19 November 2023

Daylight Modeling in Architecture

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Contents

Contents (A)

- **Daylighting**
  - City design & daylight optimization
  - Daylight & parametric massing
  - Simulation in architecture
  - Natural daylighting importance
  - Lighting simulation in architecture
  - Daylighting in green buildings
  - Efficient daylighting: Benefits
  - Effective daylighting strategies
  - Architecture + daylight = art + science
- **Tools and Techniques**
  - DIALux
  - Ladybug Tools: Honeybee
    - Honeybee relation to other engines
    - Honeybee schema
    - Case study: Daylight performance

Contents (B)

- **Practical Demo (1):** DIALux
  - Overview, interface walkthrough, and operation (15’)
  - Simulation process and interpretation of results (15’)
- **Practical Demo (2) :** Honeybee
  - Intro Rhino: NURBS modeling (5’)
  - Intro Grasshopper (GH): algorithmic modeling (10’)
  - Intro Ladybug Tools (LBT): environmental modeling (10’)
  - Intro Honeybee Radiance (HB-R): daylight modeling (20’)
  - Intro Honeybee EP (HB-EP): energy modeling (15’)
  - Simulation process and interpretation of results (20’)

Contents (C)

- **Recent research works**
    - Exploring brute force method for design optioneering in low-cost apartment
    - Integrating energy modeling into algorithmic modeling (in-progress)
- **Extras**

Daylighting

Daylighting\

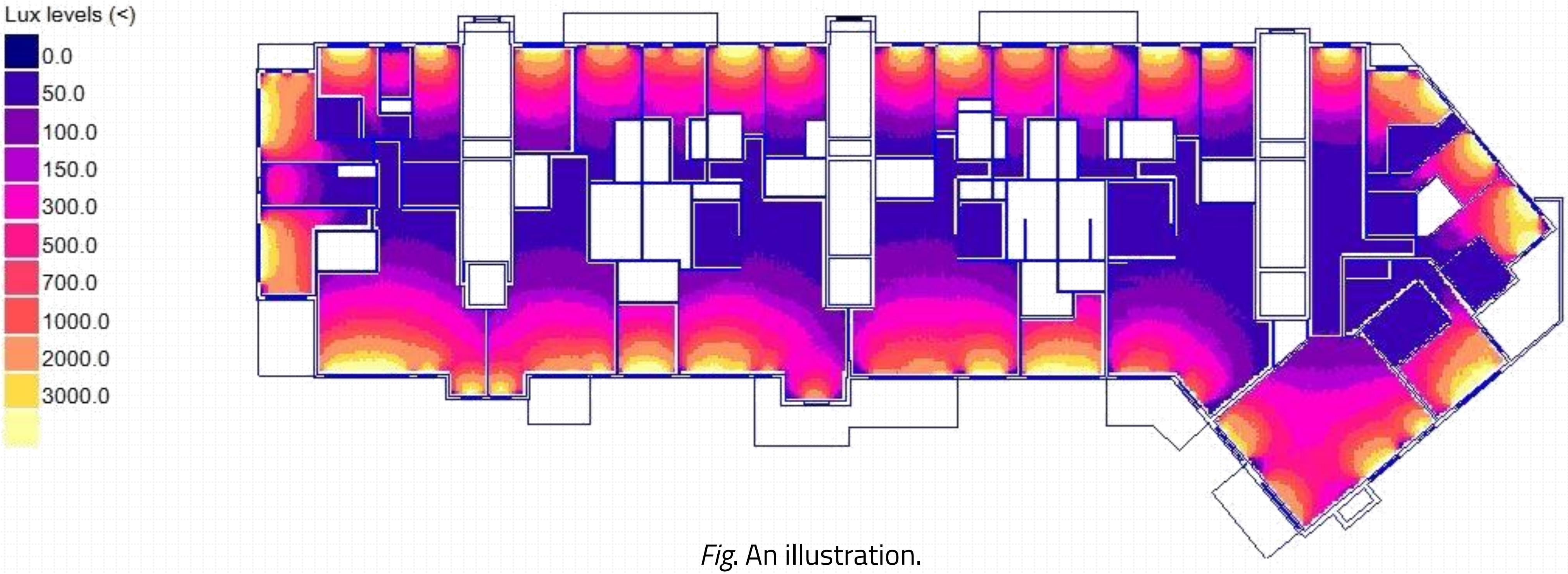

Fig. An illustration.
https://egreenideas.com/green-ideas-daylight-modeling-services/

Daylighting\
City design & daylight optimization

Urban, city, etc.

High density, population

Design approach that based on Daylight efficiency

Goharian *et al.*'s study (2023) highlights:

Urban growth challenge: Rising urban populations drive the demand for housing. Vertical development emerges as a solution due to constraints on horizontal city expansion and increased complexity.

Impact of high city density: Dense urban areas with complex structures lead to reduced natural ventilation and insufficient interior lighting, potentially compromising indoor quality.

***Solution*: Daylight lighting efficiency design approach**: Goharian *et al.* propose a design approach to improve lighting efficiency, combining manual methods with the NSGA-II optimization algorithm.

Goharian, A., Daneshjoo, K., Shaeri, J., Mahdavinejad, M., & Yeganeh, M. (2023). A designerly approach to daylight efficiency of central light-well; combining manual with NSGA-II algorithm optimization. Energy, In Press. https://doi.org/10.1016/j.energy.2023.127402

Daylighting\
Daylight & parametric massing

Daylight modeling +
parametric massing algorithm

Enhances exploration in
building mass design

Focuses on improving energy
performance in buildings

Likai Wang *et al.*'s research (2019) highlights:

Daylighting indicates that the algorithm developed in such a way can enhance the exploration of potential in building massing design, specifically for improving energy performance in buildings.

Wang, L., Janssen, P., Chen, K. W., Tong, Z., & Ji, G. (2019). Subtractive Building Massing for Performance-Based Architectural Design Exploration: A Case Study of Daylighting Optimization. Sustainability, 11(24), 6965. https://doi.org/10.3390/su11246965

Daylighting\
Simulation in architecture

Wortmann's research (2017) highlights:

Role of simulation in architectural design: Structural, building energy, and lighting simulations play a key role in the architectural design process, enabling quantitative evaluation of design variations.

Parametric modeling for rapid generation: Parametric modeling facilitates rapid and automated design generation based on numerical parameters.

Integration for optimization: When designers combine parametric models with performance simulations, optimization algorithms can identify *well-performing* design variations.

Applications in leading practices: Simulation-based optimization is increasingly used in leading architectural and engineering practices, including SOM and ARUP. For example, this method is applied in the design of the Louvre Abu Dhabi.

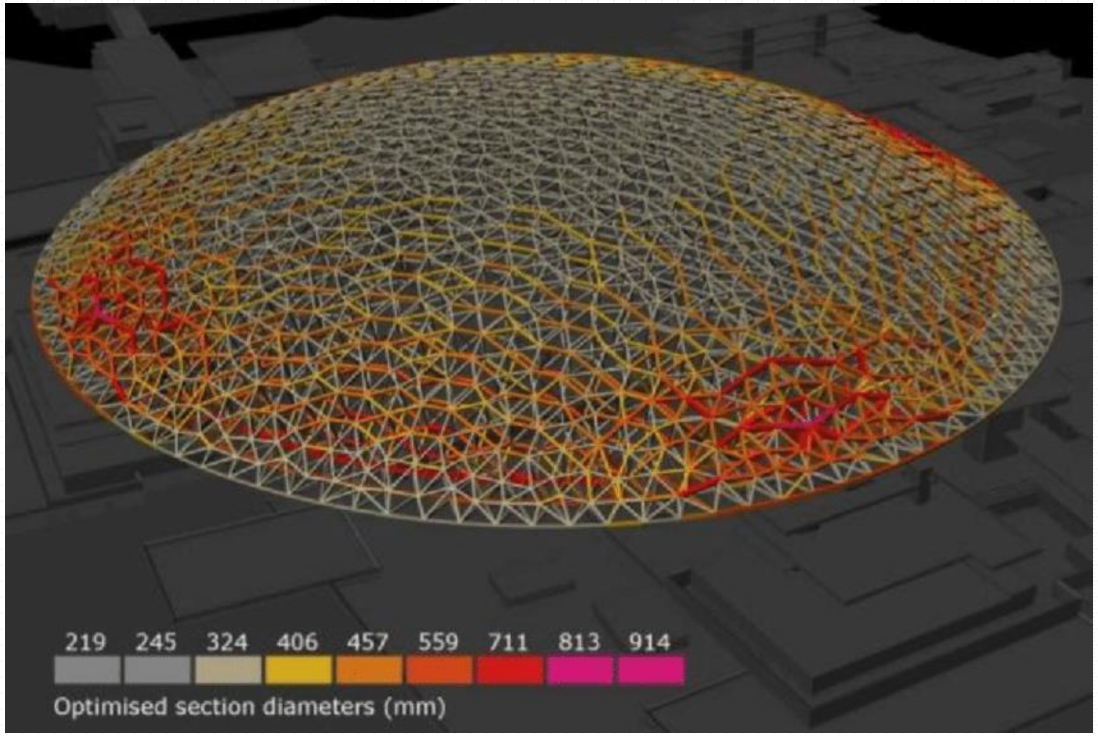

Fig. Louvre Abu Dhabi (geometry, structural optimization)

Wortmann, T. (2017). Model-based Optimization for Architectural Design: Optimizing Daylight and Glare in Grasshopper. Journal of Building Performance Optimization. https://doi.org/10.1080/24751448.2017.1354615

