system in pump water heating system - leaving the boiler at design condition	50 [°C]. data type REAL	IFC-HVAC	hvac		

[ER 2] Exchange Requirements for BIM to Energy						*Exchange Requirement Model*
Element / Property concept / Property group / Property name	Definition	Examples and further explanations	Data Source	IFC2x3 Export	Additional data	IFC2x3 Schema Representation
Return temperature	Set Point Temperature for the water inside the pipe system in pump water heating system - entering the boiler at design condition	40 [°C]. data type REAL	IFC-HVAC	hvac		
Control Mode	Method to control the set point temperature for the water leaving the boiler, either depending on the outside air temperature, the operational temperature of one or more spaces or a combination of both.	e.g. regulated by outside temperature, room dependent heat controller. data type STRING or INTEGER (if text is translated into numbers)	IFC-HVAC	hvac		
Night setback temperature	Temperature difference between 'normal' and 'reduced'	For energy saving reasons the Set Point Temperature on the boiler will be reduced during the time when the space/building is not occupied. E.g. 2,5 [-], data type REAL; unit Kelvin (K)	IFC-HVAC	hvac		
Coefficient of performance	Ratio of useable and applied heating/cooling power as an characterization of cooling or heat pump systems (ATTENTION: different interpretations in US and EU)	data type REAL, without dimension	IFC-HVAC	hvac		
Schedule	Daily operating time, start and finish time	daily, 6:30 - 22:30	IFC-HVAC	hvac		
System seasonal efficiency and delivery efficiency	Seasonal average ratio of useable and applied heating power as an characterization of heat pump systems (ATTENTION: different interpretations in US and EU)	data type REAL, without dimension	IFC-HVAC	hvac		

[ER 2] Exchange Requirements for BIM to Energy						*Exchange Requirement Model*
Element / Property concept / Property group / Property name	Definition	Examples and further explanations	Data Source	IFC2x3 Export	Additional data	IFC2x3 Schema Representation
Hot water system						
Hot water system type		textual system characterization, e.g. hot water storage with or without circulation / hot water circulatory system; data type STRING	IFC-HVAC	hvac		[IFC4] IfcDistributionSystem.PredefinedType = DOMESTICHOTWATER + IfcDistributionSystem.Name
Hot water system consumption	Total energy consumption for hot water supply	data type REAL	IFC-HVAC	hvac		
Hot water supply temperature	Set Point Temperature for the hot water inside the hot water storage or circulatory systems	data type REAL	IFC-HVAC	hvac		
Hot water storage volume	Water volume inside the hot water storage	data type REAL, unit [m³]	IFC-HVAC	hvac		
Heat loss	Heat loss of the hot water storage per day	data type REAL, unit [kWh/d]	IFC-HVAC	hvac		
Circulation pump power	Installed el. power of the pump in the circulation system - if circulation system is present	data type REAL, unit [W]	IFC-HVAC	hvac		
Cooling System						
Cooling system service zone	Group of spaces, served by the cooling system.		IFC-HVAC	hvac		[IFC2x3] IfcZone + IfcPropertySingleValue (Pset_ZoneCommon, Category) [IFC4] IfcSpatialZone.PredefinedType + .ServicedBySystems (link to ventilation system)
Type of system	Category "Cooling", additional name of system	central, local	IFC-HVAC	hvac		[IFC4] IfcDistributionSystem.PredefinedType = AIRCONDITIONING + IfcDistributionSystem.Name
Energy source/ fuel type		e.g. district cooling system / refrigerating machine / ground water; data type STRING	IFC-HVAC	hvac		

[ER 2] Exchange Requirements for BIM to Energy						*Exchange Requirement Model*
Element Property concept Property group Property name	Definition	Examples and further explanations	Data Source	IFC2x3 Export	Additional data	IFC2x3 Schema Representation
Flow temperature	Set Point Temperature for the water inside the pipe system in cooling system - leaving the cooler at design condition	8 [°C]. data type REAL	IFC-HVAC	hvac		
Return temperature	Set Point Temperature for the water inside the pipe system in cooling system - entering the refrigerating machine / cooler at design condition	12 [°C]. data type REAL	IFC-HVAC	hvac		
Free cooling	Availability of equipment like a cooling tower with closed / open circulation systems, dry chiller		IFC-HVAC	hvac		
Coefficient of performance	Ratio of useable and applied heating/cooling power as an characterization of cooling or heat pump systems (ATTENTION: different interpret-ations in US and EU)	data type REAL, without dimension	IFC-HVAC	hvac		
Operating schedule	Daily operating time, start and finish time		IFC-HVAC	hvac		
System seasonal efficiency and delivery efficiency	Seasonal average ratio of useable and applied cooling power as an characterization of cooling systems (ATTENTION: different interpretations in US and EU)	data type REAL, without dimension	IFC-HVAC	hvac		
Control scheme	Method to control Set Point Temperature of the water leaving the cooler depending on the out-side air temperature, outside air moisture, the operational temperature of one or more spaces or combination of the three.	data type STRING or INTEGER (if text is translated into numbers)	IFC-HVAC	hvac		
Night setback temperature	Temperature difference between 'normal' and 'modified', separately for each cooling system	[°C] For energy saving reasons the Set Point Temperature on the cooler will be modified during the time when the space/building is not occupied. data type REAL; unit Kelvin [K]	IFC-HVAC	hvac		

[ER 2] Exchange Requirements for BIM to Energy						*Exchange Requirement Model*
Element / Property concept / Property group / Property name	Definition	Examples and further explanations	Data Source	IFC2x3 Export	Additional data	IFC2x3 Schema Representation
Pump power	Installed electrical power of the pump in the cooling system	data type REAL, unit [W]	IFC-HVAC	hvac		
Lighting						
Lighting energy	Installed electrical power of lighting devices related to net area of the space	[W/m2]	*IFC-HVAC*	hvac		
Fuel type (wind turbine, PV, grid power)			*IFC-HVAC*	hvac		
Luminaire type		artifical or natural	*IFC-HVAC*	hvac		
Radiant fraction	Fraction of the installed power which is trans-formed into heat radiation	data type REAL, without unit	*IFC-HVAC*	hvac		
Visible fraction	Fraction of the luminous flux to then installed electrical power	data type REAL, unit [lm/W]	*IFC-HVAC*	hvac		
Control scheme (dimmer schedule, occupancy sensor)	Information about the controller equipment	data type STRING	*IFC-HVAC*	hvac		
Schedule	Daily operating time, start and finish time	daily, 6:30 - 22:30	*IFC-HVAC*	hvac		
Renewable Ressources & Low carbon measures						
Solar thermal		yes / no [-]	*eeBIM*	ee		
Photovoltaic		yes / no [-]	*eeBIM*	ee		
CHP and cogeneration		yes / no [-]	*eeBIM*	ee		

[ER 2] Exchange Requirements for BIM to Energy						Exchange Requirement Model
Element Property concept Property group Property name	Definition	Examples and further explanations	Data Source	IFC2x3 Export	Additional data	IFC2x3 Schema Representation
Grey water /rain water harvesting		yes / no [-]	*eeBIM*	ee		
Wind turbine		yes / no [-]	*eeBIM*	ee		
Biofuel		yes / no [-]	*eeBIM*	ee		
Ground sourće heat pump		yes / no [-]	*eeBIM*	ee		
Green power (purchased heat & electricity)		yes / no [-]	*eeBIM*	ee		
Legend						
Property in black	required		IFC	M		
Property in grey and italics	optional		IFC-HVAC	O		
~~*Property in grey italic and strike through*~~	not used		eeBIM	-		
~~*Property in red and strike through*~~	shall not be used			N		
-				hvac		
-				ee		

