PAVING THE WAY FOR EXHAUSTIVE AND SEAMLESS BIM-BASED BUILDING ENERGY SIMULATION

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ABSTRACT

This paper presents an on-going work, which aims at improving the support for BIM-based energy simulation. The contribution is twofold. Firstly, a discussion about BIM-based energy simulation is provided, with an in-depth review of the state-of-the-art and a synthetic highlighting of the main related research issues, i.e. provision of an extensive IFC toolkit to perform the various translations and to make the link with BIM-based collaborative work support; validation of IFC models (completeness and correctness) and translation into the data formats used by the simulation tools; enrichment of IFC to enable exhaustive description of building elements and HVAC systems; user interfaces and usability. Then, the paper focuses on the issue of HVAC systems BIM descriptions and gives the result of a study performed on the capabilities of the IFC in this matter. This study entailed reviewing the properties and parameters needed to describe HVAC systems in a representative selection of simulation environments, and proposing ways to describe accordingly the systems in IFC (relying on proper enrichment of native IFC constructs). From these two contributions, the paper draws conclusions about the limitations of current support, and about the directions to take to fully enable BIM-based energy simulations.

Keywords: BIM, IFC, Energy simulation, interoperability, HVAC systems, collaborative design

1. INTRODUCTION

Construction industry is rapidly evolving, propelled forward by growing ecological concerns, increased competition, globalized markets, and always more ambitious and stringent regulatory frameworks. This has a strong impact, both on workflows and on tools. Practices focus – more than ever – on efficiency, flexibility and integration, while stakeholders tend to make use of more advanced tools, especially of those relying extensively on ICTs [1]. This trend, which is likely to continue and further increase, has fostered innovation in the construction industry and convinced its stakeholders to push forward an innovative design paradigm, heavily relying on software tools and digital representation: the Building Information Model (BIM).

BIM covers an extensive range of assets [2], among which technological ones are prevailing - the main being the (still theoretical) possibility to rely on a single logical, consistent source for all information associated with the building [3]. BIM is now widely recognized as a cornerstone of future tools and practices in the construction industry, especially when it comes to building design and energy efficiency optimization. This recognition is as strong in the academic domain as in the software vendors one, where many works aim at improving combined support for BIM-based collaborative work and building energy optimization [4][5]. Enabling such a support is not only a technological issue but still, many technological hurdles have to be overcome before enabling easy, straightforward, and efficient use of BIM information for energy optimization purposes. Among those challenges, three are prominent. Firstly, the data format for BIM representation and storage shall, as the lynchpin of any BIM-based process, not only be comprehensive, but also open, evolutive and flexible. Then, integration of energy optimization support in current design tools has to be seamless from the designer point of view: additional functionalities shall not be synonymous of increased effort and steep learning curves. At last, and obviously, the results of energy performances simulation shall be accurate enough to be relied on. Our observation is that most tools fail to take into account the three issues together: while large commercial design tool chains (e.g. Autodesk Revit with Ecotect) offer a great level of integration and ergonomics, they often lack openness and precision in building modelling and performances computation [6][7]. On the other side, a lot of very reliable and powerful simulation tools are available but require an intensive knowledge of building physics and lack straightforward interfaces and / or seamless connections to design tools (e.g. EnergyPlus or TRNSYS) [6]. The aim is therefore to devise an approach, which will allow using advanced and efficient simulation tools without requiring advanced skills, while offering a good level of integration with design tools.