Daylighting\ Simulation in architecture

Kharvari's research (2020) highlights:

Setting	Calculation time	Results
Minimum	7 ms	Available
Fast	17 ms	Available
Accurate	789 ms	Available
Maximum I	2.7 min	Available
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Maximum III	Aborted	Aborted
Maximum IIII	6.4 s	Available
Maximum -ab 10 I	2.8 min	Available
Maximum -ab 10 II	14.5 min	Available
Maximum -ab 10 III	Aborted	Aborted
Maximum -ab 10 IIII	7.6 s	Available

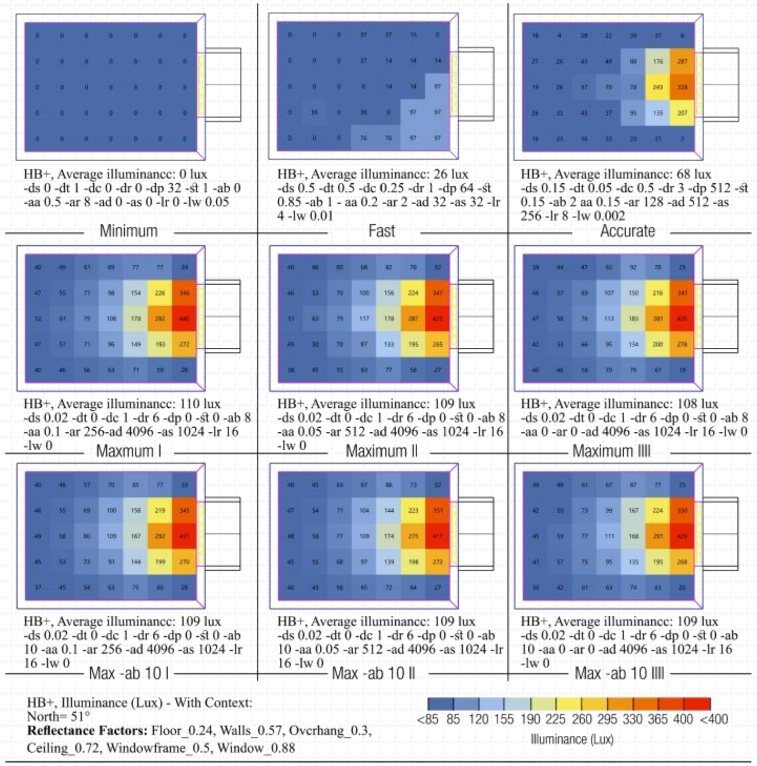


Fig. Simulation results on the analysis grid based on different Radiance parameters.

Kharvari, F. (2020). An empirical validation of daylighting tools: Assessing radiance parameters and simulation settings in Ladybug and Honeybee against field measurements. Solar Energy, 207, 1021-1036. https://doi.org/10.1016/j.solener.2020.07.054

Daylighting\
Natural daylighting importance

Visitor comfort in large buildings (visual):

Good natural lighting is crucial for helping visitors feel comfortable and less tired as they navigate through well-lit spaces, preventing the feeling of being lost in a maze of rooms.

Light and shadow (sunlight):

Sunlight enhances important architectural shapes, creating a calm shine on surfaces and improving the overall atmosphere of the space.

Fig. "The Optical Window" and shadow.
Paryna *et al.* (2020), https://www.architonic.com/en/story/vibia-building-with-light/7000714

Kim, C.S., & Chung, S.J. (2010). Daylighting simulation as an architectural design process in museums installed with toplights. Journal of Building Environment. https://doi.org/10.1016/j.buildenv.2010.07.015

Daylighting\
Lighting simulation in architecture

More than just saving energy

- Using natural light is crucial in architecture, not only for saving energy but also as an eco-friendly approach.
- Architects can maximize the advantages of natural light by using advanced technologies in their lighting plans.

Accurate predictions

- Predicting indoor lighting has become highly precise through lighting simulations, especially in places like “museums” under various sky conditions.
- Architects and lighting engineers can simulate intricate lighting setups during the early stages of architectural design.

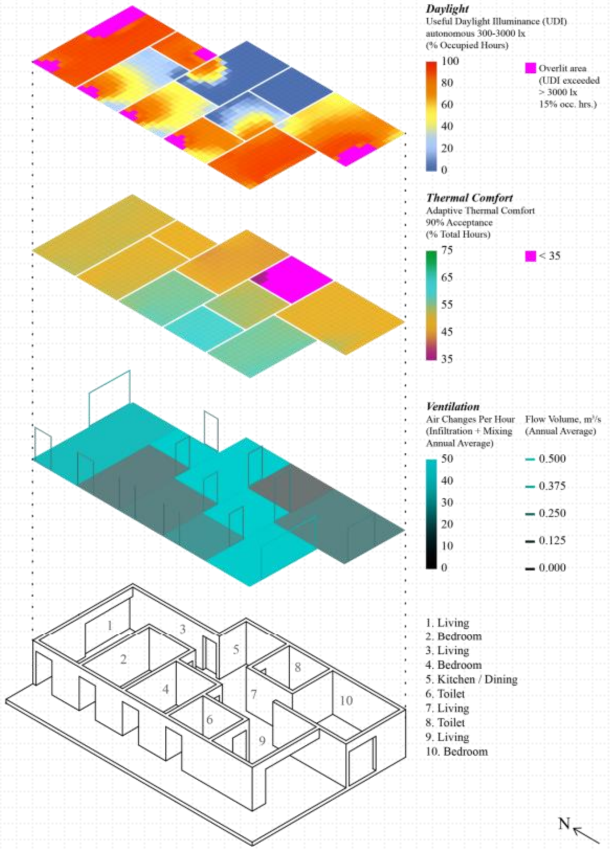


Fig. Spatial ventilation, thermal comfort, and daylighting results based on annual thermal, MRT and daylight performance simulations.
Alstan et al. (2017), https://doi.org/10.26868/25222708.2017.687

Kim, C.S., & Chung, S.J. (2010). Daylighting simulation as an architectural design process in museums installed with toplights. Journal of Building Environment. https://doi.org/10.1016/j.buildenv.2010.07.015

Daylighting\
Daylighting in green buildings

Significant for well-being

- Sunlight directly affects how we feel, and this is acknowledged in green building standards like LEED®.

Assessment and progress

- Older methods use average daylight factor (DF) calculations.
- Modern technology enables thorough daylight design by combining natural and artificial lighting considerations, including the impact on temperature.

Daylight Factor (DF), %

- An important measure showing how much daylight is available.
- Chris Croly and Martin Lupton defined it as "*the ratio of how bright it is inside compared to the brightness on a flat surface outside, facing the open sky.*"

Kubba, S. (2012). Daylighting in "Handbook of Green Building Design and Construction," Chapter 7 – Indoor Environmental Quality. https://doi.org/10.1016/B978-0-12-385128-4.00007-X

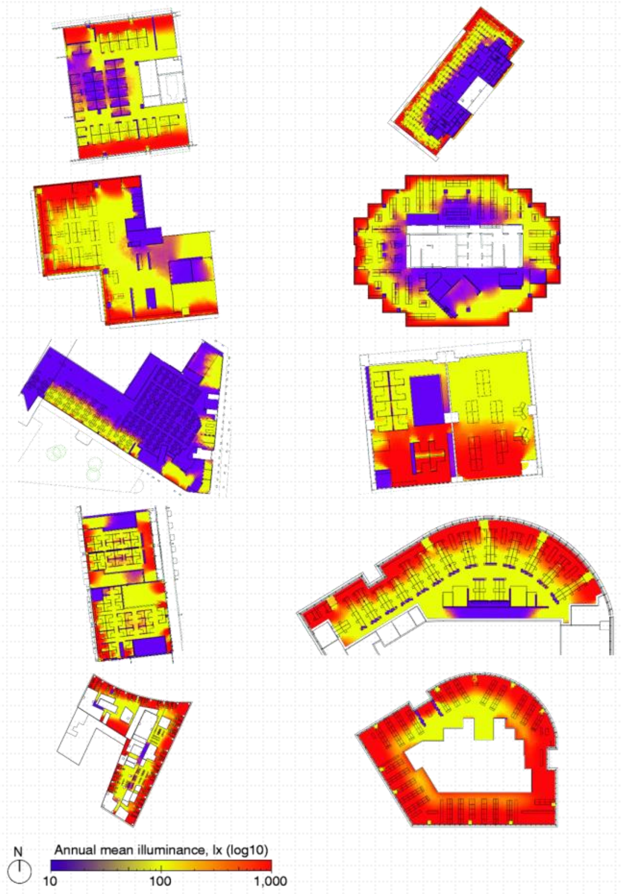


Fig. Simulated annual mean illuminance of the 10 studied buildings without shades. Jakubiec et al (2021) https://doi.org/10.1177/1477153520926528

Daylighting\
Efficient daylighting: Benefits

1. **Energy savings**: Efficient daylighting (ED) reduces energy use.
2. **Visual enhancement**: Daylighting enriches the environment and boosts occupant satisfaction.
3. **Cost efficiency**: Lower expenses result from effective daylighting.
4. **Architectural techniques**: Leading firms HOK, Gensler use features like light shelves, louvers, glazing, skylights, and light tubes.
5. **Integrated design**: Success ED involves considering architectural, mechanical, electrical, and lighting aspects from the start (beginning).
6. **Advanced systems**: Modern daylighting improves indoor lighting, enhances energy efficiency, and reduces electricity usage.

