# Practical framework for BIM-based lighting and visual comfort assessment in renovation projects

Deliverable 4.4

Deliverable Report: issue date on December 21, 2021

BIM-SPEED
Harmonised Building Information Speedway for Energy-Efficient Renovation

This research project has received funding from the European Union's Programme H2020-NMBP-EEB-2018 under Grant Agreement no 820553.

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## Colophon



This research project has received funding from the European Union's Programme H2020-NMBP-EEB-2018 under Grant Agreement no 820553.

# Change log

| Description | Author | Date |
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| Initial version for internal review | Filippo Lodi ( UNStudio ) | 30.09.2021 |
| Internal review | Mikel Cepeda (LKS) | 17.10.2021 |
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# Publishable executive summary

In Europe, buildings are accounted for about 40% of energy consumption and 36% of CO2 emissions. Furthermore, residential buildings constitute over 75% of the urban block; which implies that increasing building renovation could potentially support a major reduction of energy consumption within the EU.

BIM-SPEED research aims to innovate a user-friendly and affordable BIM-cloud platform to all or any stakeholders in the construction industry. The platform facilitates the cross-pollination of knowledge between building investors, owners, and designers through the provided access to interoperable tools and standardized procedures for building data/digital twin, 3D modelling, energy and comfort simulation, considering the implementation and maintenance of renovation solutions.

The research aims to optimize the energy and time of renovation projects across the EU through the deployment of co-creative BIM solutions with a true impact on the performances and Visual comfort of buildings. BIM Speed platform becomes a set of tools and methodologies projected to facilitate deep renovation processes, during a shorter time, with reduced costs, better quality, and better performance.

# List of acronyms and abbreviations

DoA: Description of Action

BEM: Building Energy Model

BIM: Building Information Modelling

GIS: Geospatial Information System

IEQ: Indoor Environmental Quality

IPMVP: International Performance Measurement and Verification Protocol

IPR: Intellectual Property Right

KPI: Key Performance Indicator

M&V: Measurement & Verification

POE: Post Occupancy Evaluation

IESNA: the Illuminating Engineering Society of North America

DF: Daylight Factor

sDA: Spatial Daylight Autonomy

ASE: Annual Sun Exposure

VLT: Visible Light spectrum Transmitted

IFC: International Foundation Class

LEED: Leadership in Energy and Environmental Design

BREEAM: Building Research Establishment Environmental Assessment Method

# Definitions

The methods used in the documents focuses on various daylight calculation in space:

**The Daylighting Factor (DF),** is a ratio defining the level of light that permeates a structure compared to the level of external light the structure receives. Daylight factor is one of the old measures to quantify the amount of daylight exposure in vs outside a room. Daylight Factor takes into consideration window to wall ratio, and interior material reflectance, and doesn't take into consideration building geospatial orientation, function, nor environmental context (GIS data). Because DF calculation only focuses on light permeability through glazing, the DF is found less efficient in defining the true performance of light and visual comfort in an existing building for renovation.

DF = 100 * Ein / Eext

Ein is inside illuminance at a fixed point

Eext is defined as simultaneous outdoor illuminance on horizontal plane from an unobstructed hemisphere of overcast sky (CIE sky) or uniform sky.

**Spatial Daylight Autonomy (sDA),** is a daylight availability metric that corresponds to the percentage of the occupied time when the target illuminance at a point in space is met by daylight (Reinhart,2001). A target illuminance of 300 lux and a threshold DA of 50% are values that are promoted in the IESNA,2013. (sDA300,50%) is achieved for at least 55% of regularly occupied space. In other words, at least 55% of the space receives at least 300 lux [28 fc] of daylight for at least 50% of operating hours each year.

**Annual Sun Exposure (ASE),** is the percentage of floor area that receives too much direct sunlight. ASE credits are achieved when simulation average plane is no more than 10% of regularly occupied space. In other words, no more than 10% of the area can receive more than 1,000 lux [93 fc] for 250 hours each year.

# Contents

# 1. Introduction

With the growth and accessibility of technology, there has been a shift in how space performs and is being used. Nowadays, our homes are becoming spaces for work and play as well. With these shifts in mind, comfort and performance become relevant factors in the efficiency of spatial design. D.4.4 proposes a standardized method for the implementation of BIM for lighting and visual comfort and the interoperability solutions between the analytical tools and the BIM-SPEED Platform. It also includes the analysis outcomes of the selected real demonstration cases, Vitoria, Spain (MDA5). The study was performed through climate-based daylight modelling methods using Radiance software. These tools are Climate studio (for Rhino3D) and Insight (for Autodesk Revit) which are the most notable industry-approved software for Lighting and visual comfort simulations with integrated credit validation for LEED, BREEAM, and WELLS. To be validated, compliance or non-compliance indicators of lighting performances metrics are taken into considerations. Because all the demo-cases are renovation buildings in various locations and conditions, it is important to utilize a process of assessing lighting and visual comfort that takes into consideration multiple variables such as geospatial location, building true North, physical context, window to wall ratio, interior material reflectance, and weather data. To achieve accurate reading, the research will focus on 2 metrics:

- Spatial Daylight Autonomy (sDA) takes into consideration location, energy data, building orientation, environmental context, material reflectance.
- SE/ Glare highlights zones of high solar exposure which supports the wellness added value of understanding the appropriate amount of natural light in alignment with the human circadian rhythms to reduce dependence on artificial lighting and moreover visual discomfort through the glare.

Evidently, this package defines a workflow for the assessment of the spatial visual and lighting comfort in order to reveal opportunities for improvement during the renovation phase. This process aims to reduce time and cost through a computational, human-centric, and industry-standard process towards Visual & Lighting comfort in BIM.

# 2. Ecosystem mapping for BIM based daylighting & visual comfort assessment

## 2.1 DAYLIGHTING & VISUAL COMFORT USE-CASE & INDUSTRY STANDARDS

### 2.1.1 Understanding industry-standard certifications for Daylighting & Visual Comfort assessment

**LEED** is a third-party certification program and the nationally accepted benchmark for design, construction, and operation of high-performing sustainable buildings. The first step in launching LEED v4.1 included a version of the LEED rating system for existing buildings. This rating system is for buildings that are fully operational and occupied for at least one year. The project may be undergoing improvement work or little to no construction. It must include the entire building's gross floor area in the project.
It requires the assessment to demonstrate through computer simulation that the applicable spaces achieve daylight illuminance levels of a minimum of 25 foot-candles (fc) (270 lux) and a maximum of 500 fc (5,400 lux) in a clear sky condition on September 21 at 9 a.m. and 3 p.m. Areas with illuminance levels below or above the range do not comply. [2]