This paper claims that, provided a few technological limitations are properly dealt with, all the ingredients of such an approach are available in the state of the art. The rationale is to rely on three pillars. Firstly, using as a lynchpin a standard, open, and (on the way to become) exhaustive data format for building digital representation and storage: the Industry Foundation Classes (IFCs). Doing so, the limitations related to the use of proprietary formats are avoided. Then, relying on existing, well-known, and reliable simulation tools to perform energy performances computation. This enables to reach the highest standards of precision in energy calculation. At last, enforcing the 3D representation as the integrated building and HVAC systems graphical representation, to enhance usability and accessibility. More precisely, the rationale is to rely on simulation tools only as back-end tools, running them seamlessly from the designers' point of view, while only CAD tools and 3D representations are accessible as front-end tools. In between, the IFC is used as an intermediary format between design tools and simulation tools. However, several issues have to be carefully considered to put such an approach into practice. A first one is the provision of an extensive IFC toolkit to perform the various translations and to make the link with BIM-based collaborative work support [8]. Another is the validation of IFC models with respect to their completeness and correctness, and the translation of these models into the data formats used by the simulation tools [9][10]. An additional one is the enrichment of IFC to enable exhaustive description of not only building elements but also of HVAC systems. And a last – but not least - one is related to the tools' interfaces and usability. This paper, while reviewing all these issues, especially focuses on the third one, namely IFC enrichment for HVAC systems description. A review of the properties and parameters needed to describe the most common HVAC systems in the targeted environments and modelling language (EnergyPlus, TRNSYS, a proprietary Modelica library) is performed, and ways to describe accordingly the systems in IFC are proposed.

The paper is structured as follows: a first section (section 2) reviews all issues that have to be tackled to enable (IFC) BIM-based energy simulation and gives for each a hint of related works. Then section 3 focuses on the specific issue of HVAC systems (IFC) BIM description, and the relationship with environment-specific HVAC models. At last, in section 4 a discussion about the remaining locks and about the – fortunately encouraging – perspectives is given, before concluding and describing the next steps to be taken.

2. (IFC) BIM-BASED SIMULATION: AN OPEN ISSUE

From a theoretical point of view, using BIM to perform energy simulation is not a high-end research challenge, since it eventually boils down to mere data processing. However, the vitality of the related research area tends on the contrary to show that the issue is far from being straightforward and remains open [11]. The reasons for this steady interest lie in the huge benefits that would result from effective and reliable connections between BIM/CAD tools and energy simulation tools. Indeed, energy simulation is actually now widely recognized as a mandatory step in building design phase, in order to predict energy performances and to optimize - and justify - design decisions. And until now, feedbacks from practice have failed in acknowledging accuracy and reliability of the predictions made by the simulation tools, especially with respect to as-built performances predictions [13]. The causes partially lie in the differences that may exist between the designed building and its actual, built counterpart. This comes within the skills of contractors and relates to construction practices, and shall not be further addressed here. Some other obstacles however arise from weaknesses of the available software support for energy simulation:

- Legacy software architectures: most of the energy simulation tools in use today were designed decades ago. They rely on obsolete software architecture paradigms, lack modularity, and are likely to fail to address the challenges set by modern buildings design practices [15].
- Modelling paradigms obsolescence: as a corollary of ageing tools, most modelling paradigms in use today shall be reviewed in order to fit new simulation needs. Simulating low energy buildings performances actually require to take into account fine-grained multi-physics phenomena, with low time scales, which calls for enhanced modelling paradigms [14].
- Faulty interoperability: even the available simulation tools are not properly used in typical building designs. Lack of interoperability between tools (especially between CAD and energy simulation tools) often results in discrepancies between building design data and building simulation data and, therefore, in questionable simulation results [10].
- Data models heterogeneity: simulation tools feature specific data models, which are not only different from one another, but also very frequently different from the data models implemented in CAD tools [18]. This affects both the way building geometry is represented and the way additional information (e.g. thermal properties) is allocated to building elements.

The two first points are clearly long-term challenges requiring ambitious R&D roadmaps to be implemented, and are out of the scope of this paper. The last two ones, however, stem from weaknesses of software tools and data models used at design phase and are right in the target of this paper.

When it comes to BIM/simulation interoperability enhancement, two main approaches may be differentiated. The first advocates full integration of tools and data models, and is mainly implemented by software vendors which tools span a large part of building design phases (and even life cycle). The aim is to rely on a single building data model (BIM), used as a sole reference in all design tasks, including simulation. BIM authoring and simulation tools are fully integrated at the data level, but often also at the user interface level. This approach therefore treats simulation tools as *BIM-aware tools*, using the terminology introduced by A. Watson in [12]. Examples of such implementations may be found in commercial suites of tools like e.g. Autodesk Revit. This approach is clearly the most relevant both from data integrity and from usability perspectives, but it is also the most rigid and the most demanding: rigid, because only the simulation tool(s) already embedded may be used; demanding, because any extension, e.g. to add simulation capabilities, requires a significant implementation effort. Another drawback stems from the fact that this approach is at the moment only implemented in commercial software, which rely on proprietary non-standard BIMs.