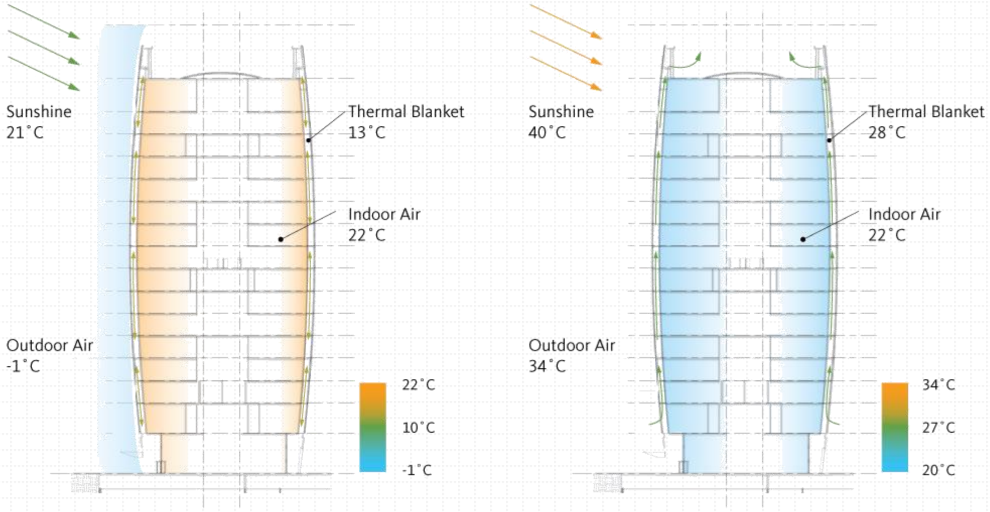


Fig. Harbin's Transparent Thermal Walls by Gensler.
https://www.gensler.com/dialogue/34/climate-change-solutions-for-workplace-design

Kubba, S. (2012). Daylighting in "Handbook of Green Building Design and Construction," Chapter 7 – Indoor Environmental Quality. https://doi.org/10.1016/B978-0-12-385128-4.00007-X

Daylighting\
Effective daylighting strategies

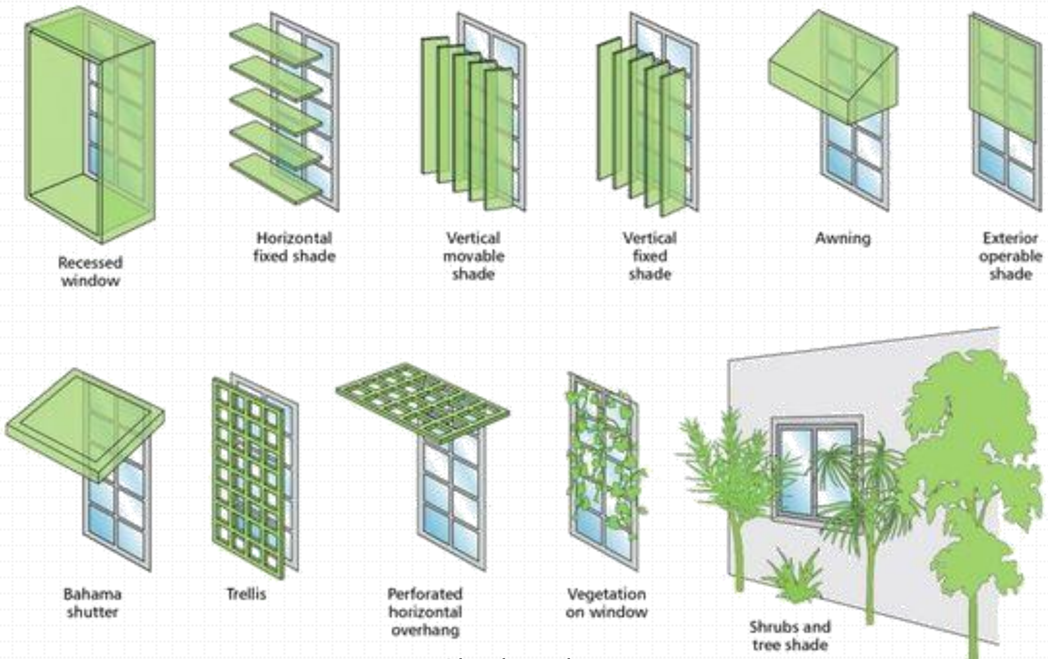
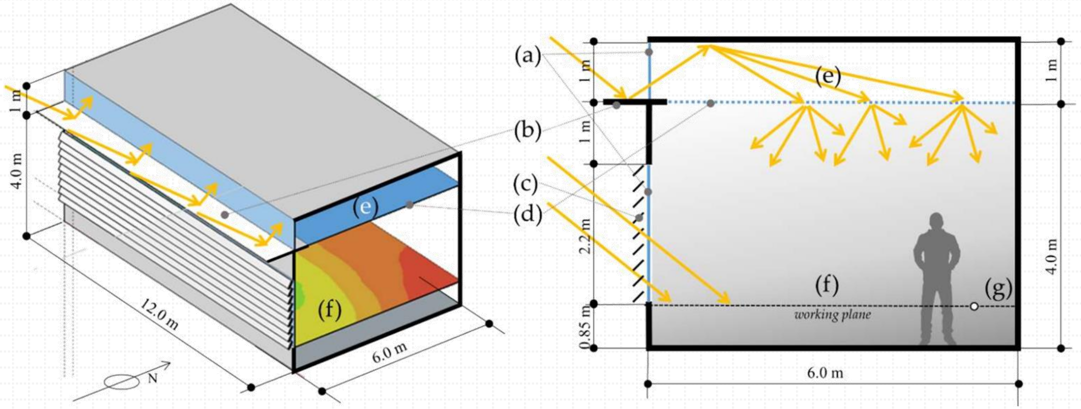


Fig. Shading devices
https://teraoasia.com/2023/10/19/expertise-optimizing-natural-daylighting-while-minimizing-heat-gains-and-glare/



Description: (a) transparent glass: clerestory window and regular window in the façade; (b) light shelf; (c) horizontal louvres; (d) translucent ceiling; (e) daylight distribution plenum; (f) evaluated working plane (g) illuminance sensor.

Fig. Right side - drawing of the space above the ceiling (plenum).
Left side - drawing showing see-through (pale blue) and semi-transparent (blue, dotted lines) surfaces.
Brzezicki, M (2021) https://doi.org/10.3390/buildings11110494

Daylighting\
Effective daylighting strategies

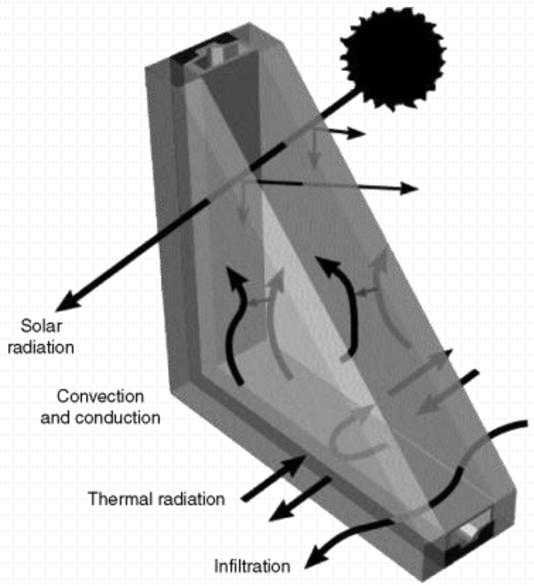


Fig. The described energy dynamics through windows are often referred to in architecture as "**fenestration**," encompassing non-solar heat transfer (conduction, convection, and radiation), solar heat gain, and intentional or unintentional airflow (ventilation and infiltration). Source: DOE.

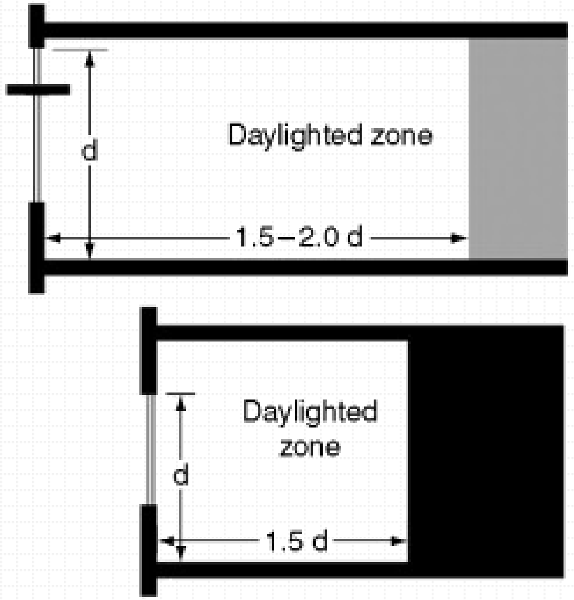


Fig. For standard windows, **a rule of thumb** is to aim for daylight penetration at 1.5 times the head height, while for south-facing windows in direct sunlight, this can extend to 1.5 to 2.0 times head height with a light-shelf. Source: Ernest Orlando, Lawrence Berkeley National Laboratory.