**BREEAM** is a third-party certification program and the nationally accepted benchmark for design, construction, and operation of high-performing sustainable buildings that ensure daylighting, artificial lighting, and occupant controls are considered at the design stage to ensure best-practice in visual performance and comfort for building occupants.
It requires the assessment to demonstrate through computer simulation that the applicable spaces achieve daylight illuminance levels of an average of 100 lux or more for 3450 hours per year, and a minimum of at least 30 lux for 3450 hours. Areas with illuminance levels below or above the range do not comply. [4]

**WELL** Building Standard™ provides guidelines that minimize disruption to the body's circadian system, enhance productivity, support good sleep quality and provide appropriate visual acuity.
It requires the assessment to demonstrate through computer simulation that the applicable spaces achieve a Spatial daylight autonomy (sDA300, 50%) is achieved for at least 55% of regularly occupied space. In other words, at least 55% of the space receives at least 300 lux [28 fc] of daylight for at least 50% of operating hours each year. Furthermore, the annual sunlight exposure (ASE1000, 250) should achieve no more than 10% of regularly occupied space. In other words, no more than 10% of the area can receive more than 1,000 lux [93 fc] for 250 hours each year. [5]

Data Sheet Standards:

- WELL

| WELL | | | |
|---|---|---|---|
| Requirements | Visual Lighting Comfort (sDA300,50%) | Sunlight exposure (ASE1000,250) | WELL Circadian Lighting |
| | average of 215 lux [20 fc] in the living room. | (sDA300lux,50% achieved for at least 55% of regularly occupied space/year | During the daytime, 200 + melanopic lux facing the wall in the center of the room 1.2 m above Ground |
| | average of 50 lux [5 fc] in the bedroom. | (ASE1000lux,250) is achieved for no more than 10% of regularly occupied space/ year | During the nighttime, lights provide no more than 50 melanopic lux as measured 0.76 m above ground. |
| | average of 100 lux [9 fc] | | |

- BREEAM

| BREEAM | | | |
|---|---|---|---|
| Building/ Area type | Minimum Area to comply | Avg Daylight Illuminance | Minimum Daylight Illuminance |
| Living rooms, dining rooms, studies (including home office) | 80% | At least 100 lux for 3450 hours per year or more | At least 30 lux for 3450 hours per year or more |
| Non-residential/communal occupied spaces | 80% | At least 200 lux for 2650 hours per year or more | At least 60 lux for 2650 hours per year or more |

- LEED

| LEED | | |
|---|---|---|
| Daylight | Calculation requirement | Measurement Time |
| Levels between 150 lux and 5,000 lux for at least 50% of the regularly occupied floor area | Calculate at 9 a.m. and 3 p.m. on a clear-sky day at the equinox. | Measurements during the day sometime between September 1st and October 30th or March 1st and April 30th. |
| average of 50 lux [5 fc] in the bedroom. | Calculate on a maximum 5 foot (1500 millimeters) square grid. | measure at 30 inches (76 millimeters) above the floor. |
| average of 100 lux [9 fc] | Exclude blinds or shades from the model. Include permanent interior obstructions. Movable furniture and partitions may be excluded. | |

### 2.1.2 Setting up a use case

The use case provides a methodology for evaluating the Visual comfort of an existing building with purpose to inform design strategies towards the renovation of the living space daylight performance. In order to validate the daylight performance of a building for renovation, the process will take into account industry standards requirement for daylight and comfort (LEED, BREEAM, WELL). Furthermore, having a real demo case to test inquires the assessment to cross-reference two types of data, the simulated data and the sensor data in order to validate the daylight performance.. (Table 1)

To achieve BIMSPEED ambitions, two different workflows are tested to define areas of opportunity to achieve speed and cost efficiency pre and post renovation.

The common practice requires the involvement of a lighting or comfort specialist to run the simulations separately from the designer, which often leads to:

- Extra budget dedicated to contracting external sustainability consultant
- Separate time dedicated to consultant package deliverable
- Interruption in design flow
- Lack of communication between designer and consultant.

The use case creates an unprecedented workflow that creates a seamless and inclusive design approach towards renovation by equipping the designer and collaborators with the tools and the “know-how” for daylight & visual comfort assessment; which, ultimately contributes to:

- 
- Facilitating designer’s understanding of daylight performance in the process of design
- Seamless workflow for assessing comfort performance and designing simultaneously
- Reduction of time by limiting contact with an external consultant
- Reducing cost by performing comfort analysis in-house
- Industry standard (LEED, WELL, BREEAM) validation for building credits and certification

Table 1: Use-case Description

| USE CASE DESCRIPTION | |
|---|---|
| **Title** | Lighting and Visual Comfort Analysis |
| **Goal** | Assess the occupants' Lighting and Visual comfort before the renovation using measured data |
| **Description** | The use case provides a methodology for evaluating the Visual comfort of an existing building, multifamily midrise |
| **Input data** | IFC model(Material library, artificial Lighting library, Glazing value) GIS Data, Env. Data, |
| **Sequence of actions** | Digital data: Use-Case>Benchmark>Workflow definition> IFC model> Simulation> real time sensor data> Calibrate simulation> Platform interoperability> documentation |
| **Primary actors** | Spatial Comfort Consultant/experts, designers and all the parties involved in the design thinking process (performing the Comfort assessment). |
| **Secondary actors** | Other BIM partners, Final end-users, residents, owner, developer |
| **Pre-conditions** | Demo case Digital Twin (IFC), Sensor placements, Simulation software/ technology |
| **Trigger** | Data accuracy, time, cost, and learning curve. |
| **Post-conditions** | Identifying Lighting and visual performances Lows and Peaks. Implementing spatial changes (artificial lighting, blinds, materials, etc) to improve lighting and Visual performance post renovation. |
| **Frequency of use** | At every Pre-design phase of a renovation |
| **Support planned for** | BIM-SPEED |
| **Use-case Created by** | UNS |
| **Date of last update** | 14/07/2021 |

**Use-case aim and scope:**

- Assessing as-built and renovation daylight performance
- Informing renovation strategies
- Designing renovation with Industry standard requirements for validation and credit
- Standardizing a workflow for seamless design thinking/ integration
- cross-platform Interoperability

**Use-case Limitations:**

- The measured GIS data acquisition could be a limitation if the available source is not updated regularly or easily accessible.

- During the simulation phase, if the IFC model is not accurately packaged (correct family, elements, material passport, true north, layers, etc.), the as-built 3D environment could potentially have missed information that will require being input manual.
- In case, the demonstration residents are not compliant to sensor placement in their living space (during the documentation phase), this could lead to insufficient amount of measured real-time data to be compared to the simulation.
- 

### 2.1.3 DAYLIGHTING ASSESSMENT TOOLS ECOSYSTEM

Considering the ambitions of BIM-SPEED to be accessible, user-friendly, inclusive, UNS conducted an industry-standard ecosystem mapping towards Daylighting & Visual comfort. The first steps broke down the feasibility of "in-house vs off-shelves" development taking into consideration, time, cost, company size, certification, and interoperability (Figure 1).