SEVENTH FRAMEWORK PROGRAMME OF THE EUROPEAN COMMUNITY
(EC GRANT AGREEMENT N° 26088)

ICT PLATFORM FOR HOLISTIC ENERGY EFFICIENCY SIMULATION
AND LIFECYCLE MANAGEMENT OF PUBLIC USE FACILITIES

D+ (Additional Deliverable):

Information Delivery Manual Work within HESMOS

-A descriptive approach to defining Information Delivery Manuals-

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Project of SEVENTH FRAMEWORK PROGRAMME OF THE EUROPEAN COMMUNITY		
Dissemination Level		
PU	Public	**X**
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

1. Overview

1.1 HESMOS

HESMOS is a research project funded by the EU-Seventh Framework Programme with the title "**H**olistic **E**nergy Efficiency **S**imulation and Lifecycle **M**anagement **O**f Public Use Facilitie**S**" and has the following objectives:

- Providing decision makers with advanced simulation capabilities during the whole life-cycle of buildings, taking into account energy savings, investment and life-cycle costs;
- Integrating a Virtual Laboratory that connects CAD and energy efficiency Tools in order to enhance building industry actors' energy efficiency competences;
- Closing the gap between Building Information Modeling (BIM) and Building Automation Systems (BAS) to enable economical decision making (energy & cost related) in all phases of a building's life-cycle;
- Integrating related topics extending current BIM to **e**nergy **e**nhanced **BIM** (eeBIM):

For developing the HESMOS eeBIM framework, reusable and adaptable for different practical configurations, a methodology was needed, that could be used to document new processes and to describe the associated information that have to be exchanged between parties. It was of importance that the output would be able to be used afterwards to specify a more detailed specification that would form the basis for a software development process.

1.2 IDM

Thus Information Delivery Manual (IDM) was chosen, developed within buildingSMART International as the standard for processes and later published as ISO 29481-1[1].

IDM's aim is to offer standardized methods to answer the following questions:

- Who needs the information extracted from the building information model?
- At which point in time this information is needed?
- Which minimal amount of data has to be exchanged?

The essential parts of this information delivery manual are:

- Defining "who" and "when" by means of a general process map
- Defining "what", thus the required data as exchange requirements listed in a tabular form.

The standard itself only describes the method how such a manual for the information exchange can be produced. The result will be a specific manual or arrangement for a specific process: e.g. HESMOS Design Phase within PPP-projects.;

[1] *ISO 29481-1:2010 "Building information modelling -- Information delivery manual -- Part 1: Methodology and format"*

Within HESMOS IDM was extended and adapted for the specific objectives of

- life cycle modeling,
- the definition of a generalized multi-model framework based on, but not limited to, a single standardized BIM (currently IFC2x3), and
- The derivation of information and processing (workflow) requirements for the components of an integrated virtual energy laboratory (IVEL).

1.3 MVD

The IDM method does not describe the technology, the data formats, that can be used to exchange the information from the building information models. This should therefore be added separately to the manual; e.g. as a recommendation to use a certain - even certified - subset of IFC, the internationally standardized exchange format for building information models. But it is also possible to add a second corresponding part to the manual containing the mapping of the exchange requirements to the data exchange formats.

buildingSMART developed a second method for this, the **M**odel **V**iew **D**efinition, MVD. MVD identifies a certain subset of the data exchange format that is to be used to deliver the required data. In case of the IFC standard a MVD identifies not only a subset of the data schema but also delivers representation and implementation requirements that are needed to implement software interfaces. Defining a new MVD is a comprehensive process performed by data model specialists. The description of MVD is beyond this document's scope.

These requirements can then also be used for defining filters to extract the data relevant for the process or for the completeness and quality control when receiving the building information models. The model views therefore define:

- how the information, how the building information models will be exchanged
- Which specific data standard will be used and which configurations, that are available for this standard, will be needed?

In a model view specific data requirements can be included, that state which data exchange elements are obligatory and for each element which range of values is applicable.

By applying the IDM and the MVD method to HESMOS, some shortcomings of this methodology and explanatory material were experienced, predominately that no easily understandable and comprehensive manual was available. To be able to explain the IDM process to the HESMOS team, a new HESMOS IDM/MVD chart was set up (figure 1) and an IDM workshop organized.

2. General HESMOS IDM Approach

The general HESMOS workflow chart (Figure 1) shows the IDM method in a chart and also the transit to the model view and the data requirements. It has been developed to easily explain the various components. It greatly helped to achieve a common understanding among the partners, comprising architects, engineers, energy consultants, software developers, information specialists and researchers.

It is recommended to include such, or similar, overviews also into the official IDM methodology.

Within the following sections, the steps in the overall methodology are explained and examples on how it has been approached and resolved in HESMOS are provided.

The steps of the **IDM-methodology** (in Figure 1 highlighted in orange) are as follows:

IDM step 1: Identify Processes and Actors;

IDM step 2: Identify Exchanges;

IDM step 3: Create Exchange Requirements.

After that the following steps of the **MVD-methodology** or in other words the technical implementation (in Figure 1 highlighted in blue) can be added:

MVD step 1: Extend to Exchange requirements Models;

MVD step 2: Unify to Model View Definition.

The overall aim of the application of these methods is to improve the processes in question. Depending on the circumstances not all five steps will be necessary every time. As shown in Figure 1 it is also possible to round things up after IDM step 3 or MVD step 1, respectively.