Kubba, S. (2012). Daylighting in "Handbook of Green Building Design and Construction," Chapter 7 – Indoor Environmental Quality.
https://doi.org/10.1016/B978-0-12-385128-4.00007-X

Daylighting\
Architecture + daylight = art + science

Definition: Combining architecture and daylight (natural light) == blending science and art.

Objectives: Cut down on artificial lighting, lower carbon emissions, and improve occupant well-being.

Integration: Use 3D simulation software and scientific principles to understand natural lighting patterns and simplify the design process.

Importance: Essential for accurately predicting, designing, and planning the impact of natural lighting in architectural spaces, preventing misunderstandings in the design process.

https://www.kalwall.com/daylight-modeling/ ,
https://egreenideas.com/green-ideas-daylight-modeling-services/

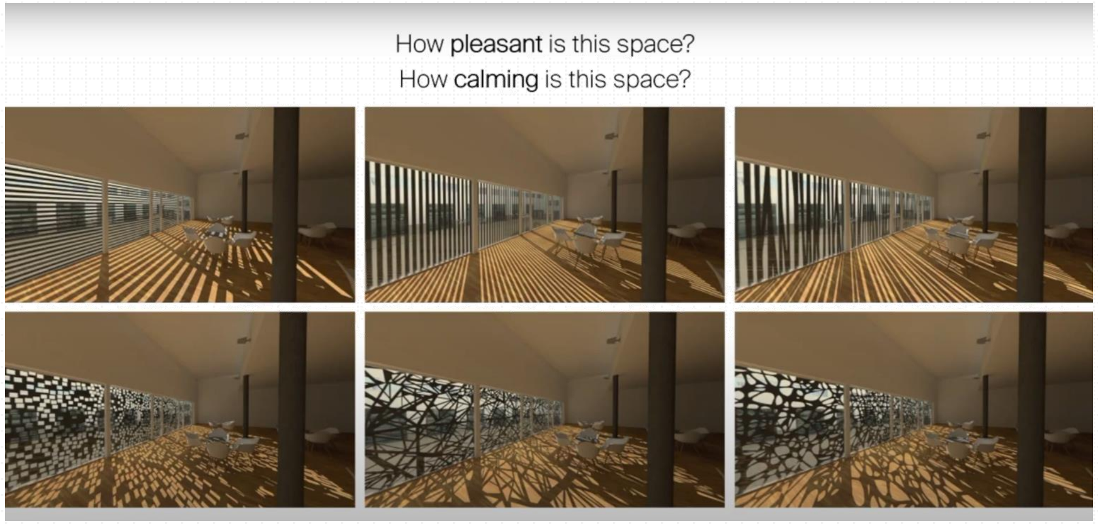


Fig. Daylight as a qualitative aspect and driving element in developing architecture. Behnisch (2017), https://buildforlife.velux.com/en/knowledge/daylight-symposium/2017/daylight-as-a-qualitative-aspect-and-driving-element-in-developing-architecture-by-stefan-behnisch

Tools and Techniques

Tools and techniques\
DIALux

DIALux is a comprehensive planning tool that provides you with all the necessary functions for professional lighting design free of charge.

- With DIALux you can calculate and visualize lighting for indoor and outdoor areas.
- From entire buildings and individual rooms, to parking spaces and road lighting, with artificial lighting, daylight and emergency lighting.
- DIALux supports you in verifying regional or international standards and helps you to document this verification.

More info:

- Website: https://www.dialux.com/en-GB/
- Installation: https://www.dialux.com/en-GB/download
- FAQ: https://www.dialux.com/en-GB/frequently-asked-questions

As DIALux evo is a 3D CAD application, you benefit from a powerful multi-core CPU and graphics card and a sufficiently large main memory (RAM).

- The RAM should be at least 4 GB, we recommend 8 to 16 GB for the professional use.
- Your graphics card should support OpenGL 3.2 and a large memory is also useful here: at least 1 GB, 2 GB+ is recommended.
- Furthermore, your graphics card should have "own memory" and not use a "shared memory".
- In our experience, there are often problems with (new) drivers of Intel graphics cards so we recommend a graphics card from Nvidia or AMD.
- Please hold your drivers as up-to-date as possible. DIALux evo runs in 64-bit on Windows 10 and 11.

Tools and techniques\ DIALux

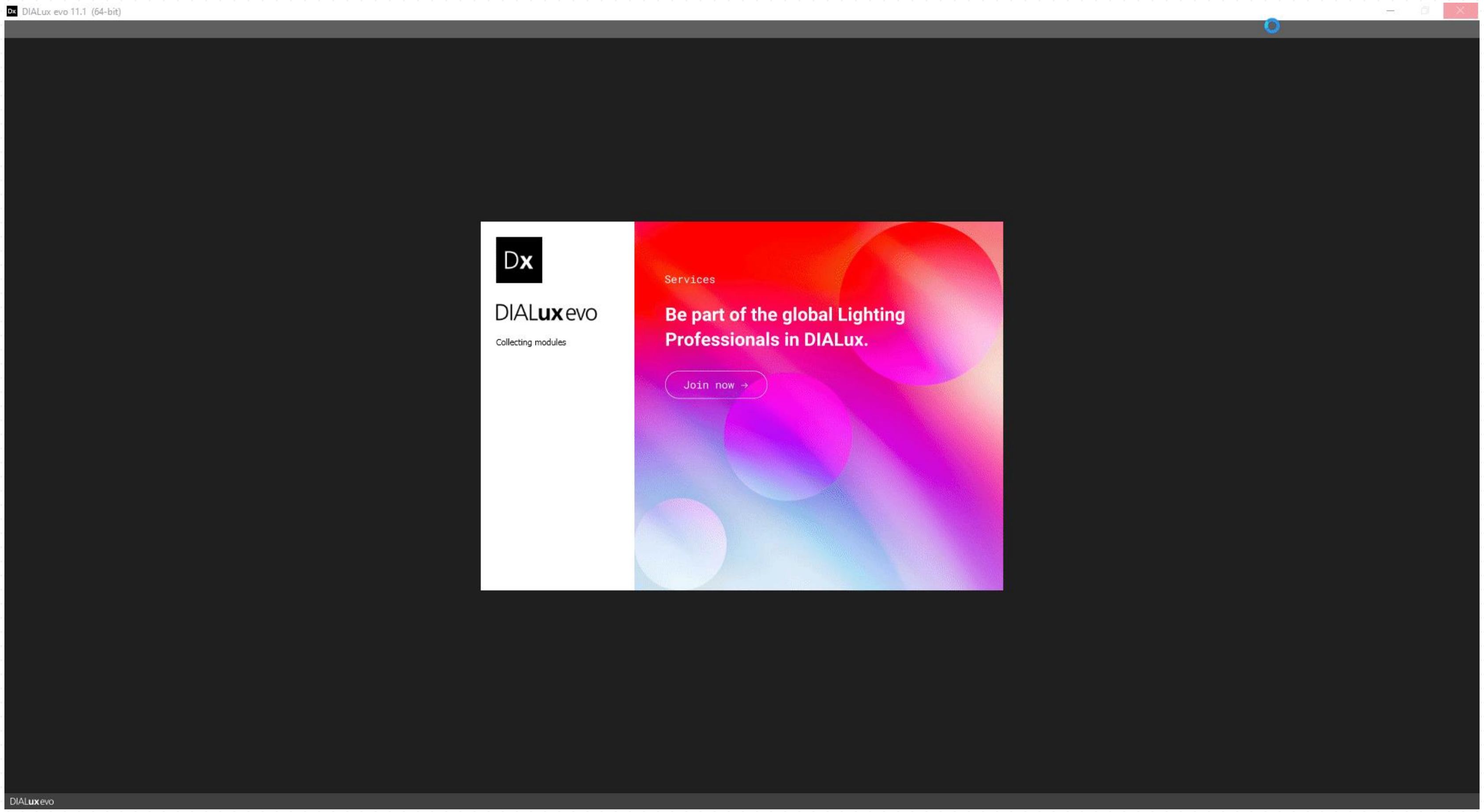


Fig. DIALux evo interface.
Ferels, A. (2023)

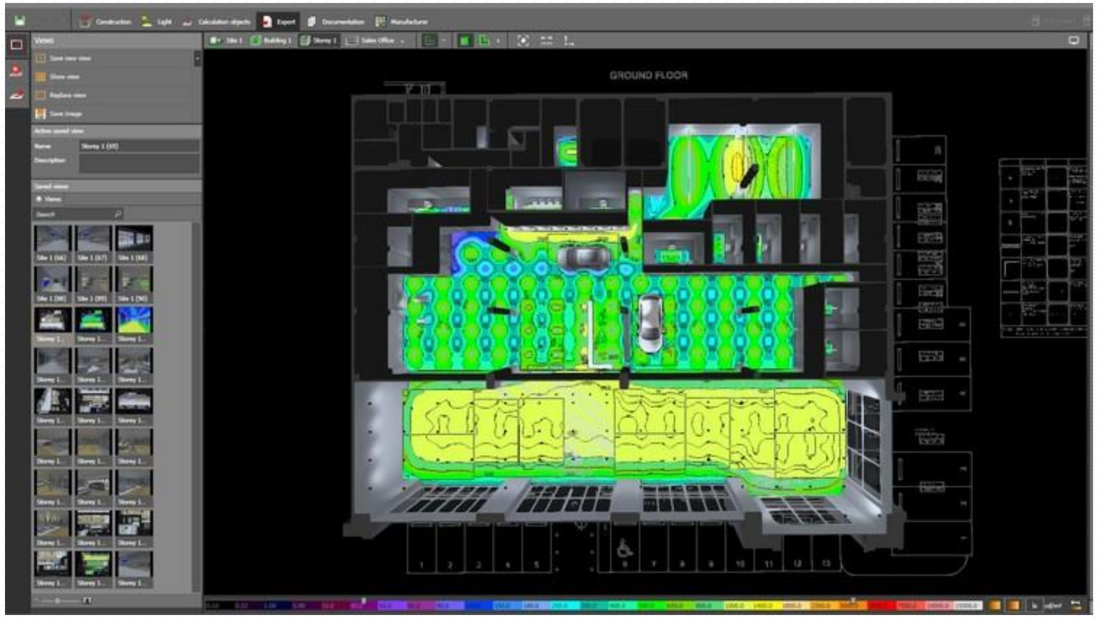
Tools and techniques\ DIALux

Well-being and motivation: Making sure there's plenty of natural light and good views outside is important for keeping people comfortable and motivated inside buildings.