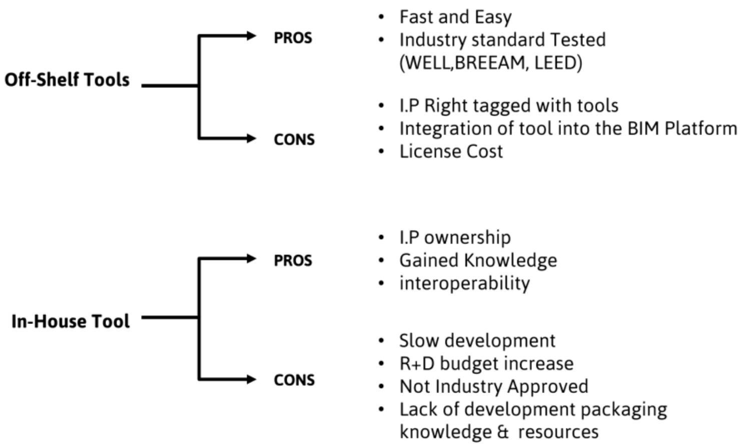


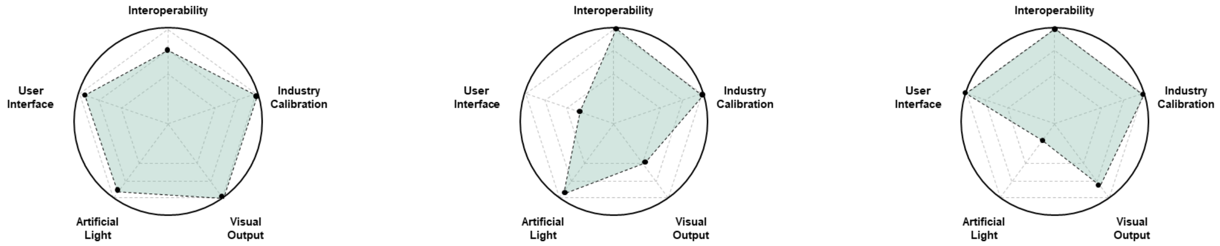

Figure 1: Tools feasibility

In order to have full compliance for the renovation, the use of "off-shelf" tools is preferable because of the benefits of already being industry-approved, expert engineered, and regularly updated. Out of the tool benchmark, two of the most architectural BIM tools , Revit and Rhino were chosen for the simulations. When preparing for the assessment of daylight and visual comfort, there is a consideration towards feasibility in terms of time reduction and integration. In 2021, there are over 20 different computer aided software for simulation of daylight in the market. Each software is categorized based on its interoperability, user interface, learning curve, cross-platform compatibility, IT investment, and workflow, in order to start defining an ecosystem map of all the software fit to the BIMSPEED ambition of reducing cost and time.

and providing a cross platform compatibility. There are three software that stands out because of their added value for being able to simulate: (Figure 2)

- Artificial lighting aside from natural light exposure which validate the human circadian rhythm
- Integrated industry standards validation for LEED, WELL, BREEAM
- Cross-platform BIM tools compatibility. (Rhino, Revit)

| | Rhino | Revit | Cove Tool | Climate Studio | Open Studio | Velux Daylight Vis. | AGI32 | DIALux | Relux | Cypelux | IESVE |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Workflows | ●●○ | ●●● | ●●● | ●●○ | ●●○ | ●●○ | ●●● | ●●● | ●●● | ●●● | ●●● |
| ICT Investments | ●●○ | ●●○ | ●●○ | ●●○ | ●●○ | ●○○ | ●●● | ●●○ | ●●○ | ○○○ | ●●● |
| User Interface | ●●● | ●●● | ●●○ | ●●○ | ●○○ | ●●● | ●●● | ●●● | ●●○ | ●●○ | ●●○ |
| Data Conversion | ●●○ | ●●● | ●●○ | ●●○ | ●○○ | ●●● | ●●● | ●●● | ●●● | ●●● | ●●○ |
| Learning curve | ●●○ | ●●○ | ●●○ | ●●○ | ●●○ | ●●○ | ●●○ | ●○○ | ●○○ | ●○○ | ●●○ |
| Compatibility with other platforms | ●●● | ●●● | ●●● | ●●● | ●●○ | ●●○ | ●●● | ●●○ | ●●○ | ●●● | ●●● |




**CLIMATE STUDIO**

High parametric personalization.
High interoperability
Low IFC compatibility (through plugin*)
Artificial Light for daylight simulation
High Personalization

**CYPELUX**

No parametric personalization.
High interoperability
IFC compatibility
Artificial Light for daylight simulation
No Personalization

**REVIT INSIGHT**

High parametric personalization.
High interoperability
IFC compatibility
No Artificial Light for daylight simulation
Low Personalization

Figure 2: Tool ecosystem benchmark

# 3. BIM based Daylighting & Visual comfort Assessment

## 3.1 BIM CLOUD PLATFORM INFORMATION SPEEDWAY

The BIM Cloud Platform serves as an Information Speedway. It is not the 'final destination', but it is the holistic infrastructure that facilitates BIM-based processes, tools and data to achieve the short-term, and long-term EEB deep renovation impacts.
The 10D BIM Toolset can be considered as the 'Service Stations' along the Information Speedway. Each tool provides one or more functions to support EEB deep renovation, for example: Built mapping; Modelling; Clash Detection; Scheduling; Cost estimation; Energy simulation.
The BIM Projects and their Data are similar to the vehicles and their content driving on the information speedway. Along the way, vehicles and passengers receive the completion of their needs at the 'Service Stations'. The BIM renovation project data is enhanced and enriched by the BIM Tools. (Figure 3)

