# Optimising energy and daylight simulation workflow through openBIM and the web

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ABSTRACT: Current daylight and energy performance evaluation practices vary greatly in the industry due to a lack of robust software packages allowing for consistent interoperability. Those deficient workflow result in high evaluation costs due to the large number of hours used for simulation preparation, and in a compliance-chasing attitude in which assessing for qualities beyond the minimum regulation is a luxury often left aside. As an attempt to create awareness around the benefits of structured hierarchy models for the building simulation community, this paper describes methods solving identified silos based on openBIM, web technologies, and custom-made algorithms, resulting in smart and streamlined evaluation workflow greatly reducing assessing time and costs. The resulting platform-neutral web application is more than a proof-of-concept, it has as ambition to lift our industry inefficient practices and inspire others in this critical time of societal green transition.

## 1 INTRODUCTION

Building codes, green certification schemes and general awareness around buildings occupant's well-being are leading architects to rely more on building simulations and their specialists to deliver conformant building proposals. The recent BREEAM-NOR v6.0 new daylight requirements for example, for which the author as advised the Norwegian Green Building Council and performed a study to assess the applicability of the NS:17037 standard in the Norwegian context, requires all room of a project to be simulated. Regarding the assessment of energetic and thermal performances, the use of simulation software is also necessary, and the Norwegian industry has developed its own solutions, with SIMIEN launched in 2008, and the newer version SIMIEN 7 based on the late specification SN-NSPEK 3031:2020. In summer 2022 the market will see a fundamental update of the SIMIEN software, SIMIEN Online, a cloud solution that opens for new user-friendly functionalities and integration of third-party data.

Although all stakeholders around a building project have potential access to the architects BIM models, the information of the exported IFC files is rarely used in a streamlined and efficient way.

Regarding daylight performances, the author has evaluated that more than 75% of assessors spends in average around 50% of the evaluation time on file conversion and modelling, with about 25% of them spending from 50% to 80% (LinkedIn 2021). The architects BIM models not being imported and used for evaluation as such is due to the lack of adequate commercial software. Simulations engines focuses mostly on the calculation of daylight metrics, not on the pre-processing of the simulation. Post-processing, reporting and communication of the results are also time consuming, again challenging the integration of daylight assessment in the design process.

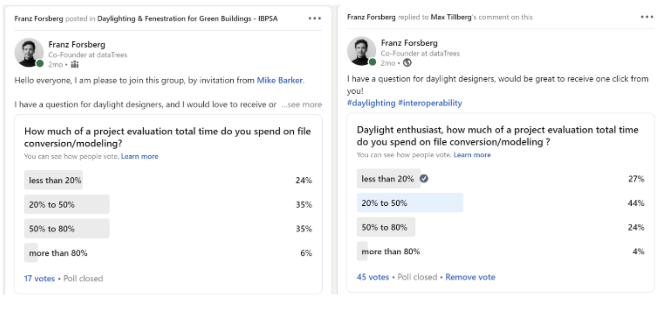


Figure 1. LinkedIn poll results asking to relevant target group: "how much of a project evaluation time do you spend on file conversion/modelling?"

In energy performance evaluations, assessors again spend great number of hours in manually inputting geometrical data into the simulation software. Interoperability in SIMIEN is limited, and the XML file import/export functions are used by only a handful of practitioners. Assessing a complex building project is therefore time consuming and tedious, and users have developed their own workflow for geometrical measurement and input, and quality assurance. Post-processing of the simulation for communication with the design team is generally not a concern, common practice being communication to the architects by emails, video meetings or phone calls, and written reports.

The assessment of daylight and energy/thermal performances of buildings is therefore costly, with great attention on the pre-processing of the evaluation. To liberate assessors from inefficient workflow, modern algorithmic and computational methods have been developed based on openBIM and packaged into a web application.

## 2 METHODS

The identified pre-processing and post-processing inefficiencies are solved through a systemic approach aiming at reducing all data losses generated by a project's stakeholders.

The use of openBIM has been chosen to focus on value creation.

Web technologies have been prioritised against desktop solutions to provide a device and operating system independent solution.

Custom-made algorithms and open-source web libraries enable opening of IFC files directly in the web browser and convert geometrical information and metadata to a structured hierarchy model ready for the desired analysis.