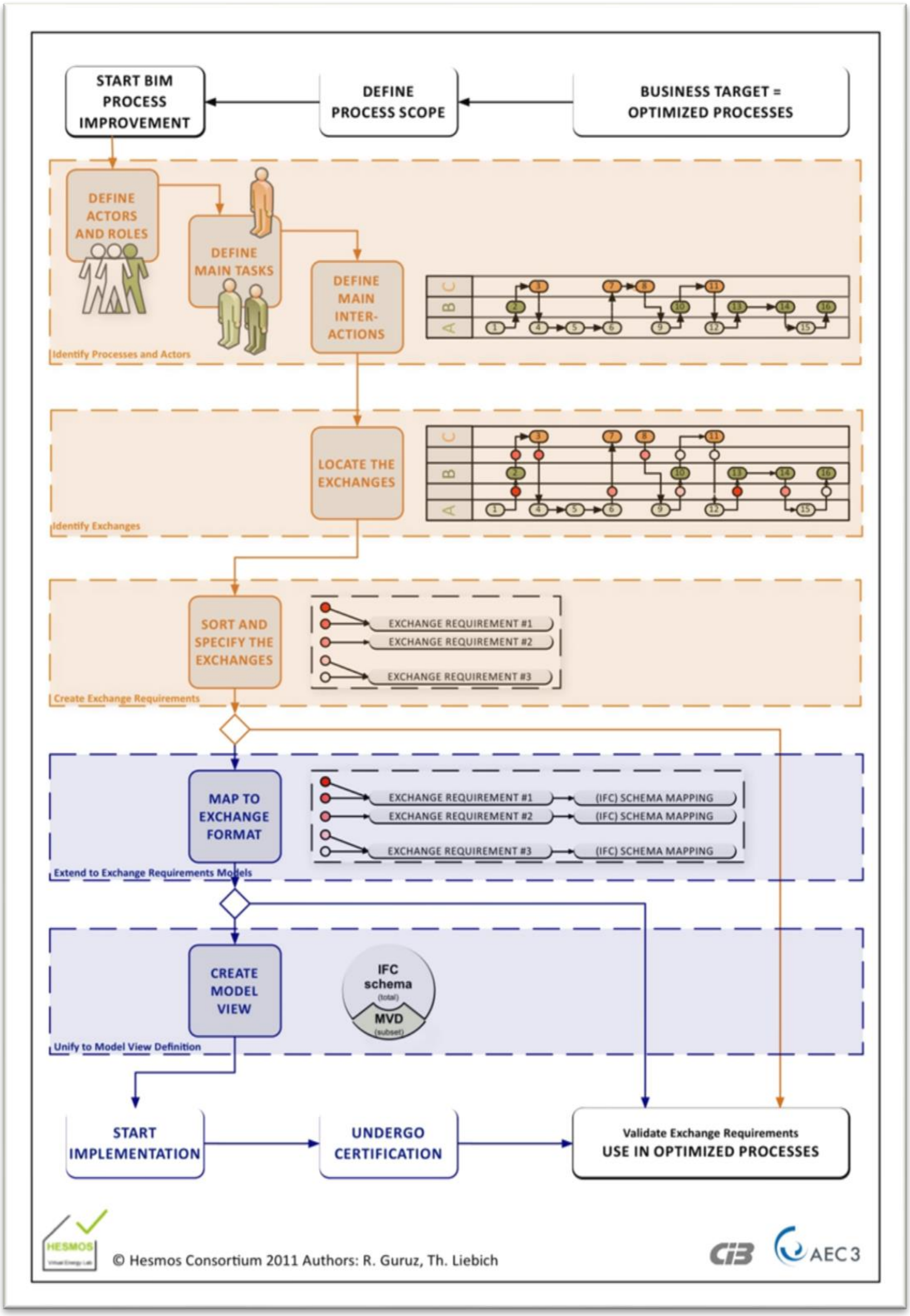

*Figure 1: General process of **IDM** (orange) + **MVD** (blue)*

2.1 Business Target - Preliminary Work

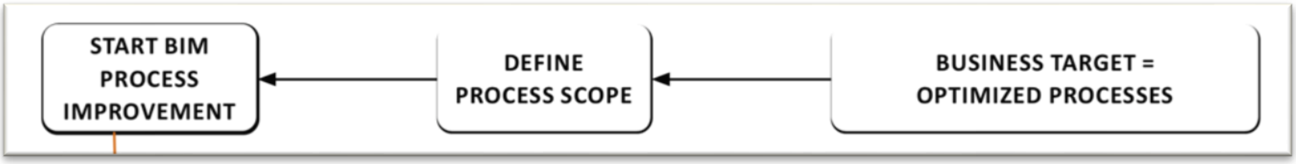

Figure 2: Preliminary Work

Before the actual IDM method was applied, some preliminary work had to be done.

As a general business target the optimization of the processes was established. Especially in an industry that is characterized by bringing many companies and authorities together in a project specific organization this is an important step. As a start the AS-IS processes are quite often not explicitly defined[2], and by examining them it is seen, that the overlap and repeat themselves.

For the HESMOS project it was of importance, that not only a single phase within a building's whole life cycle was analysed but that the scope was extended beyond the designing phase. Thus the following phases were included as well: constructing, commissioning, operating, refurbishing and retrofitting.

As part of the preparations in the HESMOS project the current processes were analysed focusing especially on simulation capabilities and available sensor data. Points of special interest were the interactions among the different participants. Thus the AS-IS-processes were lined up and used as a base to develop the optimized TO-BE-processes, the ideal aimed-at scenarios.

Having done all this, the first step of the IDM method could be taken.

[2] So the discovery of these AS-IS processes, making everybody aware of them is already a goal in itself (s. for example the procedure in getting certified for ISO 9001, as well.)

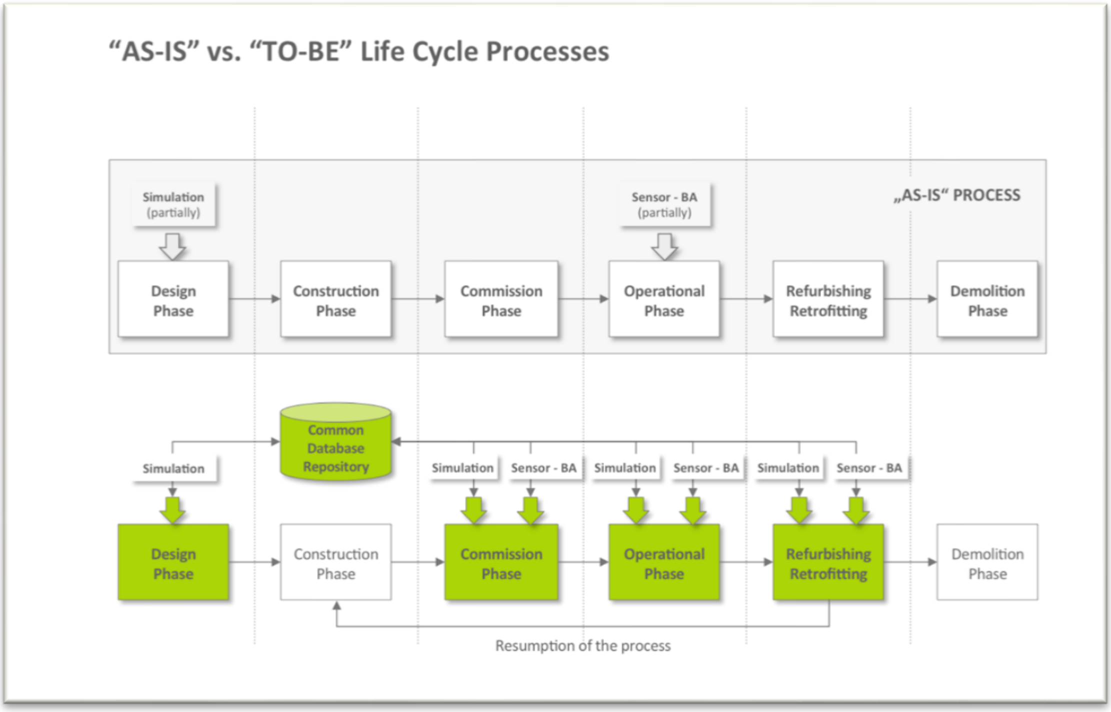

Figure 3: HESMOS: AS-IS vs. TO-BE-Processes

2.2 Process-Support Target - Identify Processes and Actors

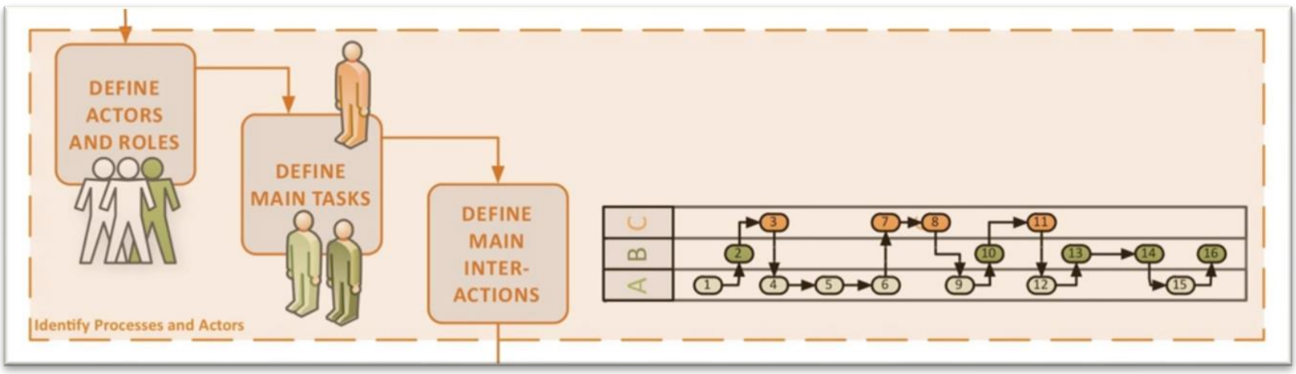

Figure 4: IDM method step 1: Identify Processes and Actors

Following the standardized process the main participating parties of the TO-BE-processes were specified first, see Figure 5. Then the time frame for the information exchanges was set by defining the main work phases. In the end the interrelation of the processes was examined, the points within the processes where the interactions between the participating parties take place.