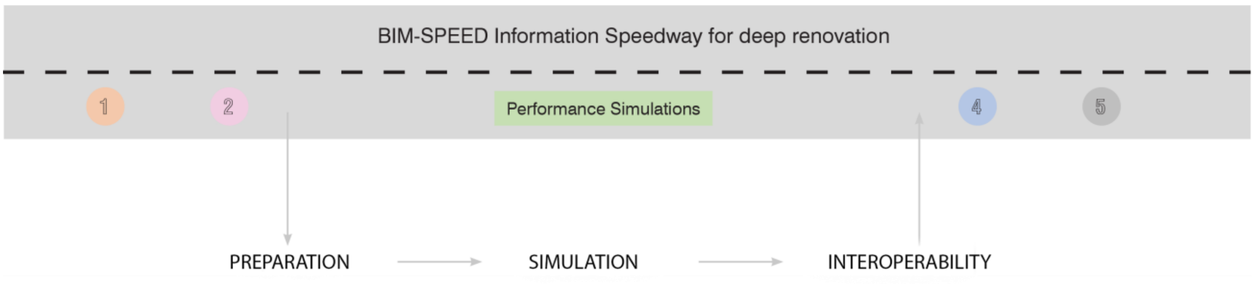



Figure 3: Lighting Simulation Process

## 3.2 WORKFLOW DAYLIGHTING & VISUAL COMFORT SIMULATED DATA

### 3.2.1 Pre Simulation details include several items

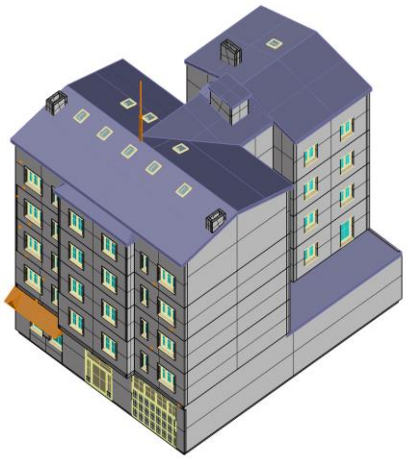
An assessment for daylighting performance and probability for LEED daylight and views credit EQc8.1 was performed for the prototype building in Vitoria Spain. The daylighting analysis was carried out using 2 industry-approved software: Climate Studio lighting simulation software developed by Solema for Rhino 3D, and Insight simulation software developed by Autodesk for Revit.

- IFC -> Revit ->Revit Insight
- IFC -> Rhino -> Climate studio

### 3.2.2 Daylight Measurement

Points are accredited to the building if it achieves illuminance levels between 300 lux and 3,000 lux for at least 50% of the regularly occupied floor area with furniture, fixtures, and equipment in place. For spatial Daylight autonomy points: Demonstrate through annual computer simulations that spatial daylight autonomy$_{300/50\%}$ ($sDA_{300/50\%}$) of at least 55%, 75%, or 90% is achieved. Use regularly occupied floor area. Finally, the living areas' Annual Sunlight Exposure$_{1000,250}$ ($ASE_{1000,250}$) should not exceed more than 10%. [2]

***Simulation details***



- The building is located in Vitoria, Northeast of Spain.
- Building address: Manuel Diaz de Arcaya Kalea, 5 01012 Gasteiz, Araba, Spain.
- True North= 21.5 deg (Northeast Quarter facing façade)
- Building Occupancy=Midrise Apartment
- All of the assessment results in this study were conducted on an analysis plane positioned 85 cm above each finished floor.
- To be industry compliant, the date and times for the simulation were set on the Equinox, Sept. 21 between 9 a.m. and 3 p.m.
- The measurement plane grid size ($x$) should be between 25cm> $x$ < 300cm
- The luminance sky distribution set in Climate studio and Insight lighting simulation software was clear sky.

### *Simulation preparation*

The best practice for daylight-compliant simulations should consider criteria's below:

- GIS Data/Location/Context/weather data
- Material Finishes
- Glazing Properties
- Floor Areas/rooms

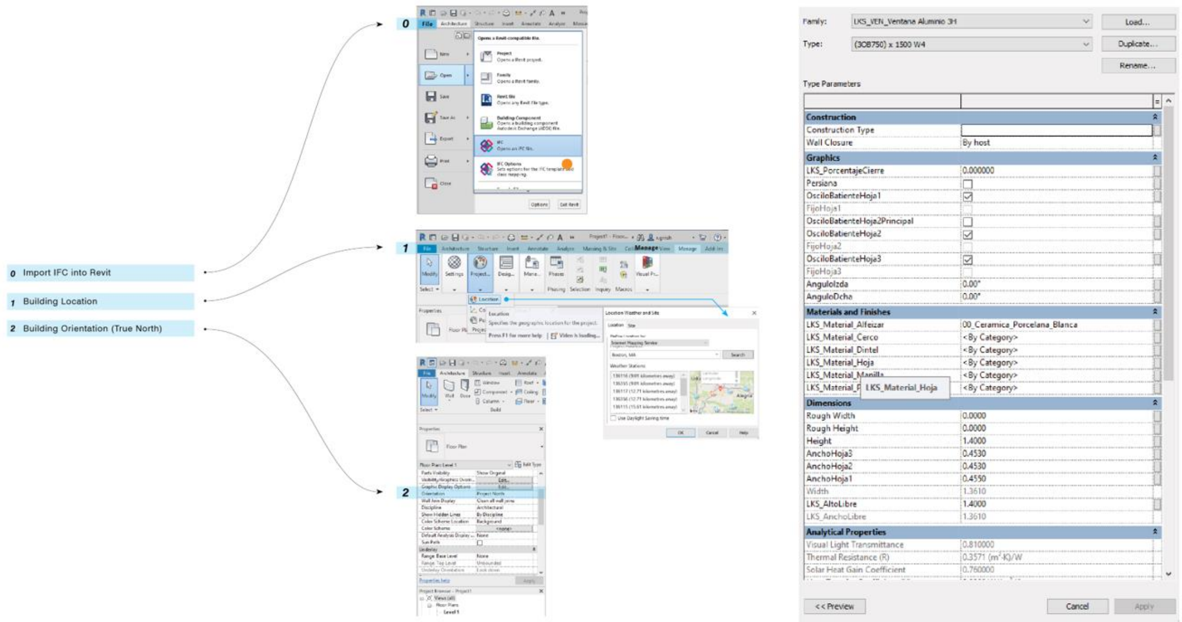



Figure 4: Model Setup (Revit_Insight)

The IFC (International Foundation Class) model of the demo-case taken from BIM-SPEED should already contain a high accuracy of documentation comprising of Location, context, rooms, material finishes and glazing VLT values (Visible Light spectrum Transmitted). Nonetheless, before to running the simulation, it is best to go through the BIM model to check the accuracy of the imported IFC. Each software tested for simulation (Revit & Rhino) uses slightly different simulation processes. On the Rhino side, the process of preparation involves layer structures (floor, walls, glazing, and context), location, and material assignment. Distinctively from Revit Insight, Rhino Climate Studio uses a layers system to assign material properties to objects in the simulation environment. When setting up a model, objects with different material properties should be placed on different layers, with each layer given an appropriate material. Objects on layers without an assigned material are ignored when running the simulation all lighting simulations. (Figure 6)