The overall process can be summarised in the following steps:

- Login to the web application
- IFC file upload with supervised model conversion
- Model rendering in a 3d enviornment, with CAD editing capabilities and quality assurance tools
- Daylight or energy simulation related settings
- Sending of the model to external server for daylight analysis, download of XML file to import in SIMIEN 7 or sending of information through API to SIMIEN Online
- Notification of simulations results
- Analysis results (daylight) available in the same 3d environment

### 2.1 *OpenBIM*

IFC is the only well-established common BIM format which is based on open standards. Its unique attributes make it possible for anyone to develop custom-made solutions based on that open format. The ecosystem around openBIM grows fast and several frameworks for handling IFC files are widely used: xBIM, IFC Web Server, IFC OpenShell, IFC++, IFC.js…

Our Nordic market is BIM dependant and architects can export IFC files. IFC classifications of elements and IFC SPACES contains necessary geometrical information for daylight and energy analysis, and output of the simulations can also be injected in the BIM model through the BCF format.

IFC.js, a JavaScript library for IFC manipulation on the web, has been chosen to perform a quality insurance of the uploaded model and insure minimum requirements (such as classified slabs, walls, windows) are met. Typical issues regarding the file import are missing classifications

of IFC elements, uncomplete export of the model and the elements of interests and the modelling overall quality. To solve classification issues, it is of great importance to firstly inform and educate the architects on BIM, secondly to use advanced algorithms which tries to comprehend the model and finally use other elements which can have similar geometrical function. Regarding uncomplete export, missing information can be acquired form other open sources, for contextual geometries for example. Unsatisfactory BIM modelling issues are solved by setting specific requirements for model consistency and level of detail, and algorithms for filtering relevant elements. The openBIM ecosystem finds its strength in its users and is a valuable format for the development of niche-specific applications which are not prioritised by traditional software companies.

### 2.2 *Web technologies*

Interoperability and format silos challenges can be eased by lifting software applications from device and operating system dependent to totally free of access web platforms. Every device, every operating system has a web browser and connection to the internet is today not an issue for professional practitioners. A 3d application can therefore be accessed through a single URL with almost no files store locally on the device. The innovative web application framework Vue.js is chosen to build the architecture of the application. The 3d rendering library Three.js is chosen for creating the 3d rendering scene of the algorithmically computed geometries. IFC.js is used to open the user uploaded IFC file and access relevant information by custom algorithms. API communication to authentication frameworks and computation servers delivers the data back and forth from the user device.

Users are no longer dependant on a specific device or personal computer. Results can for example be access when notified on a phone or presented on a tablet during a meeting. An URL can be shared with the project information to all the design team. Heavy computation is delegated to external servers, extending the choice of device for the assessor from solely heavy machines to lighter notebooks.

### 2.3 *Custom algorithms*

Beyond the use of open-source technologies, the development of custom algorithms is necessary to create a uniform data representation of buildings in the form of a data tree.

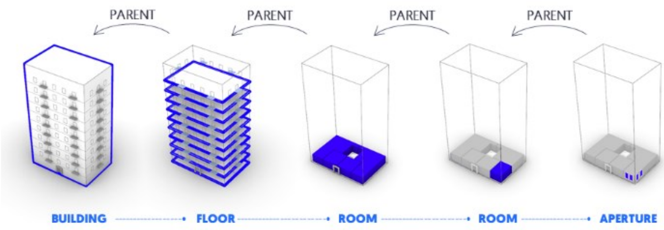


Figure 2. Building's parent-children relationship diagram.

Meaning, that every single element in a building is aware of its surrounding and hierarchical position and can thereby react and respond to changes to neighbouring elements (diagrams in figure 2 describes the parent-children hierarchy of certain building elements). This system structure allows representation and documentation of any building in a uniform and standardised manner, thus enabling space comparison and evaluation objectively and allows for extraction of meaningful training data for machine learning problems, which can relate among other things to daylight access, thermal performances, and energy consumption. Buildings become then knowledge graphs, represented as data trees (diagram representation in figure 3) and operated in our system by tools that understand topology, including graph neural networks.