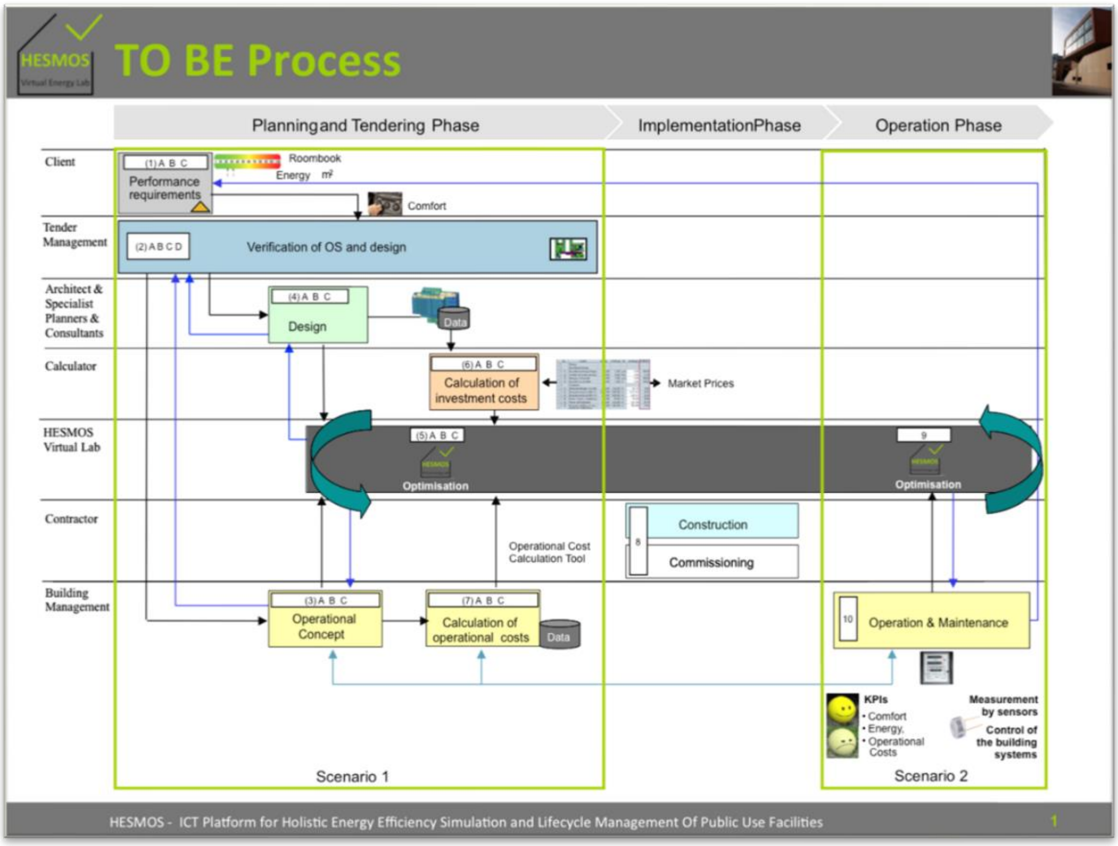

Figure 5: HESMOS: Identifying Processes and Actors

The main actors, defined by their roles, are symbolized by the so called swim lanes [A, B, C] in Figure 4. Thus indicating the usage of another international standard, the Business Process Modeling Notation (BPMN). In Figure 5 they are defined as main rows. The main activities that require interactions, exchanges between the processes are symbolized as small ellipses in Figure 4. In Figure 5 they are illustrated as rectangles and illustrative symbols.

Additionally to the BPMN process tables, a written description of each task and gateway was documented in HESMOS.

These analyses were carried out for the AS-IS as well as the TO-BE processes. All further developments on the IDM then concentrated on the to-be scenario.

2.3 Interoperability Target

Identify exchanges

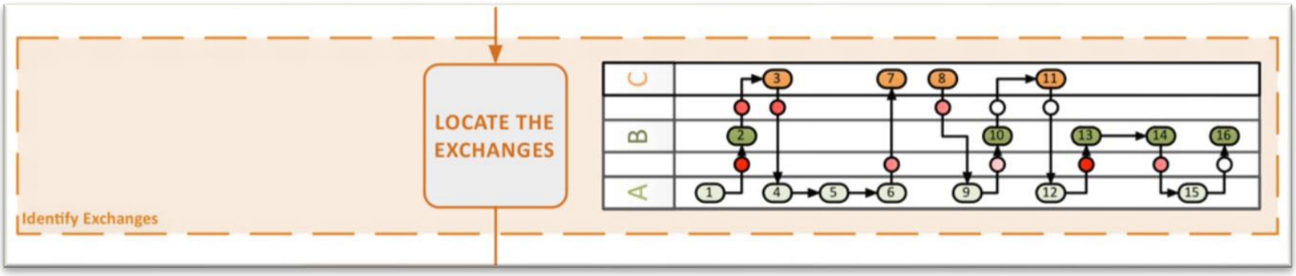

Figure 6: IDM method step 2: Identify Exchanges

As a next step the general information requirements for the exchanges between the identified business processes were examined. As a result the following was specified:

- Between which activities during the reference processes an information flow is necessary and what the purpose of this information exchange is, basically.
- If the information requirement can be fulfilled by exchanging a building information model. If so then this exchange must be described in more detail in the next step.
- Who the information supplier is
- Who the information recipient is - what the reason behind the information exchange is and how the information can be elaborated on further down in the process.

Based on the previous step, a process map was developed for each of the critical interactions. The selection was made based on importance, impact and general scope and helped in effect to stay focused. Figure 7 shows one of the process maps, developed using BPMN.

Each map is specific to a life-cycle phase identified in the previous step. The main swim lanes reflect the actors, and the exchanges are shown by the document icon placed in small interaction swim lanes within the BPMN diagram show in Figure 7. By adding some project specific colour coding, the blue exchanges describe the way BIM based data is utilized and the green ones the additional external data sources.

The diagram in Figure 6 symbolizes the exchanges as small circles in separate swim lanes.