The second approach to BIM/simulation interoperability advocates "light" integration and, relies on data translation – or, more precisely on *model transformation* [19] – in order to generate the building model required by the simulation tool from a building model conforming to a given BIM. This approach is the most frequent and several works have already attempted - and to some extent, managed – to perform such connections [9][10]. Implementing such a linkage basically requires the following assets:

- A base data format, in which architectural building models will be expressed. It may be a proprietary one, like e.g. Autodesk DWF, or a public, open one - like the Industry Foundation Classes

[20]. The main requirement however is that this format shall be able to express all information needed for simulation.

- (optionally) a pivotal data format. Using an intermediary translation step between may be useful, especially when the architectural model data format is not able to embed all information necessary to simulations [18][21].
- Software tools to process the architectural model data format and possibly a pivotal data format, and to generate corresponding input files for simulation. These tools will not only have to translate the files, but also to check them for validity: improper constructions will be identified, possibly some missing information (e.g. related to geometry) will be added [22].
- A simulation tool. In this paper, the references mainly point to connections with dynamic thermal simulation tools. However, any kind of simulation may theoretically be targeted.

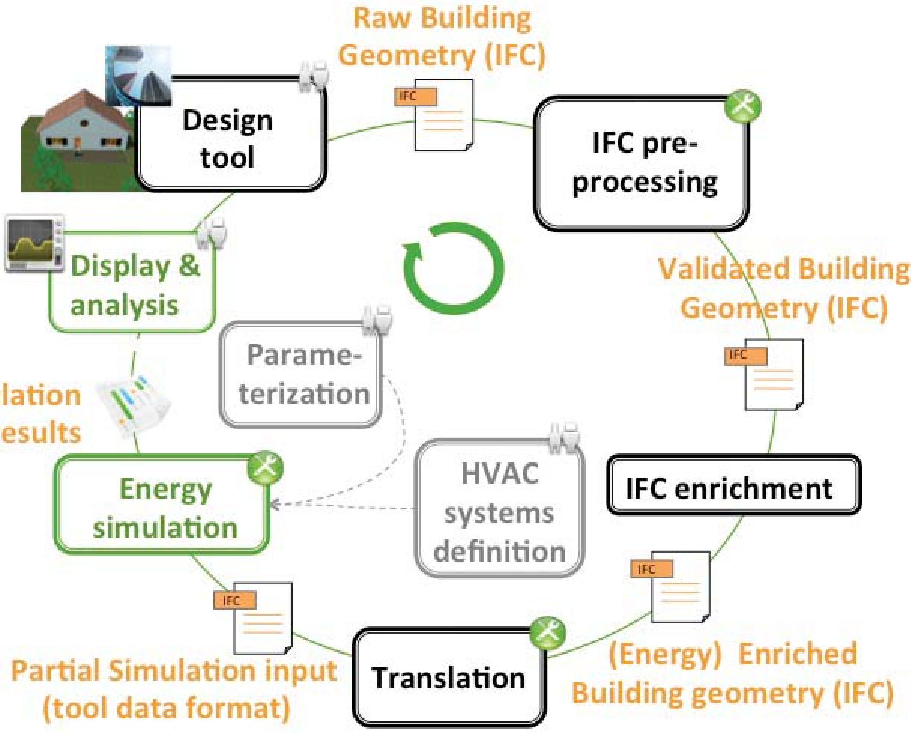

Figure 1: from design to simulation, a schematic view

The choice of the data format to be used for architectural models has already been discussed extensively. Most authors tend to prefer relying on an open, standard, public format than to rely on proprietary formats, and the IFC appears clearly as a reference. The reason for fending off proprietary formats is quite obvious and stems from the necessity to ensure interoperability between tools from several – if not all – software vendors. The IFC is currently the only format implemented (as export / import functionalities) in most of the CAD tools, and the only open generalist format standardized by an international consortium. According to [12], it is likely that IFC will "play a longer-term role at the boundary between BIM domains (…) IFC could be used for interoperability between different BIM platforms – possibly between disciplines, but perhaps more likely when moving a model downstream". IFC also happens to be the most exhaustive data model, especially with respect to geometry definition [22]. Despite these positive aspects, the IFC still suffers some limitations. For instance, it is still quite difficult – as will be shown in the next section – to specify HVAC systems and components with the IFC. And, would it be possible, those specifications would have to be written directly in IFC files, since no available IFC-compliant BIM authoring tool provides such functionalities. This would obviously be too tedious, and this is the reason why works that have attempted to implement connections between IFC and simulation have until now focused on geometry translation, while HVAC systems definition is left to a third-party tool generally relying on the targeted simulation tool's data model [9][10]. The process usually implemented is sketched in Figure 1. It starts with generating an IFC file from a BIM authoring tool This IFC file generally contains all information pertaining to the building geometry, but does not contain any thermal properties or HVAC system definition. This file is then pre-processed. This pre-processing consists first in a model-checking phase to identify errors and inaccuracies in modelling – e.g. meeting and intersection of objects. Model-checking generally relies on a dedicated tool: the platform described by V. Bazjanac et al in [10] relies for instance on the Solibry Model checker [23]. After this pre-processing, a further step is needed to enrich building geometry with so-called upper levels space boundaries – those are necessary to obtain a valid geometry before translation to the simulation tool and, IFC-compliant BIM authoring tools do not generate them. The issue of upper level space boundaries is detailed in [22]. Space boundaries generation requires an ad hoc tool, since no commercially available tool features the functionality. The platform described in [10] includes a component – the Space Boundary generation Tool (SBT) –, which offers such a functionality.