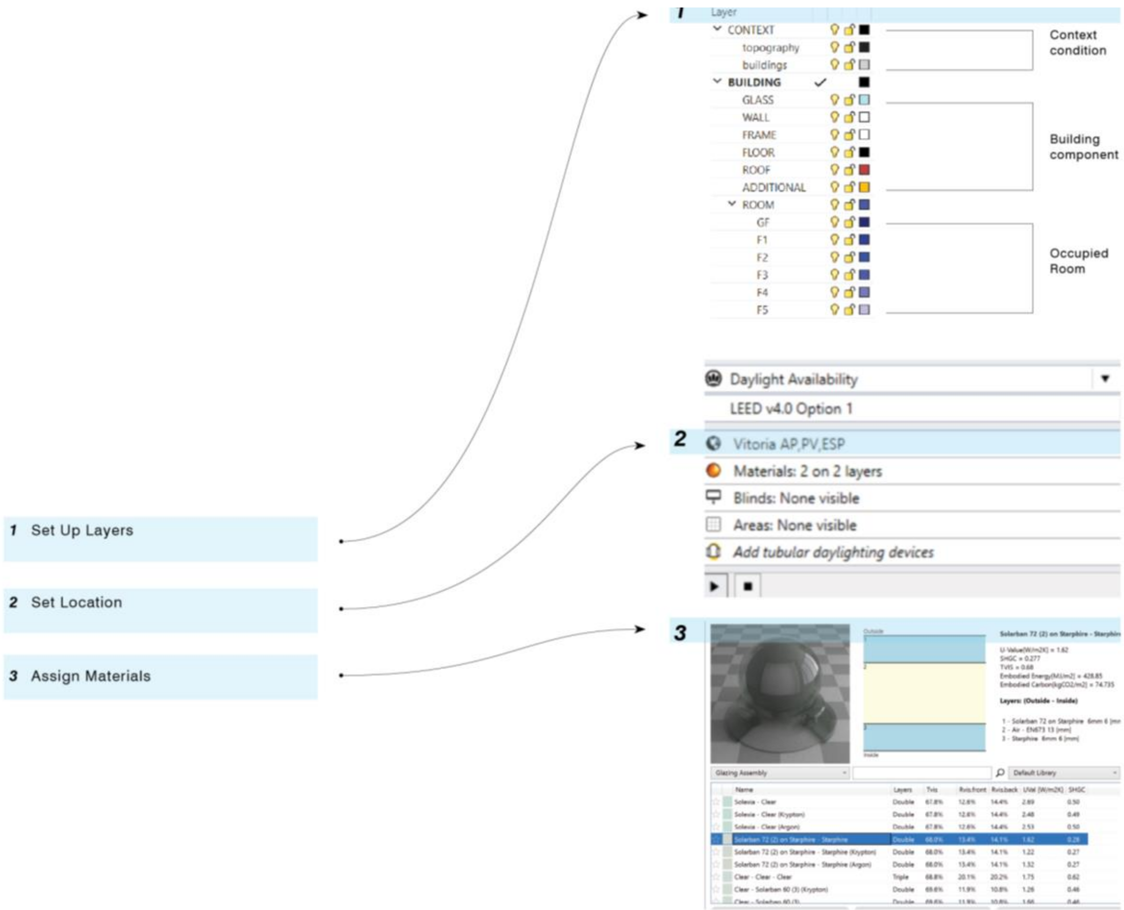



Figure 5: Model Setup (Rhino_ClimateStudio)

Essentially, regardless of the tools used for simulation, there should be a control or assignment of materials to get an accurate reading of the demo case conditions. More specifically, the elements that should be checked are the windows and façade properties. Since demo cases are existing buildings in poor condition, there are chances that some of the materials found on site are damaged or too old to be found. In the case of these materials that are not available in the IFC documentation, a generic or close to original option should be chosen when running an as-built simulation. The correct properties of the element should be used when running a simulation after renovation.

Once ready, we run the simulation. The simulation time is a factor in the tools used. For the simulation of this demo case, the average time for simulation is 18-25 minutes with the mentioned settings (Figure 4). The time of the simulation depends on multiple factors, most notably the measurement plane grid size. The timestamp of the simulation was done with a grid size of 100cm which led to approximately 25 min. with a grid size of 200cm, the time will be cut down to 15 min. Though the time of simulation can be reduced by scaling up the grid size, the accuracy of the reading will also be affected. Beyond the grid size resolution, the workstation used for the simulation is also a key factor in achieving the speed of simulations. For the simulation done for Vitoria, the workstation specs and simulation settings are: (Figure 6)

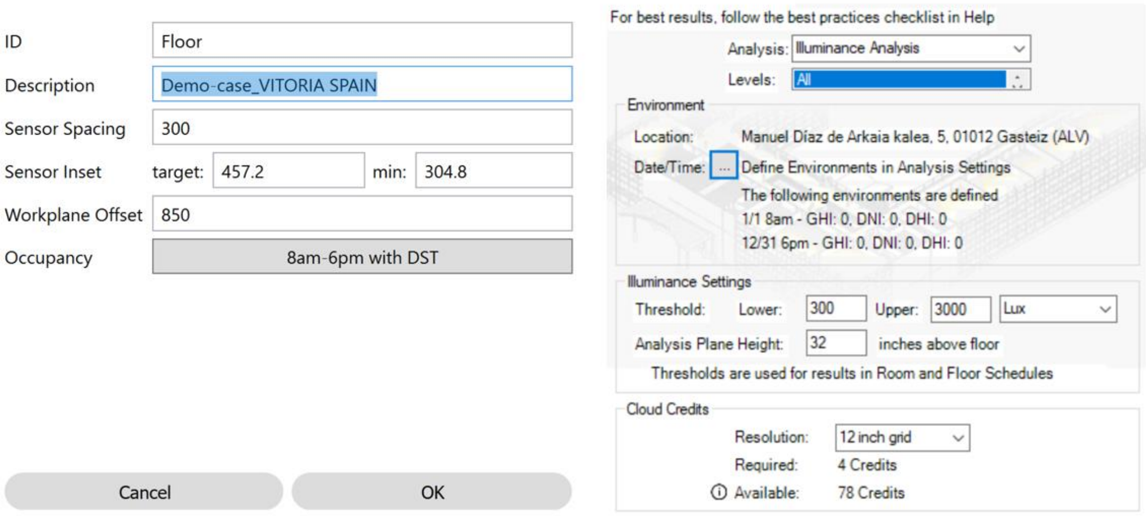



Figure 6: right: Rhino simulation Panel, left: Revit Panel

***Workstation Specs:***

- DELL Precision 5550 laptop
- Processor: Intel(R) Xeon(R) W-10855M CPU @ 2.80GHz 2.81 GHz
- RAM: 32GB
- System Type: 64-bit operating system
- Graphic card: NVIDIA Quadro T2000

Furthermore, it is important to know that the speed of simulation could be increase using a workstation with higher computing power.