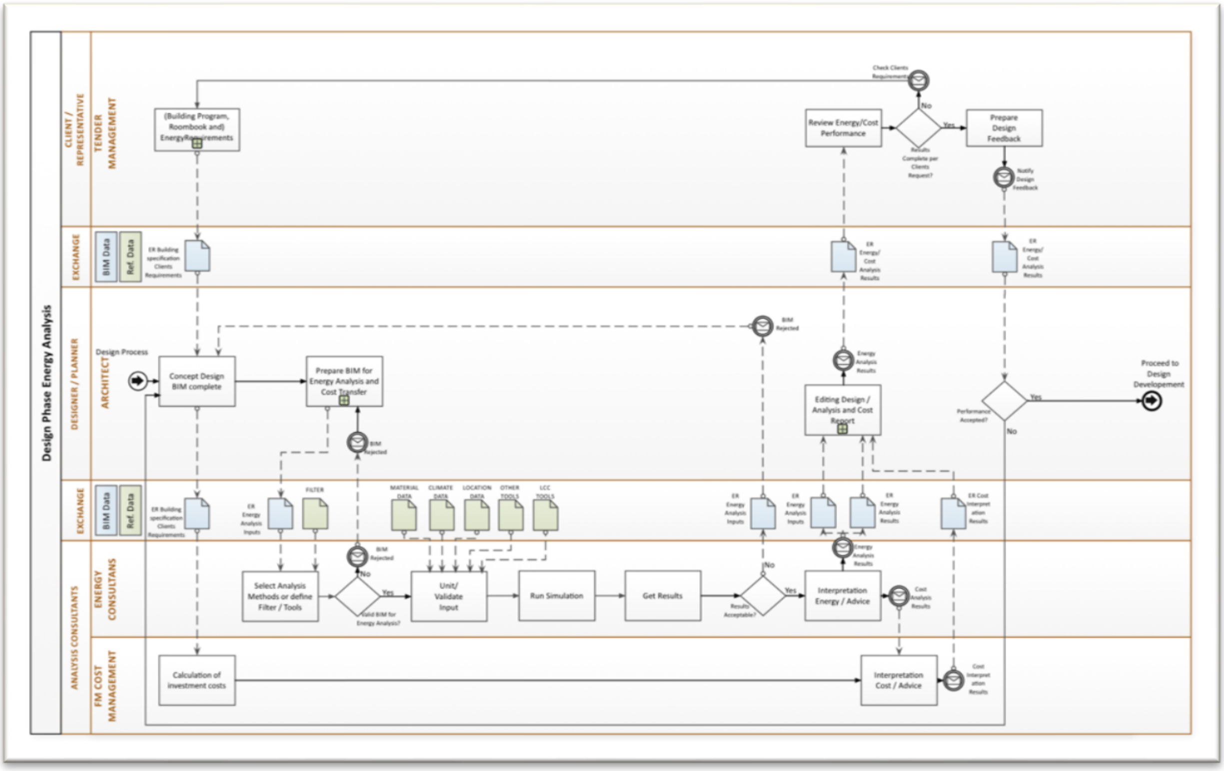

Figure 7: HESMOS: Identifying Exchanges

2.4 Content Target

Sort and specify the exchanges

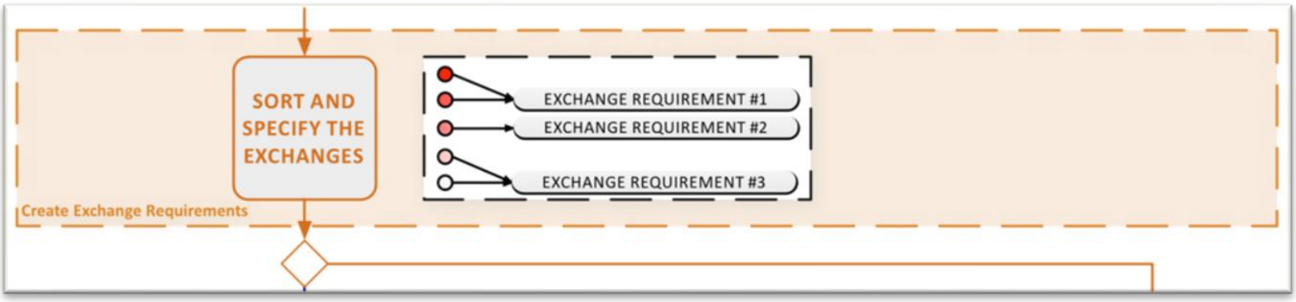

Figure 8: IDM method step 3: Create Exchange Requirements

The required exchanges were then further analyzed in terms of the information required by the follow-on processes. As several exchanges had similar exchange requirements they were combined into a common exchange requirement (ER). Figure 9 shows the main exchange scenarios in HESMOS:

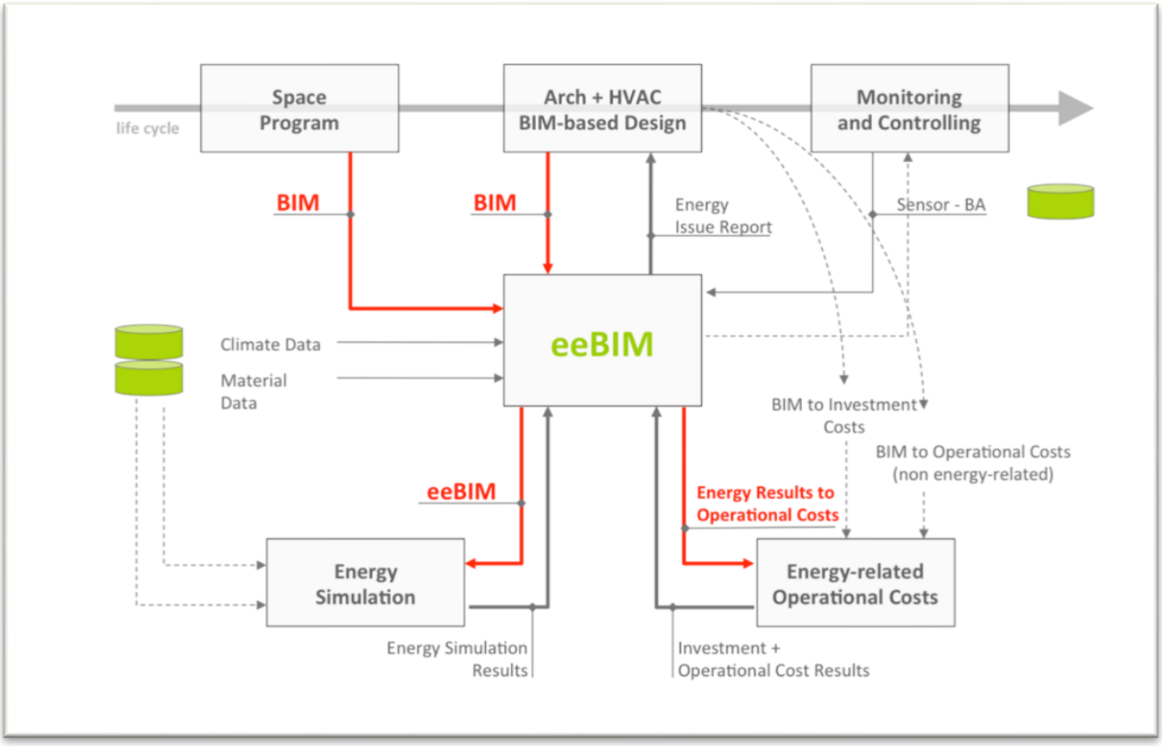

Figure 9: HESMOS: Identifying general exchange scenarios

In Figure 8 this is symbolized as several small circles resulting in one exchange requirement.