The result of pre-processing is a *clean* (containing no errors or inaccuracies) and *complete* (with an enriched geometry) IFC architectural file. This file may then be enriched with material thermal properties: this enrichment may be fully manual or semi-automated, by relying on a link with a product database to automatically fill the properties based on the material names [9]. The result is a simulation-ready architectural file (often called *Building Simulation Model*). It is then necessary to add HVAC systems and equipment specifications, and to set the input parameters of the simulation (building usage scenarios, localization, etc). For these two points, it is generally necessary to call on interfaces specific to the targeted simulation environments: for instance, in [10], a HVAC GUI for EnergyPlus is used, while in [9], EnergyPlus and Trnsys perspectives were implemented in an IFC 3D viewer. Then, simulation may be performed and the results analysed to assess design choices.

From this section, and especially from this archetypal process description, several preliminary conclusions may be drawn:

- To benefit fully from the state of the art in simulation, it would be beneficial to enforce reliable and efficient connections between BIM and simulation tools.
- On the whole, few works have attempted to tackle the issue. Those that have tend to deal only with building geometry.
- The most advantageous data model to implement this connection is the IFC.
- The required tool support is significant (model checking, geometry and thermal properties enrichment, data translation)
- HVAC systems BIM-based specification is poorly addressed. In particular, IFC exhibits limitations in this matter.

If we consider the desired goal, which would be to enable fully automated simulations from BIM - possibly following an on-the-cloud architecture [8] -, the last point must be tackled. As a first step, the subsequent section gives the outcomes of an evaluation of IFC capabilities with respect to HVAC systems.

3. HVAC SYSTEMS IFC DESCRIPTION

As part of an ongoing French collaborative research project, one thread of work aims at achieving an implementation of a connection between BIM (here we implicitly refer to IFC BIM) and dynamic thermal simulation. On the contrary to the works advertised in the state of the art (e.g. [10]), the objective is not to implement a link between a specific simulation tool and IFC, but actually to demonstrate the possibility

– or, would it happen, the impossibility - to implement a tool-neutral connection, therefore able to target multiple simulation environments of the same kind. The class of tools targeted here is the one of dynamic thermal simulation tools, for these are the most used for energy performances prediction during design phase. The rationale of the study is not to target completeness (i.e. reviewing all simulation tools, all systems, and assess IFC capabilities), but more to follow an iterative process: (i) choosing a set of target environments; (ii) select a set of HVAC systems to model; (iii) model those systems in the targeted environments; (iv) model those systems with IFC; (v) confront the models and analyse the outcomes; (vi) when required: issue propositions of IFC enhancements. Our approach is therefore to try to find, for each system, the greatest common divisor (g.c.d) of its models in the targeted environments, and to propose ways to implement it in the IFCs.