DIALux and sky models: DIALux uses various sky models—cloudy, overcast, and clear skies—following CIE 110-1994 to calculate natural lighting.

Focused daylight calculation: Daylight calculations concentrate on the inside, highlighting important windows to bring sunlight into the building.

Exterior visual illumination: Outside the building, visual illumination is provided for visualization purposes, without specifically calculating exterior lighting levels.



https://evo.support-en.dial.de/support/solutions/articles/9000121044-daylight

Roco N (2023) DIALux evo for Beginners. https://www.udemy.com/course/dialux-evo-for-beginners/

Tools and techniques\
Ladybug Tools: Honeybee

Honeybee creates, runs, and visualizes daylight simulations using *Radiance* and energy models using *OpenStudio* and *EnergyPlus*.

- Honeybee supports detailed daylighting and thermodynamic modeling that tends to be most relevant during mid and later stages of design.
- It accomplishes this by linking the Grasshopper/Rhino CAD environment to these engines.

More info:

- Website: https://www.ladybug.tools/honeybee.html
- Publications: https://www.ladybug.tools/publication.html
- Download: https://www.food4rhino.com/en/app/ladybug-tools
- Forum: https://discourse.ladybug.tools/
- Installation: https://github.com/ladybug-tools/lbt-grasshopper/wiki
- Example files: https://github.com/ladybug-tools/lbt-grasshopper-samples/tree/master/samples/honeybee-radiance
- EPW file:
  1) https://www.ladybug.tools/epwmap/ ; 2) https://climate.onebuilding.org/

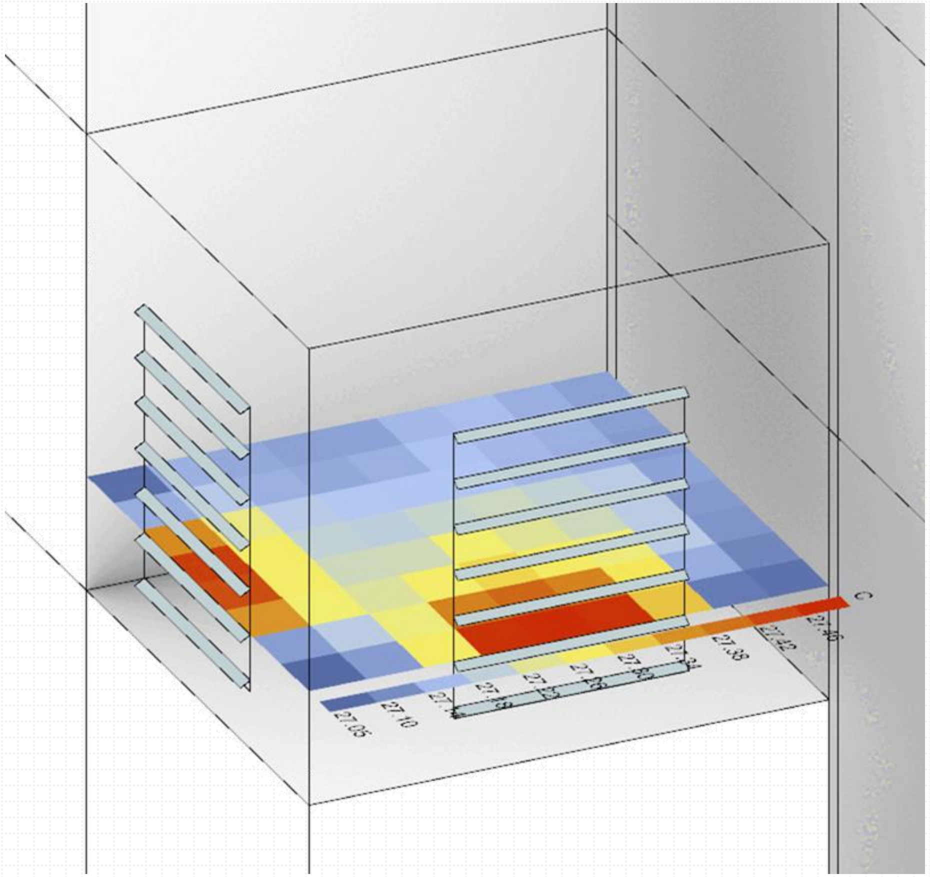
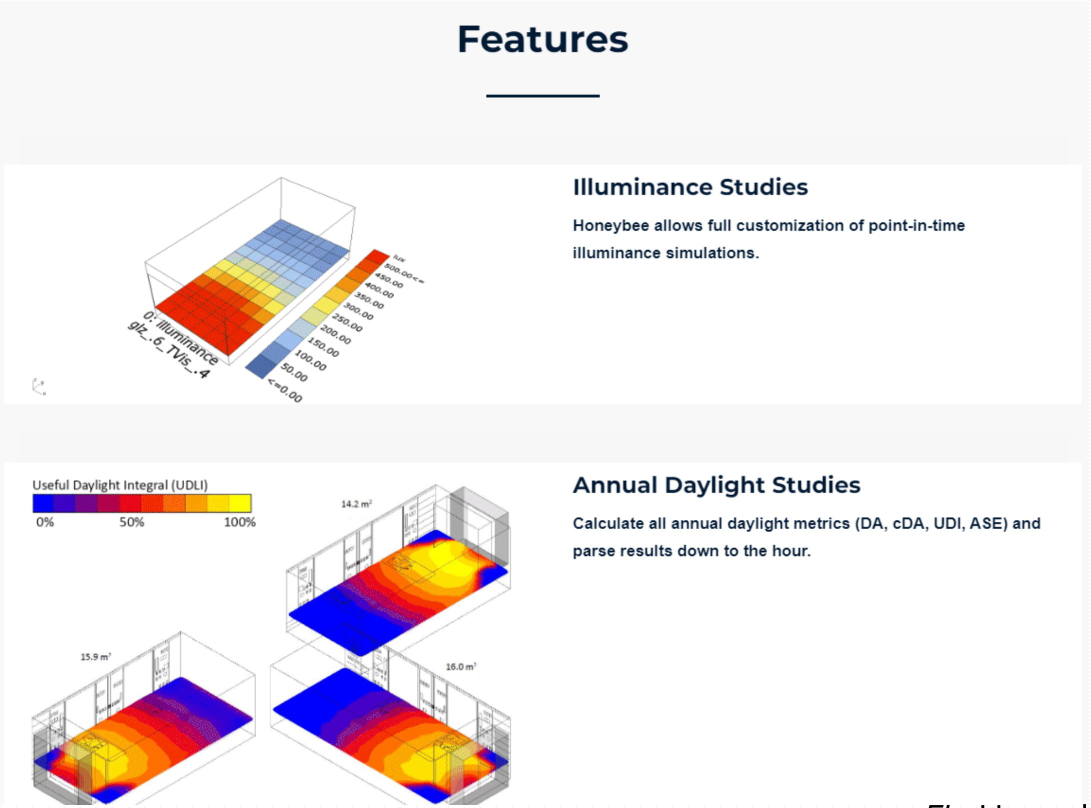


Fig. Energy simulation (with Honeybee-EP)
Ferels, A. (2021)