Each of the exchange requirements was then specified in detail based on an interactive and iterative process between domain experts and information specialists.

This means that the exchange requirements were narrowed down now to single information elements like model elements (beam, space, screw connection) and the associated properties (material, steel grade, fire resistance).

This ensures that it can be checked later on, if the exactly right information is exchanged at the intended point in the identified process.

The exchange requirements were documented in an exchange requirement table (Figure 10). This table was seen as an improvement to the original table that is part of ISO 29481-1. A low-tech approach, using spread sheets, was chosen in order to not raise technology barriers for the domain experts driving the process.

With this step the IDM is complete. Without the need of elaborating the exchange requirements in a technical sense, the results can be used in an optimized process (s. Figure 1).

As it was the aim of the HESMOS project, however, to develop software solutions for their exchange requirements, the steps of the technical implementation were be added.

[ER 2] Exchange Requirements for BIM to energy

Element / Property concept / Property group / Property name	Definition	Examples and further explanations
Construction		
Building Structure		
Building general		
geographical position - latitude	World Latitude at reference point	**47° 25′ N** / 010° 59′ E
geographical position - longitude	World Longitude at reference point	47° 25′ N / **010° 59′ E**
High above sea level	Datum elevation relative to sea level	113 m over sea level Amsterdam
Orientation	North arrow, true north direction relative to the bulding model y axis	+30° (true north is +30 degree from project y-axis)
Type of use	Name of the type for the building	"Office", "School"
Location description	*Textual description of constructions, buildings, landscape, nearby this facility*	*A selection from a catalogue with predescribed text, e.g.: city center, field*
Air tightness (infiltration rate)	*Normalized air infiltration rate on a normalized air pressure setpoint - 'blower door' result*	*Information typically not available to the designer - to be added in the eeBIM enrichment process.*
Spaces		
Spaces general		
Space number	Unique number of the space (e.g. in context of the building or story)	"EG-001"
Space name	Descriptive name of the space	"Foyer"
Space quantities		
Space area	area as stated in ÖNORM B 1800, SIA 416, SN 504416 or DIN 277	Net area as covered by base quantities
Space volume	volume as stated in ÖNORM B 1800, SIA 416, SN 504416, DIN 277	Net area as covered by base quantities
Thermal requirements		
Design temperature maxmium	Temperature of the space or zone, that is required from user/designer view point.	[°C]
Design temperature minimum	Temperature of the space or zone, that is required from user/designer view point.	[°C]
Humidity, summer	Humidity of the space or zone that is required from user/designer view point.	[% relative humidity]
Humidity, winter	Humidity of the space or zone that is required from user/designer view point.	[% relative humidity]
Lighting requirements		
Illuminance level	Required average illuminance value for this space.	[lux]
Direct or indirect lighting	Indication whether this space requires artificial lighting or not.	True/False
Air quality requirements		
Natural Ventilation	Indication whether the space is required to have natural ventilation (TRUE) or mechanical ventilation (FALSE).	True/False
Natural Ventilation Rate	Indication of the requirement of a particular natural air ventilation rate	[l/h] general rate of replacing the air volume of the space per hour
Mechanical Ventilation Rate	Indication of the requirement of a particular mechanical air ventilation rate	[l/h] general rate of replacing the air volume of the space per hour

Figure 10: HESMOS: Creating Exchange Requirements

2.5 Standardization Target - Map to exchange formats

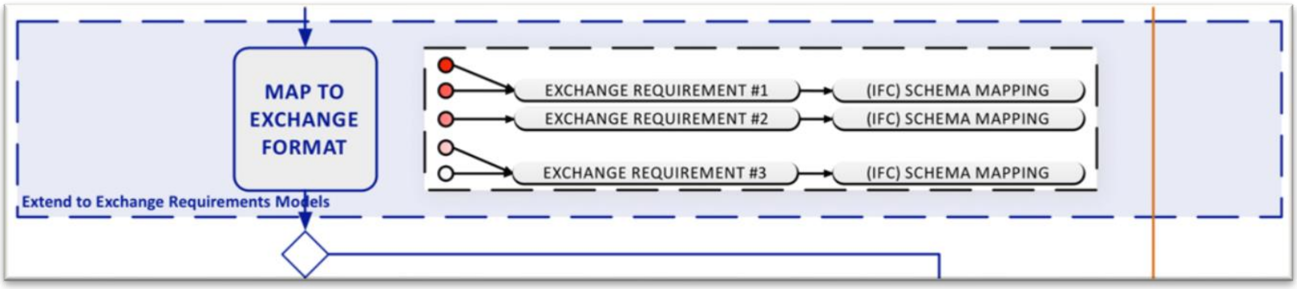

Figure 11: MVD method step 1: Extend to exchange requirement models

For each of the main exchange requirements identified in the previous step the target exchange format was chosen based on suitability. This lead to IFC for the main exchanges, but also to other formats, including BCF and specific XML based exchanges. See Figure 12 for the selected exchange formats.

Based on this choice, the mapping of the data requirements to their representation in the exchange format specification, such as IFC, was done. In the cases where no target definitions in the exchange format existed yet, the gaps were identified and extensions proposed. When mapping to IFC those extensions were mainly realized by defining extra property sets.

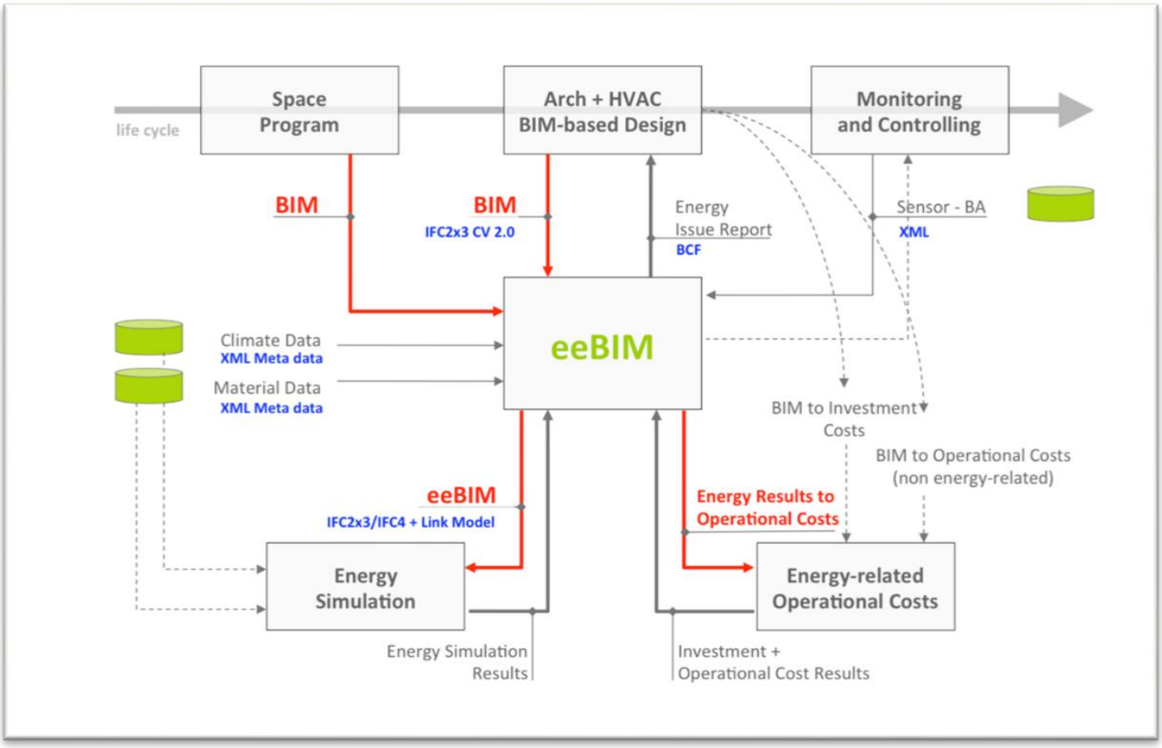

Figure 12: HESMOS: Deciding on exchange formats for general exchange scenarios

The principal links and transformations, closing the eeBIM life cycle circle, detailed modeling issues can be further defined and partial model views can be specified as necessary. Moreover, support ICT services and their interfaces can be more easily and clearly identified. Workflows providing efficient service/tool orchestration of various sub-processes in the overall life cycle business process can be worked out; e.g. the automated creation of single-zone energy simulation models from architectural BIM.