For the purpose of the study, three target environments were selected: EnergyPlus [24], TRNSYS [25], and Osmosys, a Modelica [27] library designed with Dymola [26] by EDF R&D, one of the partners of the project. The same way, three HVAC systems were selected: a ventilation system (double flow controlled mechanical ventilation system coupled to a ground coupled heat exchanger), a solar water heater (with an auxiliary energy source), and a central heating system. This list was completed with an electricity production device, namely a photovoltaic panel. Each system included in turn several interconnected components:

Table 1: selected systems and associated components

System	Components
Ventilation system	Cross-flow unit; fans; air flow regulator
Water heater	Solar thermal collector; pumps; flow regulator
Central Heating system	Boiler; heaters; heat pump
Electricity production	Photovoltaic panel

The aim was then to model these systems and components with each simulation environment and, to identify the IFC construct that would best fit the considered system / component. As far as IFC versions are concerned, both IFC 2x3 (current stable release) and IFC2x4 (upcoming release) versions were considered. IFC 2x3 was however considered a priority target, since most IFC-compatible tools implement this version. This is in particular true for the software we plan to use as a base for the subsequent prototyping [8][9]. By way of illustration, the following table shows the outcomes of this work for the fan component:

Table 2 : Modeling constructs for fan component

Modelling environment	Construct
EnergyPlus	Fan:OnOff
Trnsys	Variable speed pump or fan without humidity effect (type 3a and 94b)
Modelica/Osmosys	Ventilateur[1]
IFC 2x3	IFCFlowMovingDevice (and property set Pset_ifcFlowMovingDeviceFan)
IFC 2x4	IfcFan (and property sets Pset_FanTypeCommon, Pset_FanPHistory, quantity set Qto_FanbaseQuantities)

In a second step, the objective was to map the system/component properties and input / output to properties of the considered IFC construct. For this purpose, all properties available for the considered system in each target environment were listed and confronted to the available properties in IFC. As a complement, HVAC systems specifications available in the Edibatec dictionary [28] were also considered. This online dictionary is the French frame of reference for HVAC systems specification; its aim is to reference, for all classes of HVAC system, the essential features to advertise in products catalogues and databases. By way of illustration, here follows the properties specified by Edibatec for fans:

Table 3 : Fan properties as specified in the Edibatec dictionary

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[1] « Ventilateur » is the French word for « Fan »

Name	**Unit**	**Type**	**Choice**
Usage	-	Cumulated	Supply/extraction
Type	-	Enumerated	Axial/reaction/action
Acoustic power curve	-	Array	-
Measure distance		Real	-
Max flow rate	m3/h	Real	-
Min flow rate	m3/h	Real	-

Then, all properties available from all the considered sources – energyPlus, Trnsys, Osmosys, edibatec - were studied and confronted to those specified in IFC2x3 and 2x4, in order to select the most relevant set for each HVAC component. The criteria were to ensure that there would be no redundancies and that the properties selected had a potential for being generic. The following table gives the results of this study:

Table 4: Additional properties for the equipments considered in the study

Considered equipment	**Parameter Name**	**Description**	**Unit**
Photovoltaic panel	NominalShortCircuitCurrent	Short circuit current for an individual module in the PV array at reference conditions	Amps
	NominalOpenCircuitVoltage	Open circuit voltage for an individual module in the PV array at reference conditions	V
	ModuleVoltageAtMaxPower	Module voltage at the maximum power point and reference conditions.	V
	ModuleCurrentAtMaxPower	Module current at the maximum power point and reference conditions	Amps
	TemperatureCoefficientOfShortCircuitCurrent	This field accounts for the fact that the module short circuit current is temperature dependent.	°K
	TemperatureCoefficientOfOpenCircuitVoltage	This field accounts for the fact that the module open circuit voltage is temperature dependent.	°K
	NumberOfCellsWiredInSeries	Integer representing the number of individual cells wired in series to make up a single module.	Dimensionless
	NumberOfModulesInSeries	Number of modules wired in series to form the PV array	Dimensionless
	NumberOfModulesinParallel	Number of modules wired in parallel to form the PV array	Dimensionless
	ModuleTemperatureAtNOCT	Cell temperature from the Nominal Operating Cell Temperature (NOCT) test.	°K
Fan	MaximumFlowRate	The full load air volumetric flow rate at standard temperature and pressure (dry air at 20°C drybulb)	m3/s
	FractionOfMotorHeatToAirStream	The fraction of fan power that is converted to fluid thermal energy	
Pump	MinimumFlowRate	The minimum volumetric flow rate while operating	m3/s
	MotorHeatLossFraction	Pump's fraction of power loss to the fluid	%
Solar collector	AbsorberPlateEmittance	The emittance of the absorber plate of the solar collector	Dimensionless
	Absorptance of absorber plate	The absorptance of the absorber plate of the solar collector	Dimensionless
Boiler	Nominal capacity	The nominal operating capacity of the boiler	W
	Night light electric load	Electric power consumed by night light	W
	Design Water Outlet Temperature	Designed boiler water outlet temperature	°K
	Design Water Flow rate	Maximum design water volumetric flow rate.	m3/s
Heater	*No additional parameter required*		
Flow regulator	TemperatureHighLimit	A high limit cut-out which will turn the control signal OFF if the monitored temperature is higher than the high limit cut-out	°K
	TemperatureLowLimit	the outdoor air temperature low limit for economizer operation.	°K
Heat pump	SourceSideFlowRate	The flow rate of the liquid source when the pump is operating	m3/s
	Energy Efficiency Ratio	The effectiveness refrigerating coefficient of (represents energy performance of the heat pump functioning in cooling mode)	0-1
	Minimum temperature for direct liquid heating	Minimum temperature of the liquid source supply stream necessary to operate the pump in direct liquid source heating mode	°K
	Mimimum source temperature for liquid operation	Minimum temperature of the liquid supply necessary to operate the dual source heat pump using the liquid source	°K
	Nominal COP	The nominal coefficient of performance of the heat pump	
	Nominal Capacity	Numeric field contains the nominal capacity of the heat pump	W
	Constant Part of Electromechanical	Estimated parameter power loss, which accounts for the loss of	W

	Power Losses	work due mechanical and electrical losses in the compressor.	
	Loss Factor	This numeric field contains the factor of electromechanical loss that is proportional to the theoretical power.	%
	High Pressure Cut Off	the design pressure limit of the compressor	Pa
	Low Pressure Cut Off	the design low-pressure limit of the compressor	Pa
	Cycle Time	the full on and off cycle time of the heat pump unit.	H
Air flow exchanger	Flow Arrangement Type	The user-specified flow arrangement of the heat exchanger (CounterFlow, ParallelFlow, or CrossFlowBothUnmixed)	Dimensionless
	Nominal Supply Air Flow Rate	The nominal primary side air flow rate	m3/s
	Nominal Supply Air Inlet Temp	The nominal primary side air inlet temperatures	°K
	Nominal Supply Air Outlet Temp	The nominal primary side air outlet temperature	°K
	Nominal Secondary Air Flow Rate	The nominal secondary side air flow rate	m3/s
	Nominal Secondary Air Inlet Temp	The nominal secondary side air inlet temperature	°K
	Nominal Electric Power	The electric consumption rate of the unit	W