### 3.2.3 OUTPUT DATA DAYLIGHTING & VISUAL COMFORT SIMULATED DATA

The main goal in as-built simulations, is to indicate areas of daylight improvement to the architect/designer therefore, achieving the LEED point is not as relevant. For the post-renovation simulation, the purpose is to see if it has improved visual comfort with the planned renovation strategy and if a LEED point can be achieved.

An assessment for daylighting performance and probability of achieving LEED daylight and views credit EQc8.1 was performed for Vitoria Demo Case (MDA5) in Spain. The daylighting analysis was carried out using Climate Studio and Revit Insight lighting simulation software. The daylighting performance of the building did not meet the requirements to achieve EQc8.1. The overall daylighting performance is poor. From the daylighting analysis results, 9% of the regularly occupied space floor area is 300 to 3000 lux illumination level at 3 p.m. and 3% at 9 a.m. The “as-built” status does not achieve any LEED points.

The living areas' Annual Sunlight Exposure$_{1000,250}$ ($ASE_{1000,250}$) is 1.2% which meets the requirement by not exceeding more than 10% annual exposure. The 1.2% which are areas of exposure should be addressed by adding darker blinders to reduce high glare and improve visual comfort.

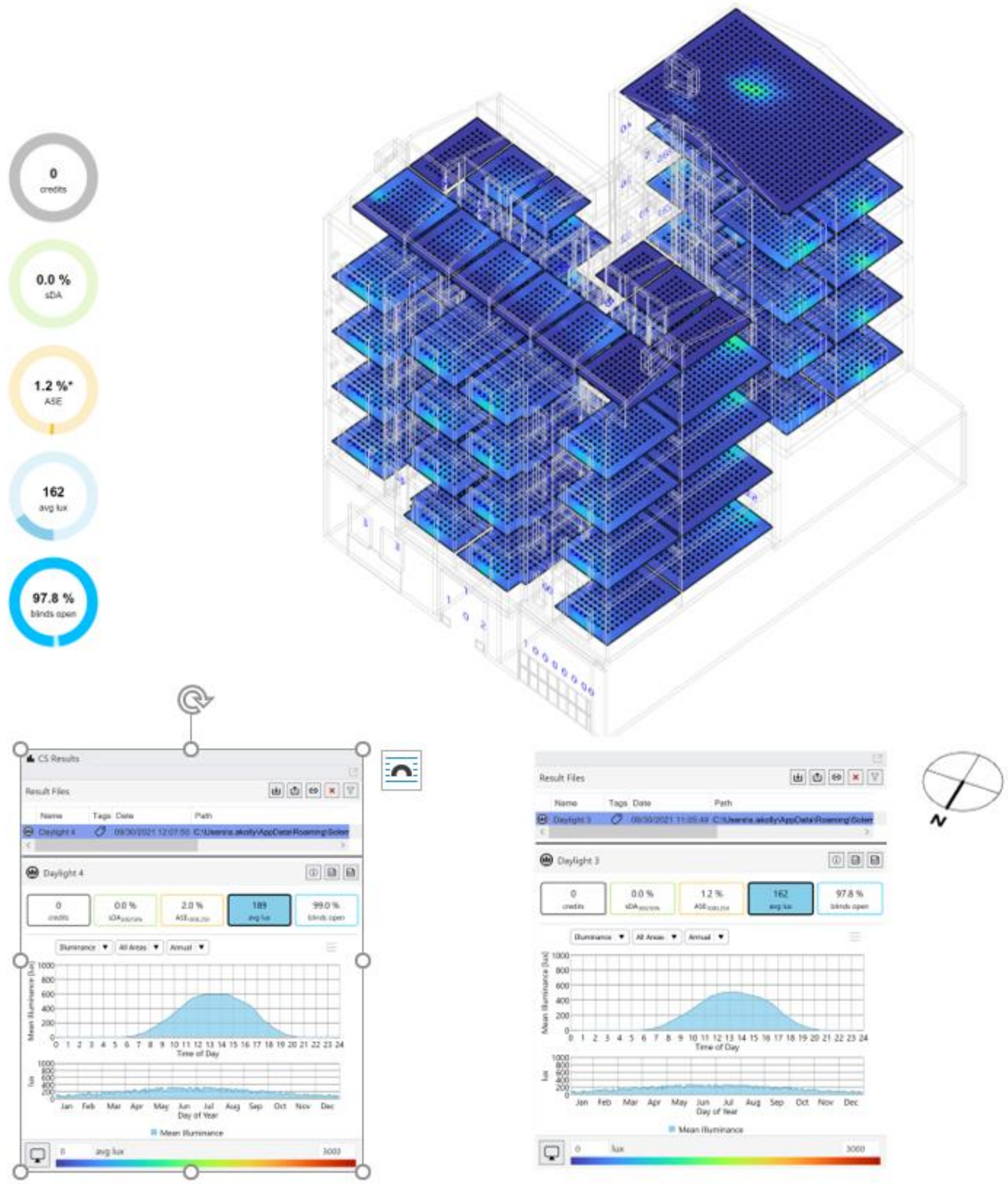



Figure 7: Simulation Result

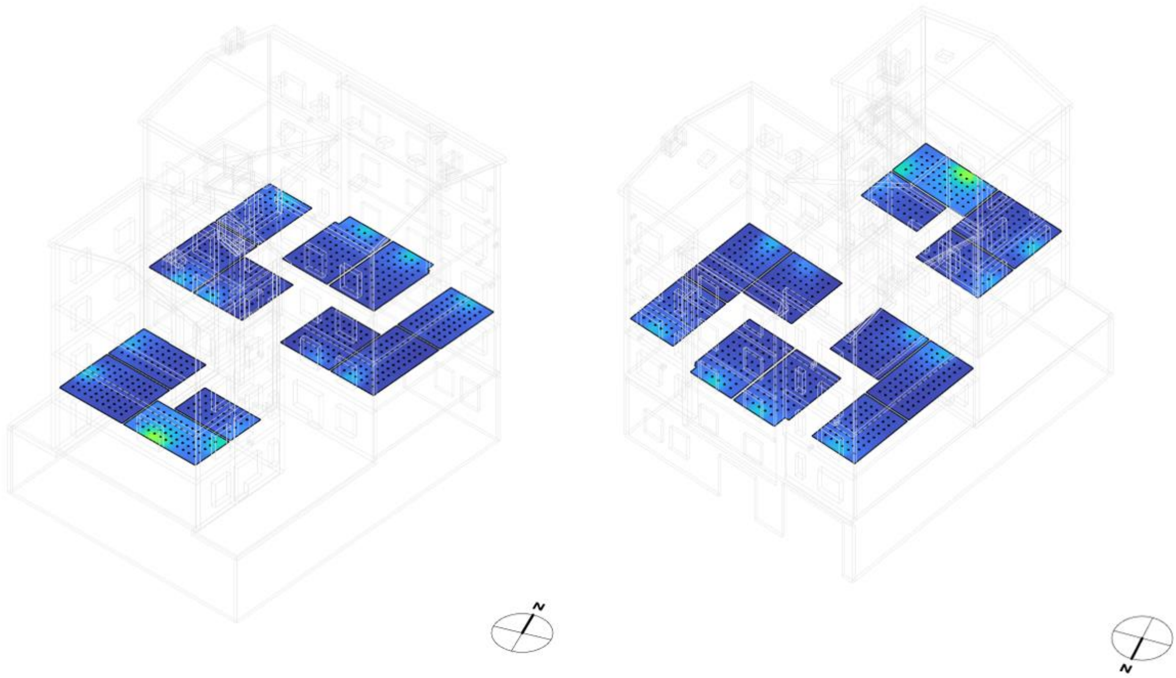


Figure 8: Highest Daylight Floor 02 - 189lux

The simulation shows that the Vitoria demo-case being a North facing Building does not meet the required daylight exposure for assessed living areas. The South façade being situated in a courtyard and having only a few windows does not allow light to permeate through the building. The highest daylight level