This steps' results are the Exchange Requirement Models (ERM) that are based on the Exchange Requirement (ER) tables with additional rows showing the mapping to the data exchange formats (Figure 13). The work was done and documented by information modelling specialists using spread sheets. But it is anticipated that proper tools that provide easy access to the available definitions within the chosen exchange format (such as the class/attribute and property set/property structure of IFC) could help to speed up this step in the future.

[ER 2] Exchange Requirements for BIM to energy					*Exchange Requirement Model*
Element / Property concept / Property group / Property name	**Definition**	**Examples and further explanations**	**Data Source**	**IFC Export**	**IFC2x3 Schema Representation**
Construction					
Building Structure					
Building general					
geographical position - latitude	World Latitude at reference point	**47° 25' N** / 010° 59' E	IFC	M	IfcSite.RefLatitude
geographical position - longitude	World Longitude at reference point	47° 25' N / **010° 59' E**	IFC	M	IfcSite.RefLongitude
High above sea level	Datum elevation relative to sea level	113 m over sea level Amsterdam	IFC	M	IfcSite.RefElevation
Orientation	North arrow, true north direction relative to the bulding model y axis	+30° (true north is +30 degree from project y-axis)	IFC	M	IfcGeometricRepresentationContext.TrueNorth
Type of use	Name of the type for the building	"Office", "School"	IFC	M	IfcBuilding + IfcPropertySingleValue (Pset_BuildingCommon, OccupancyType)
Location description	*Textual description of constructions, buildings, landscape, nearby this facility*	*A selection from a catalogue with predescribed text, e.g.: city center, field*	*eeBIM*	ee	
Air tightness (infiltration rate)	*Normalized air infiltration rate on a normalized air pressure setpoint - 'blower door' result*	*Information typically not available to the designer - to be added in the eeBIM enrichment process.*	*eeBIM*	ee	
Spaces					
Spaces general					
Space number	Unique number of the space (e.g. in context of the building or story)	"EG-001"	IFC	M	IfcSpace.Name
Space name	Descriptive name of the space	"Foyer"	IFC	M	IfcSpace.LongName
Space quantities					
Space area	area as stated in ÖNORM B 1800, SIA 416, SN 504416 or DIN 277	Net area as covered by base quantities	IFC	M	IfcQuantityArea (BaseQuantities, NetFloorArea)
Space volume	volume as stated in ÖNORM B 1800, SIA 416, SN 504416, DIN 277	Net area as covered by base quantities	IFC	M	IfcQuantityVolume (BaseQuantities, NetVolume)
Thermal requirements					
Design temperature maxmium	Temperature of the space or zone, that is required from user/designer view point.	[°C]	IFC	M	IfcPropertySingleValue (Pset_SpaceThermalRequirements, SpaceTemperatureMax)
Design temperature minimum	Temperature of the space or zone, that is required from user/designer view point.	[°C]	IFC	M	IfcPropertySingleValue (Pset_SpaceThermalRequirements, SpaceTemperatureMin)
Humidity, summer	Humidity of the space or zone that is required from user/designer view point.	[% relative humidity]	IFC	M	IfcPropertySingleValue (Pset_SpaceThermalRequirements, SpaceHumiditySummer)
Humidity, winter	Humidity of the space or zone that is required from user/designer view point.	[% relative humidity]	IFC	M	IfcPropertySingleValue (Pset_SpaceThermalRequirements, SpaceHumidityWinter)
Lighting requirements					
Illuminance level	Required average illuminance value for this space.	[lux]	IFC	O	IfcPropertySingleValue (Pset_SpaceLightingRequirements, Illuminance)
Direct or indirect lighting	Indication whether this space requires artificial lighting or not.	True/False	IFC	O	IfcPropertySingleValue (Pset_SpaceLightingRequirements, ArtificialLighting)
Air quality requirements					
Natural Ventilation	Indication whether the space is required to have natural ventilation (TRUE) or mechanical ventilation (FALSE).	True/False	IFC	M	ifcPropertySingleValue (Pset_SpaceThermalRequirements, NaturalVentilation)
Natural Ventilation Rate	Indication of the requirement of a particular natural air ventilation rate	[l/h] general rate of replacing the air volume of the space per hour	IFC	O	ifcPropertySingleValue (Pset_SpaceThermalRequirements, NaturalVentilationRate)
Mechanical Ventilation Rate	Indication of the requirement of a particular mechanical air ventilation rate	[l/h] general rate of replacing the air volume of the space per hour	IFC	O	ifcPropertySingleValue (Pset_SpaceThermalRequirements, MechanicalVentilationRate)

Figure 13: HESMOS: Extending to Exchange Requirement Models

At this point in the IDM- & MVD-procedure it needs to be tested if the defined exchange requirements are fulfilled by an already existing valid IFC subschema, a so called IFC Model View. If that is the case the work can be rounded up at this time.

2.6 Implementation Target - Define model views

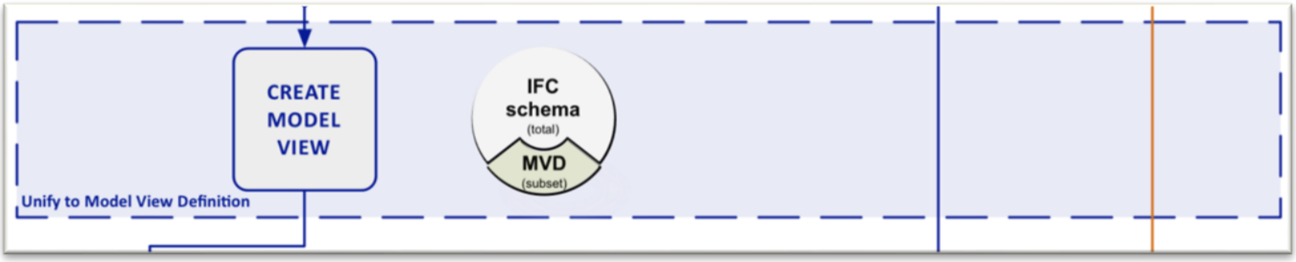

Figure 14: MVD method step 2: Unify to Model View Definition

With the exchange requirements mapped to the data exchange format and these requirements not met by any existing model views, a new model view can be defined. Figure 14 shows an MVD as a subset out of the total set of IFC.

The work of defining model views is carried out by the information modelling specialists with consultation of the software engineers that will later implement it in actual software interfaces.