The outcomes are the following: a first issue is that IFC are not expressive enough to properly specify the selected systems. This is especially true for IFCx3, where the entities available to model the HVAC systems and components are way too generic. If we consider for instance the solar collector and the photovoltaic panel components, both are modelled using the "IfcEnergyConversionDevice" entity, which does not own any property relevant to solar collectors nor to photovoltaic panels. IFC2x4 do however redress the balance, by introducing more specialized entities. For instance, they introduce an IfcSolarDevice object, which may notably be typed as "SOLARCOLLECTOR" or "SOLARPANEL", and is completed with dedicated property set ("Pset_SolarDeviceTypeCommon") and quantity set ("Qto_SolarDevicebaseQuantities). But even IFC2x4 shows limitations. Our review shows actually that it is, in almost every case, necessary to complete the properties list, whether being in the scope of IFC2x3 or 2x4, with a minimum of two additional properties. For instance, six additional properties are required for photovoltaic panels, and two for solar collectors. It is therefore required to enrich IFC expression capabilities, either by creating new properties known as "User Property Set", or by proposing to integrate the most common parameters (from simulation environments) as new attributes of the existing common properties (Property Set common) in the next evolutions of the IFC specification. A second issue concerns BIM authoring tools and IFC export. As part of the review, we have investigated the capabilities of two major BIM authoring tools, namely Autodesk Revit MEP [17] and Graphisoft Archicad [16], with respect to HVAC systems IFC models export. And the outcome is clear: these tools do not export in many cases the proper IFC entities. For instance, a solar panel is exported as an "IFCBuildingElementProxy" by both Revit MEP and Archicad[2]. The third and last issue is related to components assembling. Our review has shown that modeling practices were quite different from one environment to another. This does not impact much modeling of isolated components, but may strongly influence the way components are interconnected when their deployment inside buildings is modeled. This may considerably hinders the possibility to defined generic assemblies in IFC that could be mapped to various simulation tools.

4. CONCLUSION AND FUTURE WORK

The work presented in this paper has shown that it is necessary, to fully leverage the potential of available simulation tools, to enable effective and reliable connections between BIM and simulation. Such connections require an extensive software support entailing validation, geometry completion, and data model translation. While many simulation tools may be targeted on the downstream side, the IFC seems to be the most relevant data model for the upstream (BIM) side, given its openness and completeness. Some implementations to translate IFC models into simulation input models are already effective, but focus at the present time on geometry and leave aside HVAC systems. The study presented in the paper shows that IFC has some limitations with respect to HVAC systems modelling that call for further enrichment. Moreover, the available tool support for HVAC systems IFC export seems to be inadequate.

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[2] Note however that some experiments – which have to be confirmed – tended to show that the DDS-CAD [33] IFC exports were more reliable.

Another step to take is to enable connection between IFC and multiple simulation environments, while current work tend to implement connections with specific tools. Taking this step is likely to be hindered by heterogeneous modelling practices, especially when it comes to HVAC components assemblies modelling. However, some positive perspectives also arise from this study. Firstly, the IFC is rapidly evolving since the first attempts to provide support for HVAC systems modelling [29], and it is likely that upcoming evolutions will be more fit for purpose. Then, some promising works advocate using an intermediate (pivotal) data format between IFC and simulation tools [18]. This seems most relevant, since there is actually a need to be able capitalize and reuse building models specialized for simulations (e.g. with respect to geometry modelling), while generic enough to enable targeting multiple simulation environments. This approach has proved to be efficient in the field of software systems engineering, where the so-called Model-Driven Architecture (MDA) [30] advocates a design approach based on iteratively refined models. In particular, the notion of Platform-Independent Model (PIM) introduced by the MDA is actually a generalization of the tool-neutral building simulation model mentioned earlier (this analogy could be further developed but this would be out the scope of this paper). Another related work that could dramatically help in implementing a connection between BIM and simulation is the one aiming at defining Model View Definitions (MVDs) in IFC. This effort aims basically at defining subsets of the IFC data model relevant to specific field and/or interests. Several have focused on building energy performances analysis – among which the Concept Design BIM 2010 MVD [32] – and, provided the effort is pursued in the scope of IFCx4, they could provide a robust and coherent foundation for bridging BIM and simulation.

In the scope of this research work, the next steps that are planned to be taken deal with prototyping[3]. The aim is to show that, despite the imitations of the currently available support (current version of IFC and available commercial CAD tools), it is feasible to build enriched IFC models and to run energy simulations relying on the latter. This prototyping work will rely on previous developments [8][9] and will implement a process entailing: (i) IFC export from CAD tools (two different tools will be used: Revit for architectural parts, and DDS-CAD [33] for HVAC systems parts); (ii) Model import and iterative enrichment in an IFC viewer to produce simulation-ready IFC models; (iii) Translation of IFC models into simulation tools input files formats and simulation execution.

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