Tools and techniques\
Ladybug Tools: Honeybee



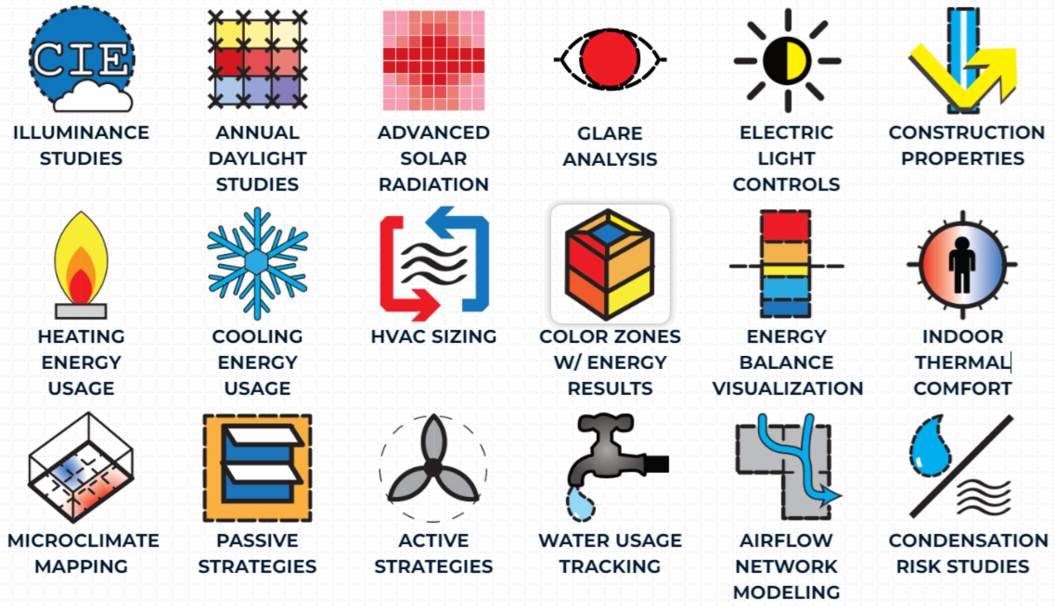


Fig. Honeybee features.
https://www.ladybug.tools/honeybee.html

Tools and techniques\
Ladybug Tools: Honeybee

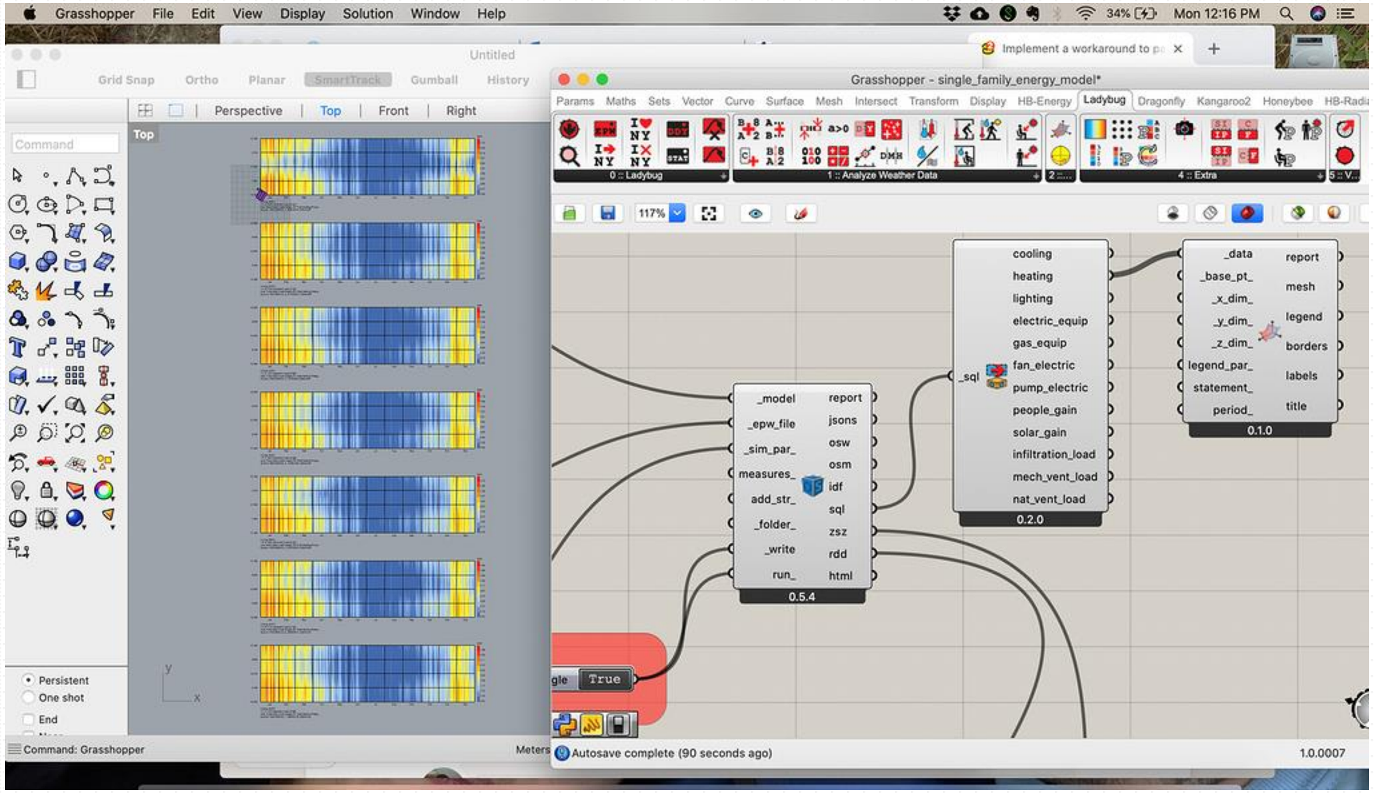


Fig. Rhino-Grashopper-Honeybee interface.
https://discourse.ladybug.tools/t/ladybug-tools-for-grasshopper-1-0-0-release/11241

Tools and techniques\
Ladybug Tools: Honeybee

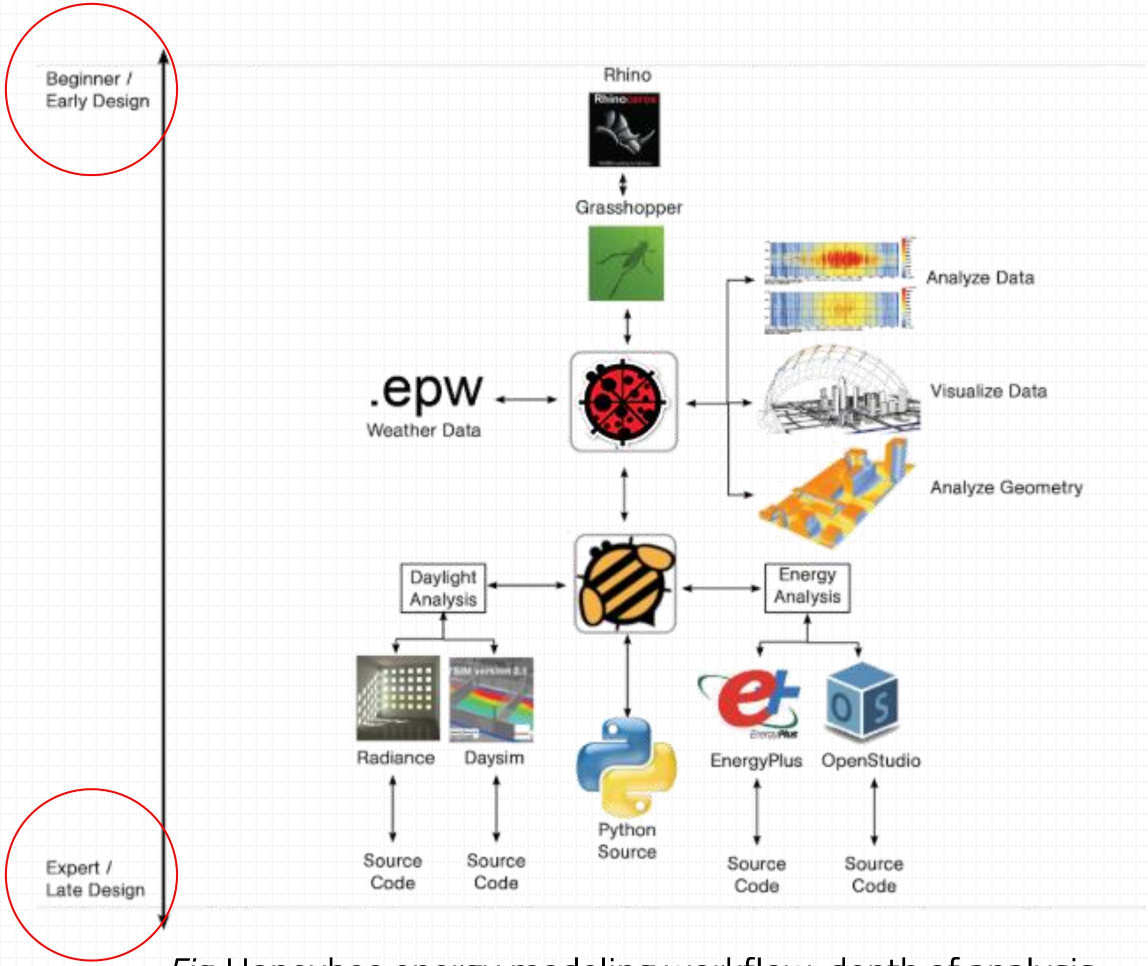


Fig. Honeybee energy modeling workflow: depth of analysis .
https://docs.ladybug.tools/honeybee-wiki/