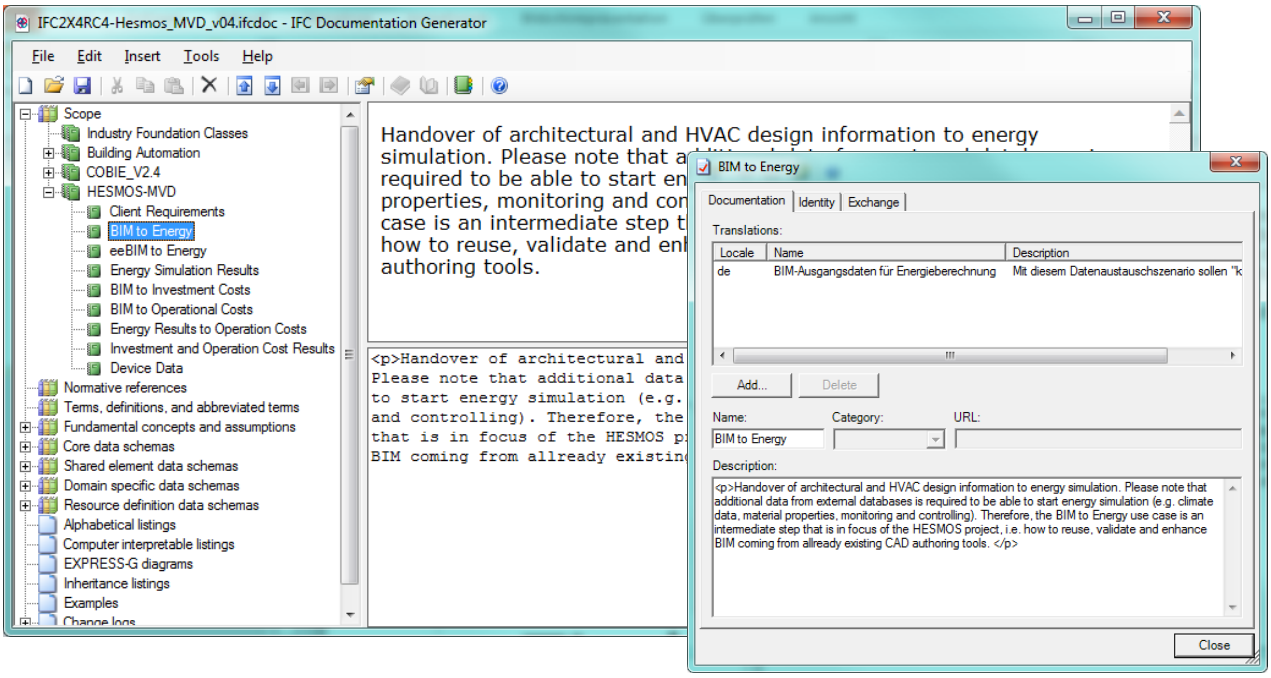

Figure 15: Formalization of MVDs using the IFC Documentation Generator tool.

In the HESMOS project the creating of an MVD is ongoing at this moment. It will be based on the latest developments within buildingSMART like the new mvdXML framework. Figure 15 shows the ifcDoc tool[3], which supports the IFC documentation and MVD filtering process.

[3] More information on ifcDoc s. http://www.buildingsmart-tech.org/blogs/msg-blog/ifcdoc-the-new-mvd-development-tool

The ifcDoc tool is being developed by buildingSMART and the HESMOS project significantly contributed to its improvement by giving feedback to its developers on usability and other subjects. In addition, the ViewEdit tool that allows extracting automatically a valid MVD subschema out of the general IFC schema is being used.

2.7 Deployment Target - Implementation and Use

Figure 16: Implementation and Use

After implementation the software can undergo certification. An example is the software certification for implementing the currently most used model view: IFC Coordination View 2.0[4]. It doesn't matter if the exchange requirements are being used in an optimized process right after being specified (s. 2.4), being mapped to the data exchange format (s. 2.5) or just after being implemented and possibly even certified (s.2.6), one thing is very important: their validation as an essential quality check. Tools like the aforementioned ifcDoc can be used to support the documentation and the validation.

3. Experiences from using IDM/MVD in HESMOS

In general, the combined IDM-/MVD-methodology has been applied successfully in HESMOS. The main obstacle at the beginning had been the lack of easy to understand literature that in particular would have informed the domain experts about the required steps.

Therefore developed a more easy to use guideline was developed within the project and tested for the IDM/MVD development. The Figure 1 as general overview was found to be useful for getting a basic and common understanding of the overall process. Now the HESMOS consortium intends to contribute its findings back to the international community in buildingSMART and ISO/TC59/SC13.

The work on an improved methodology for IDM (ISO 29481-1) is going to be handed back to the international standardization community, ISO/TC59/SC13 "Organization of information about construction works" and buildingSMART, and the actual IDM for energy enhanced BIM is going to be submitted to buildingSMART International for consideration as an international template for similar exchange scenarios.

[4] More information on IFC CV2.0 s. http://www.buildingsmart-tech.org/specifications/ifc-view-definition/coordination-view-v2.0/summary

4. Glossary

BIM "BIM" does contain both, the 'building information model**ing**' and the resulting "building information **model**"

BIM (method) **Building Information Modeling**

Building Information Modeling is a new working (and cooperating) process where building information models are being used to realize and to coordinate a continuous execution of building projects (planning, constructing, operating and demolishing).

BIM (model) **Building Information Model**

A Building Information Model is being generated during the working (and cooperating) process using mostly object-oriented 3D-CAD software. 'Model' shouldn't be seen as a single overall model but rather as the coordination of several part models from the participating consultants and engineers (architectural model, engineering model, MEP model, etc.) These part models are called aspect models.

buildingSMART buildingSMART International, formerly known as International Alliance for Interoperability (IAI), is a neutral, international and unique non for profit organisation supporting open BIM through the life cycle. More information at: http://www.buildingsmart.org

eeBIM **engergy enhanced BIM**

Energy enhanced BIM specification framework containing elementary models and the overarching link model. The main BIM data scheme is based on **IFC**, with linked XML schemas to cover device data and other non-BIM information, and XML meta data to supplement the data flow for external climate and material data bases. Some enhancements were proposed to those selected standards and a link schema to combine them as the input for the energy simulation, and investment and operational cost calculation.

ER **Exchange Requirements**

Exchange Requirements are a detailed, mostly tabularized, breakdown of the data requirements of particular model elements (building elements) and their properties that are to be included and exchanged in a building information model for a certain purposes.

IDM **Information Delivery Manual**

IDM is a method that is used to analyze working and planning processes in the construction industry as well as the resulting data requirements for the information exchange between these processes. IDM is published by the International Organization for Standardization as ISO 29481-1. The Exchange Requirements (**ER**) are a part of the Information Delivery Manual.

IFC **Industry Foundation Classes**

IFC are an exchange format for model based data and information in all planning, constructing and operating phases of buildings and built assets. **buildingSMART** International develops and establishes IFC as an open standard for the construction industry, thus tied nor to a particular software vendor nor country. IFC is published by the International Organization for Standardization as ISO 16739.

MVD **Model View Definition**

MVD specifies on the base of certain model requirements the necessary subset of the complete **IFC** schema and as a result defines a valid **IFC** subschema. This subschema can be taken as an implementation guideline for an **IFC** interface, which fulfils all the defined exchange requirements. The certification of an **IFC** interface will always be done on the basis of a MVD.

The often used IFC 2x3 Coordination View Version 2.0 (IFC2x3 CV2) describes the coordination of different trades.