is situated on the 2nd Floor and the 5th Floor of the building where there is a higher window to wall ratio. The lowest daylight exposure is found on the 1st floor which is the lowest living area plane of the building. These results give in-depth insight on areas for improvement for daylighting and visual comfort.

# 4. Interoperability of Simulated Data

## 4.1 Simulation and Calibration Workflow

The goal of T.4.4 is to assess the demonstration building daylighting performance and to interpolate the output data back to the BIM-SPEED platform. To achieve BIM interoperability, a process of data exchange loops between the simulation data, the sensors data, and the BIM platform. Once the interchangeable file types and data set are decided, the phase for documentation and interpolation begins.

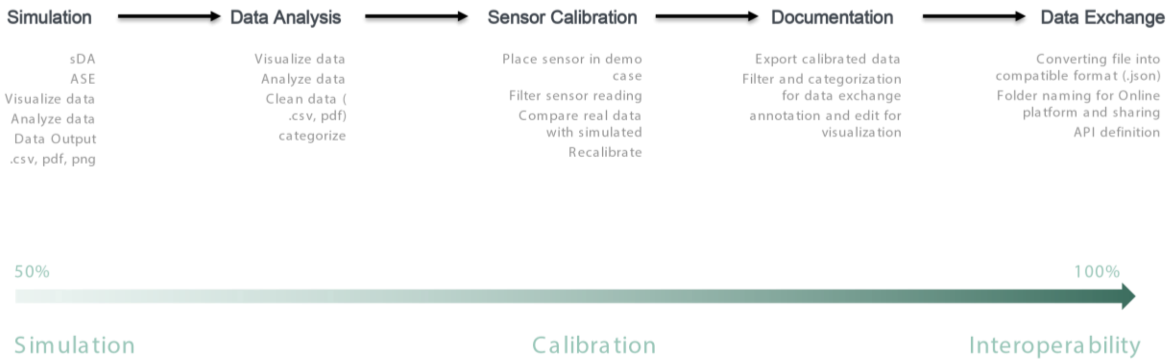



Figure 9: Interoperability workflow

## 4.2 SIMULATION OUTPUT FORMAT

Throughout the BIMSpeed Research, the consortium partners communicate and exchange files through the BIM platform. It is a central collaborative platfor m where all the demo case data are stored for documentation and coordination. The BIM platform functions as a folder-based interface with each demo case having its own digital folder, building 3D information, drawings document, research, energy, and comfort studies.

For the Daylight and Visual Comfort assessment, there is a two-way interaction with the platform. It is the starting point where the IFC of each demo case is stored and imported into the designer's server. Once exported out of the platform, the IFC is checked in order to verify the accuracy of the information packaged such as: (Figure 10)

- Spreadsheet structure (.CSV)
- Raster-graphic file (.PNG,.JPEG)
- Portable Document format (PDF)