Tools and techniques\
Ladybug Tools: Honeybee\Honeybee relation to other engines

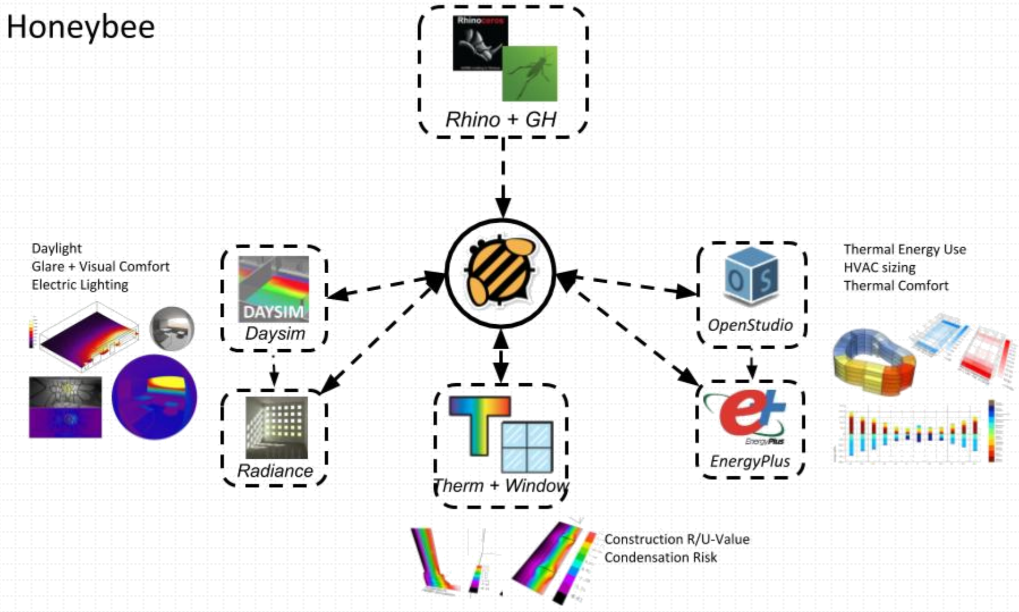


Fig. Honeybee relation to other engines
https://docs.ladybug.tools/honeybee-wiki/

It's important to make one distinction clear:

- Honeybee does not actually run simulations.
- Honeybee is an interface that creates instructions for other software programs ('*engines*') to run simulations.
- As of Nov 2018 Honeybee has interfaces to five analysis engines:
  1. **Radiance** for point-in-time lighting.
  2. **DAYSIM** (which uses Radiance) for lighting over time
  3. **EnergyPlus** for heat, electrical and fuel resource modeling.
  4. **OpenStudio** for integration of Radiance and EnergyPlus
  5. **THERM** for conduction through construction models and condensation risk.

Tools and techniques\
Ladybug Tools: Honeybee\Honeybee schema

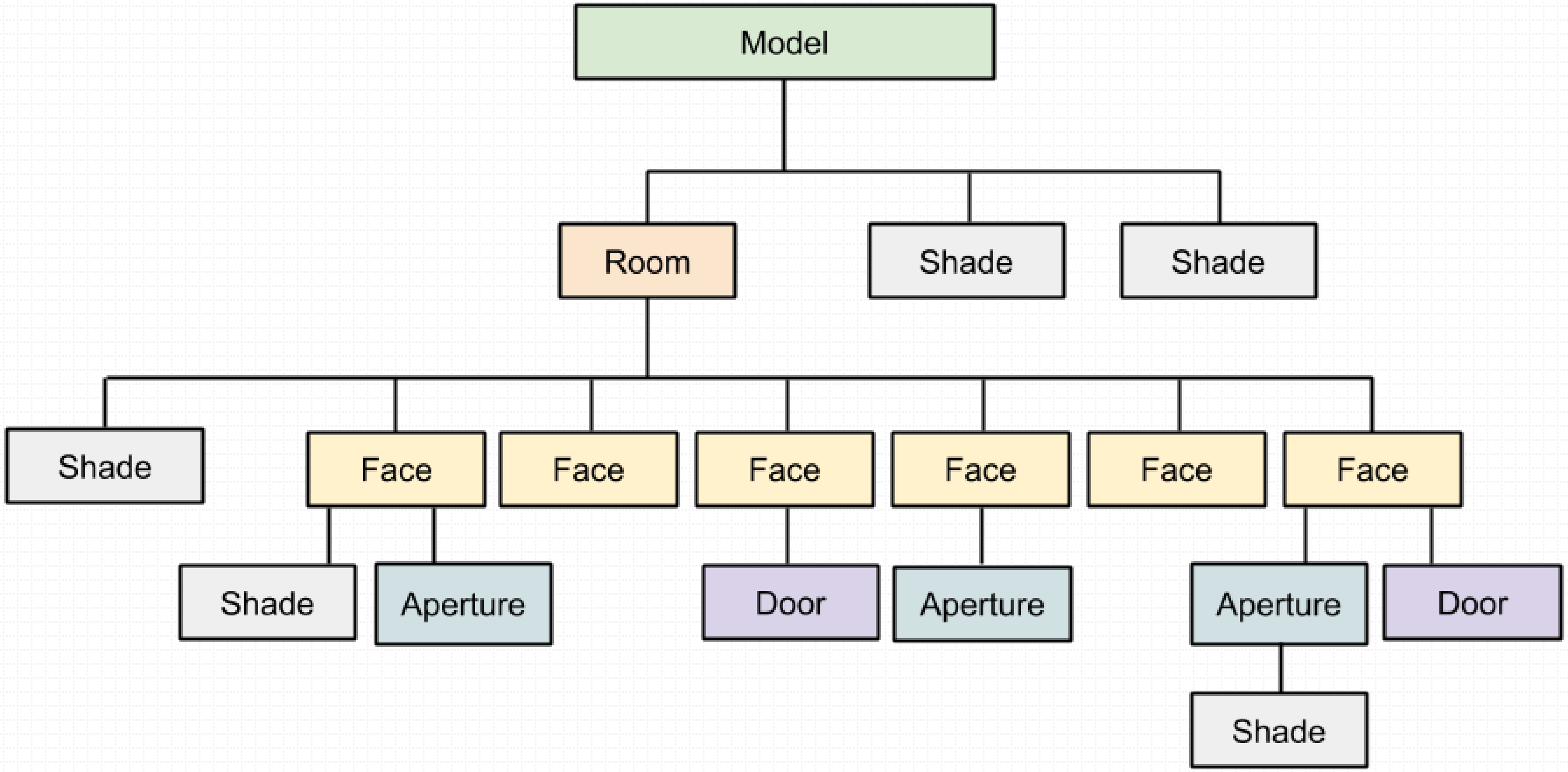


Fig. Honeybee energy modeling: Model schema.
https://github.com/ladybug-tools/honeybee-schema/wikioneybee-schema-documentation

Tools and techniques\
Ladybug Tools: Honeybee\Honeybee schema

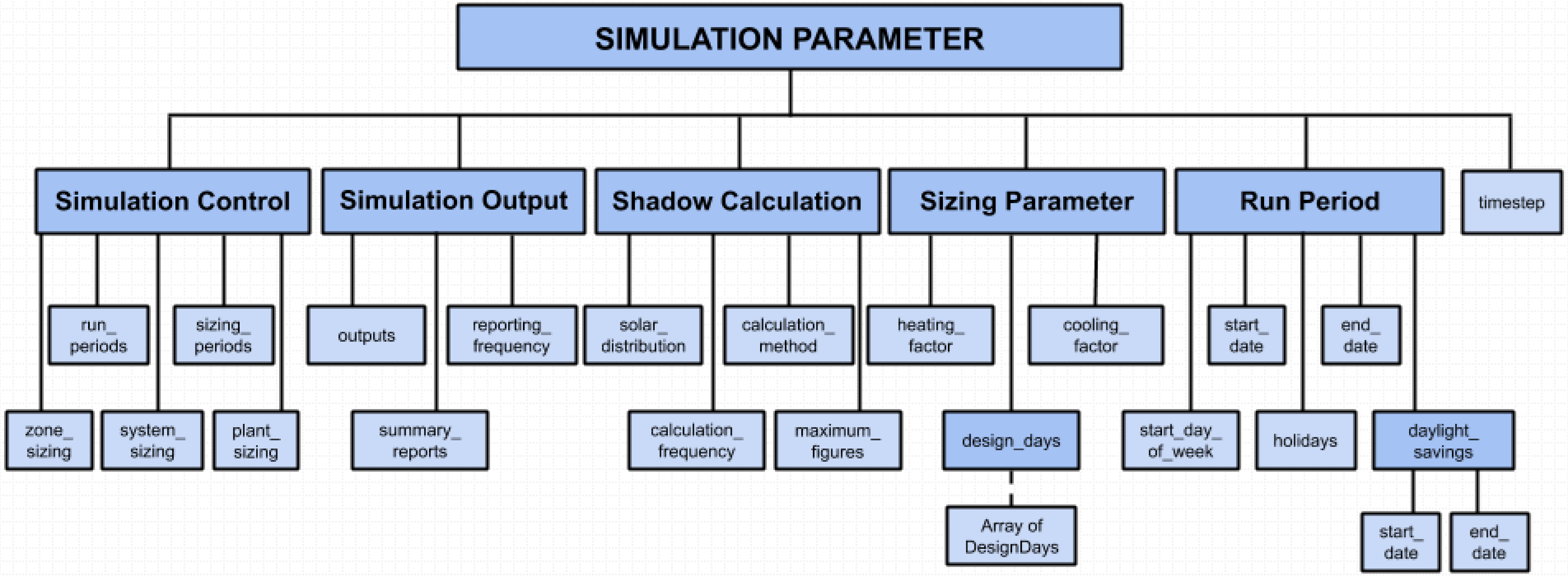


Fig. Honeybee energy modeling: SimulationParameter schema.
https://github.com/ladybug-tools/honeybee-schema/wikioneybee-schema-documentation

Tools and techniques\ Ladybug Tools: Honeybee\Case study: Daylight performance

Tilted windows outperform: Surprisingly, tilted windows perform better than roof-installed ones, offering natural and even light, especially in high sun altitudes.

Consistent results: Performance remains consistent in various sky conditions. Tilted windows consistently absorb more light, even in overcast conditions with uniform illumination.

Enhanced light penetration: Tilted windows contribute to increased light penetration depth, particularly when the sun is perpendicular to the inclined surface.