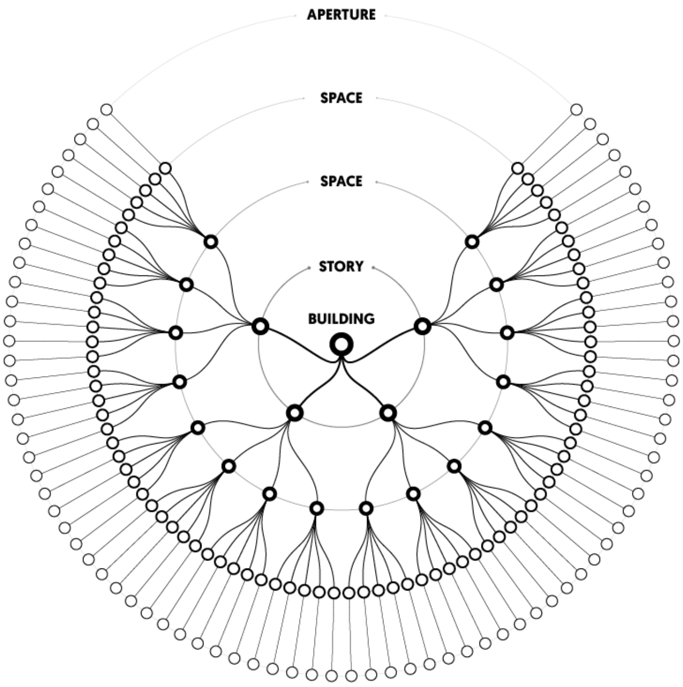


Figure 3. Data tree topologic relationships of building elements.

The conversion of the BIM model into a topological space data tree even allow for models with missing information to be suited for analysis. The topological information is also used to group spaces together for example by apartment level, so it is possible to say which bedrooms belong to a same unit.

Pre-processing of daylight simulations can therefore be highly automated from uploading of the IFC file to its final conversion to a daylight model. Material properties are automatically assigned, and analysis grids set on rooms based on their function and aperture availability. Post-processing is automated as well with raw daylight hourly information accessed by the application through API calls and processed to the desired metrics on demand. Point values are rendered in the application with complementary relevant information. Machine-learned based semantic recommendation can be generated for every room to furthermore assist the building performance evaluation.

Pre-processing of energy simulations using the SIMIEN software is also automated by the topological relationship of spaces. Boundary conditions for horizontal and vertical surfaces are pre-set and can be adjusted. Spaces can be merged or split. Features can be edited, such as space or aperture dimensions, and added such as for example shading elements, balconies, walls, or contextual buildings. Automatic, fast, and precise calculations of shading properties for facades and apertures are also a strong benefit of working in a 3d environment. The model is at any time downloadable in XML for direct import in SIMIEN 7. SIMIEN Online being soon released at the moment of writing this paper, the seamless communication between the application and the online version of SIMIEN will furthermore increase interoperability. Sending back and displaying the simulation results in the 3d environment is currently under development and is a promising feature, to better understand for example the effects of shading element, heat transfers, effect of specific loads, to be displayed as heatmaps on the model.

## 3 RESULTS

The resulting web application (figure 4 shows a preview of a loaded model and the user-interface) is built with future interoperability and needs of the industry in mind and is therefore modular. Radically different in nature than traditional executable software, the application is customisable and responds to the need of specific workflow.

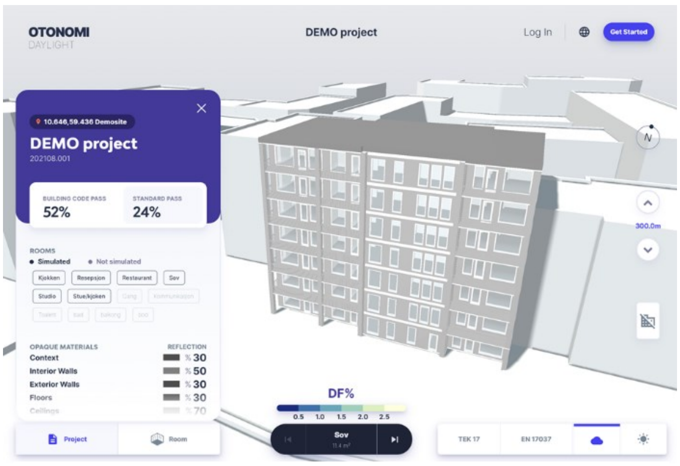


Figure 4. Application screenshot of a converted IFC model into a daylight model. Click to access.

For 3d modelling, only relevant CAD tools are displayed, allowing the creation of structured models using simple elements such as “buildings”, “walls”, “apertures”, “balconies”, etc.
For daylight analysis, the user interface adapts to show daylight workflow related information. The model grayscale colouring reflects the chosen light reflections values of the materials. Navigation is intuitive and the design team easily relates to their native BIM model.
Climate-based metrics are computed from the simulation raw data and displayed as point values, as shown in figure 5. For a more contextualised overview, metric results are benchmarked against the appropriate building code or certification for the project and shown in a simple green/red colouring. It is then simple for non-experts to identify rooms which are not complying with the requirements.