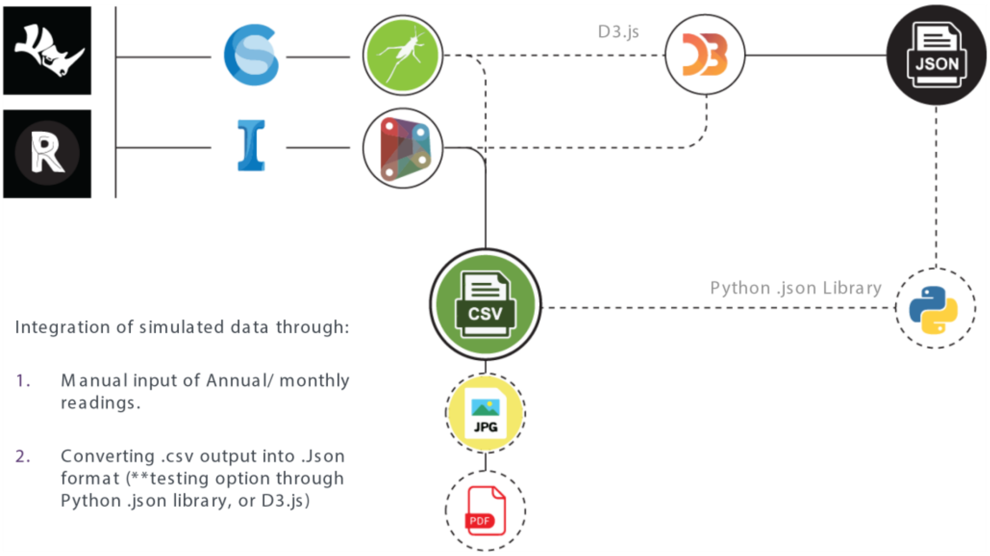



Figure 10: Interoperability feasibility

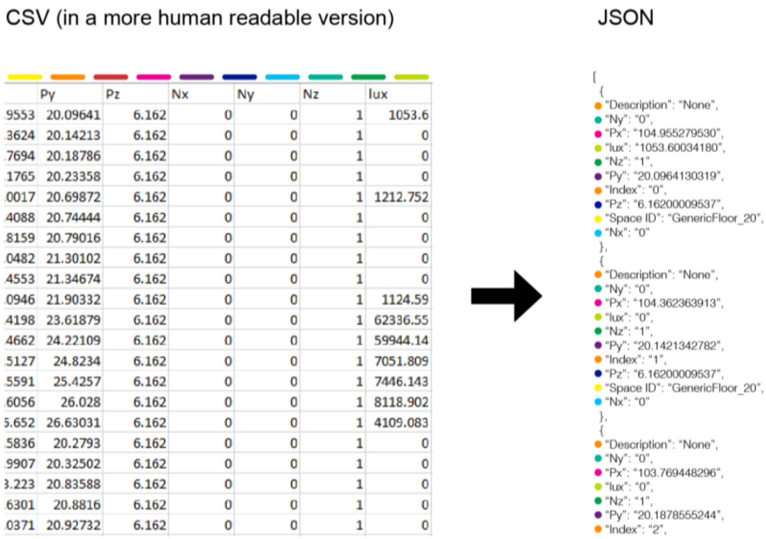
These files type become exchangeable data that is translated into the BIM platform for the user to access. Furthermore, in order to the data to be easily interchangeable with digital application through a JSON format. This process required an extra process of converting the compatible exported file, CSV into a JSON file through python. Both used simulation tools, Revit Dynamo and Rhino Grasshopper have capability to host Python, an open source plugin interpreter which can execute dynamic scripts of any type. (Figure 11) Once translated, the JSON output becomes a compatible format that is imported into a digital app platform that translate the data into visualization. This process enables the Daylight & Visual Comfort simulated data to be shared and visually communicated to multiple stakeholders beyond the designer (tenants, engineers, consultants, owner, investors, etc...)

***Definitions:***

CSV: A comma-separated values (CSV) file is a delimited text file that uses a comma to separate values. Each line of the file is a data record. A CSV file typically stores tabular data (numbers and text) in plain text, in which case each line will have the same number of fields.

JSON: JavaScript Object Notation, is an open standard file format and data interchange format that uses human-readable text to store and transmit data objects consisting of attribute–value pairs and arrays (or other serializable values).

PYTHON: Python is an interpreted high-level general-purpose programming language. Its design philosophy emphasizes code readability with its use of significant indentation. Its language constructs as well as its object-oriented approach aim to help programmers write clear, logical code for small and large-scale projects.




| | Py | Pz | Nx | Ny | Nz | lux |
|---|---|---|---|---|---|---|
| 9553 | 20.09641 | 6.162 | 0 | 0 | 1 | 1053.6 |
| 3624 | 20.14213 | 6.162 | 0 | 0 | 1 | 0 |
| 7694 | 20.18786 | 6.162 | 0 | 0 | 1 | 0 |
| 1765 | 20.23358 | 6.162 | 0 | 0 | 1 | 0 |
| 0017 | 20.69872 | 6.162 | 0 | 0 | 1 | 1212.752 |
| 4088 | 20.74444 | 6.162 | 0 | 0 | 1 | 0 |
| 8159 | 20.79016 | 6.162 | 0 | 0 | 1 | 0 |
| 0482 | 21.30102 | 6.162 | 0 | 0 | 1 | 0 |
| 4553 | 21.34674 | 6.162 | 0 | 0 | 1 | 0 |
| 0946 | 21.90332 | 6.162 | 0 | 0 | 1 | 1124.59 |
| 4198 | 23.61879 | 6.162 | 0 | 0 | 1 | 62336.55 |
| 4662 | 24.22109 | 6.162 | 0 | 0 | 1 | 59944.14 |
| 5127 | 24.8234 | 6.162 | 0 | 0 | 1 | 7051.809 |
| 5591 | 25.4257 | 6.162 | 0 | 0 | 1 | 7446.143 |
| 6056 | 26.028 | 6.162 | 0 | 0 | 1 | 8118.902 |
| 5.652 | 26.63031 | 6.162 | 0 | 0 | 1 | 4109.083 |
| 5836 | 20.2793 | 6.162 | 0 | 0 | 1 | 0 |
| 9907 | 20.32502 | 6.162 | 0 | 0 | 1 | 0 |
| 3.223 | 20.83588 | 6.162 | 0 | 0 | 1 | 0 |
| 6301 | 20.8816 | 6.162 | 0 | 0 | 1 | 0 |
| 0371 | 20.92732 | 6.162 | 0 | 0 | 1 | 0 |

Figure 11: CSV to JSON conversion

### 4.2.1 DATA STORAGE EXCHANGE

The BIM-SPEED research aims to optimize the energy and time of renovation projects across the EU through the deployment of co-creative BIM solutions. In this effort, the BIM-SPEED platform becomes a hub for knowledge and data exchange which enables a co-creative approach to design and decision making. T4.4 makes use of the platform through 2 interactions:

- The import of data (IFC, GIS data, As-built documentation, etc.)
- Data storage for exchange (PDF, PNG, CSV, JSON)

This process becomes a seamless loop that reduces time of exchange and increase efficiency in the process of accessing, processing, and exchanging data.

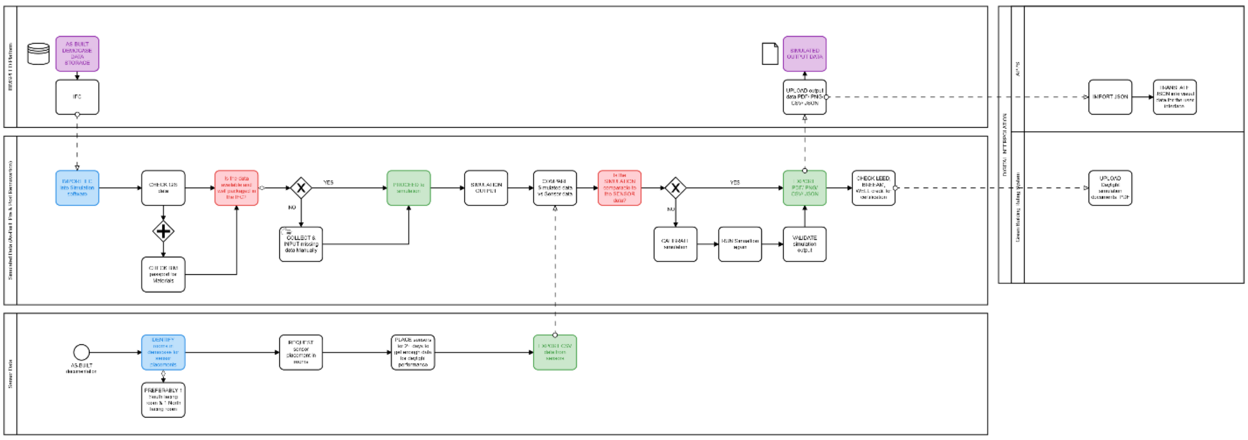


Figure 12: File Exchange workflow for Daylight & Visual Comfort

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