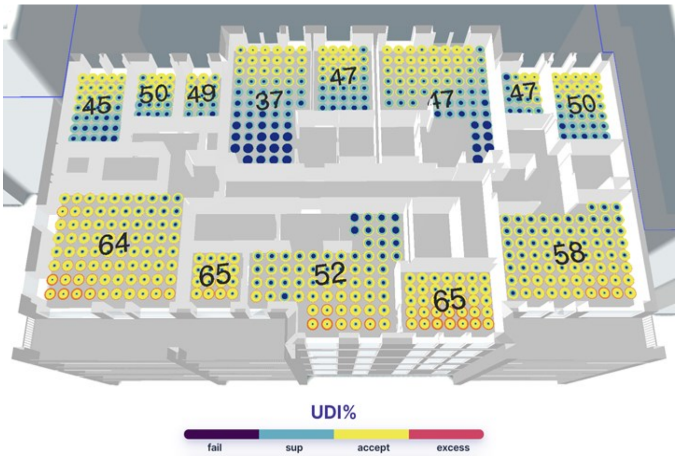


Figure 5. Application screenshot of daylight results in the converted model.

Regarding energy simulations, the application can render the model in a specific colour-scheme where each surface has a colour corresponding to its boundary condition for the SIMIEN software, as shown in figure 6. This allows for an efficient quality assurance of the model before export.

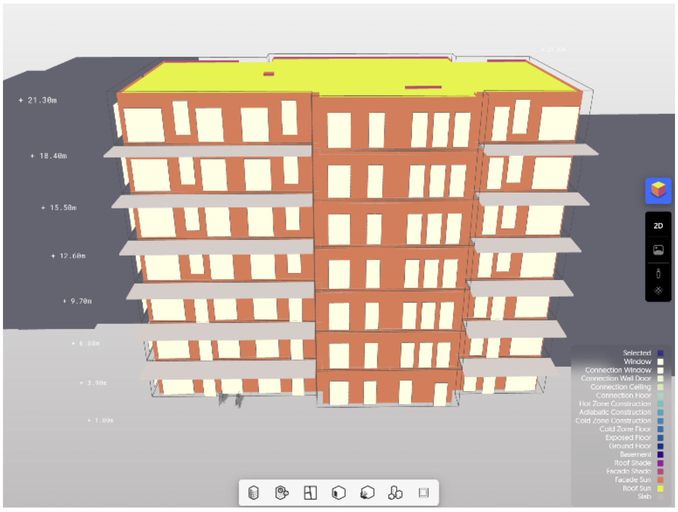

Figure 6. Application screenshot of the boundary conditions of the converted model for export to SIMIEN.

## 4 DISCUSSION

The web-application and the model conversion algorithm have been tested during its development in the first half of 2022 by several building performance analyst from various large consulting firms in Norway. We collected interesting feedback from those real users greatly improving along the way the application’s usefulness, by for example implementing more pertinent quality control measures. Regarding robustness, the feedback also helped in clarifying current limitations regarding the conversion of IFC files into structured topological models. Discussing with users, it has been accepted that successful conversion will remain challenging in some cases since not all projects are modelled using best practices. In those difficult cases, users have the choice between creating an energy model directly into the application taking advantage of the other features, or to simply use their previous methods solely relying on SIMIEN.
Close relationship is maintained with the users to furthermore take their feedback into consideration.

## 5 CONCLUSION

An approach to daylight and energy/thermal evaluation focusing on the pre- and post-processing of the simulation data is made possible through open-source standards and packages coupled with custom algorithms for creating a topological structured relationship of all building elements of a project.

This focus of streamlining generally tedious tasks is an attempt to reduce building performance evaluation time and costs, and to free practitioners from tasks little or not related to pure project evaluation.

This data manipulation serves as the foundation for exporting building information to relevant software for precises tasks. Parallel to the work described in this paper, application for structural analysis, urban wind comfort CFD and LCA analysis is undergoing.

The Scandinavian building energy simulation industry already sees great benefit of the released daylight application and SIMIEN users will soon be able to better evaluate and evaluate more projects and communicate results with higher flexibility for designing more performative architecture.

It is the hope of the author that this paper inspires others to create value-creating systemic evaluation processes, in a mindset to lift our industry practices so we can solve together the challenges of our societies.

## 6 ACKNOWLEDGMENTS

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Thanks also to our customers and their feedback contributing to make the platform always better and responding the needs of the industry.

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## 7 RFERENCES

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