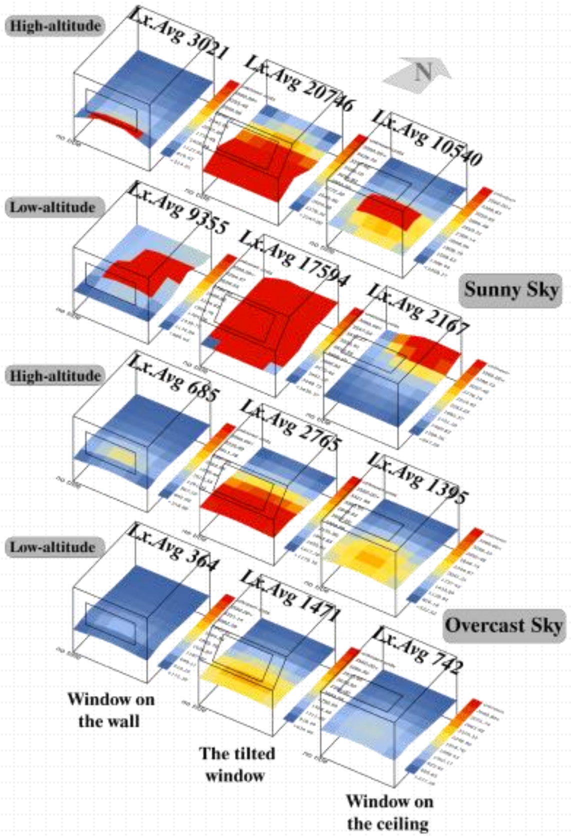


Fig. In both sunny and overcast skies, when the sun is high, the tilted window surprisingly outperforms the roof-installed window. This is likely because the tilted openings allow light to enter obliquely.

Goharian, A., Daneshjoo, K., Shaeri, J., Mahdavinejad, M., & Yeganeh, M. (2023). A designerly approach to daylight efficiency of central light-well; combining manual with NSGA-II algorithm optimization. Energy, 127402. https://doi.org/10.1016/j.energy.2023.127402

Tools and techniques\
Ladybug Tools: Honeybee\Case study: Daylight performance

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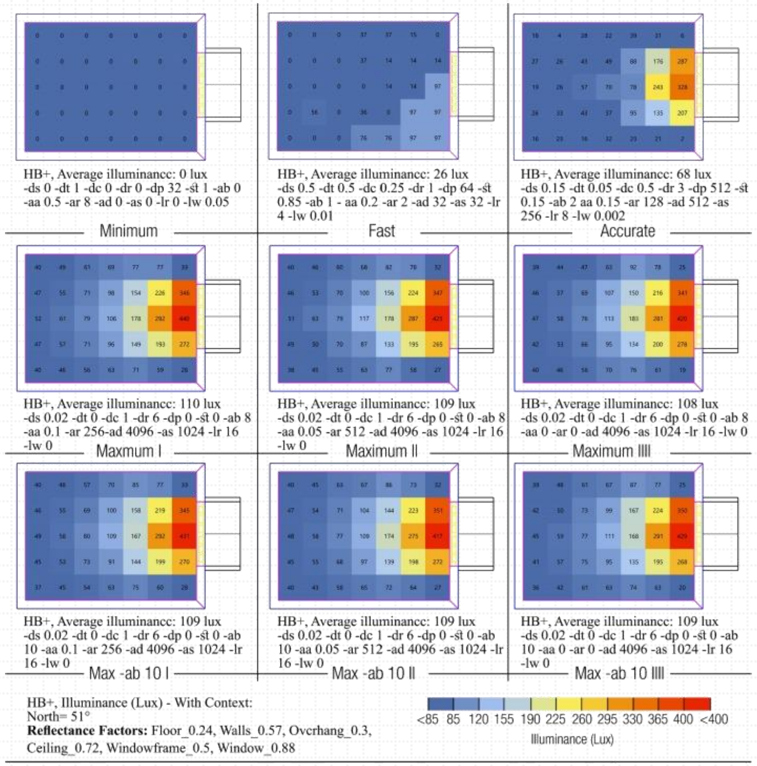

Fig. Simulation results on the analysis grid based on different Radiance parameters.

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Demo (1): DIALux

Demo (1): DIALux

- Overview, interface walkthrough, and operation (15’)
- Simulation process and interpretation of results (15’)

1. Download DIALux evo (latest version, 5.12.0.5586).
2. Download CAD (.dwg) file model and IES file.
   - Links & Installation guides: https://docs.google.com/document/d/11SgShxHkQ7yHc7BqLR3m-lsxgppjN_vp/edit
3. Open Program > DIALux Evo. (30’)

Demo (1): DIALux\ DIALux

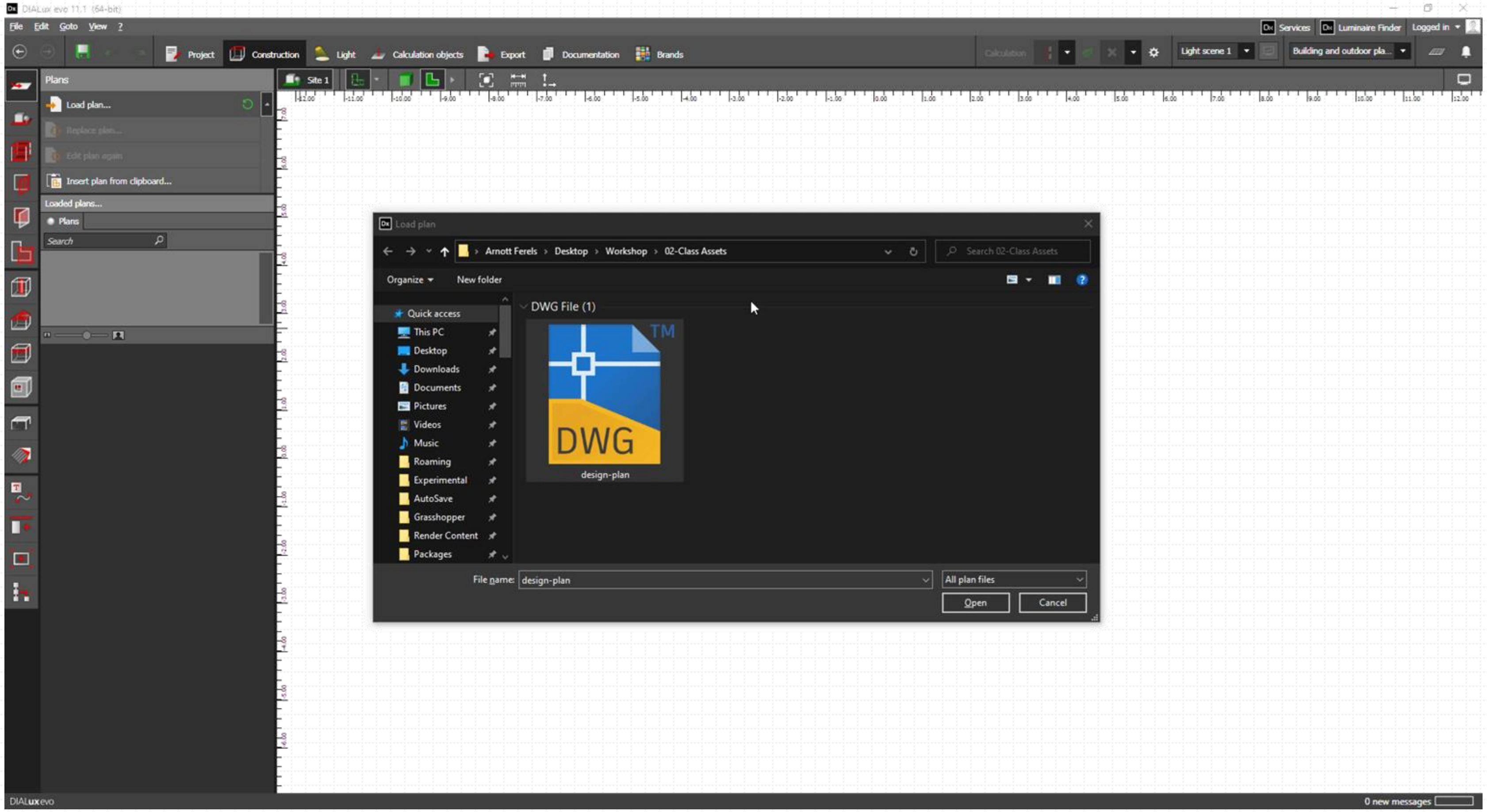

Fig. DIALux

File: https://drive.google.com/drive/folders/11EQ586_R2-iObMeFWxS18cYFFEcGKSdv

Demo (2): Honeybee

Demo (2): Honeybee

- Intro Rhino: NURBS modeling (5')
- Intro Grasshopper (GH): algorithmic modeling (10')
- Intro Ladybug Tools (LBT): environmental modeling (10')
- Intro Honeybee Radiance (HB-R): daylight modeling (20')
- Intro Dragonfly (DF): daylight modeling (15')
- Simulation process and interpretation of results (20')

1. Download Rhino, Grasshopper, Honeybee, RADIANCE, OpenStudio, etc.
2. Download Grasshopper definition (.gh) file model.
   - Links & Installation guides: https://docs.google.com/document/d/11SgShxHkQ7yHc7BqLR3m-lsxgppjN_vp/edit
3. Open Program > Rhino > _Grasshopper (80').

Demo (2): Honeybee\
Rhino + Grasshopper + Honeybee

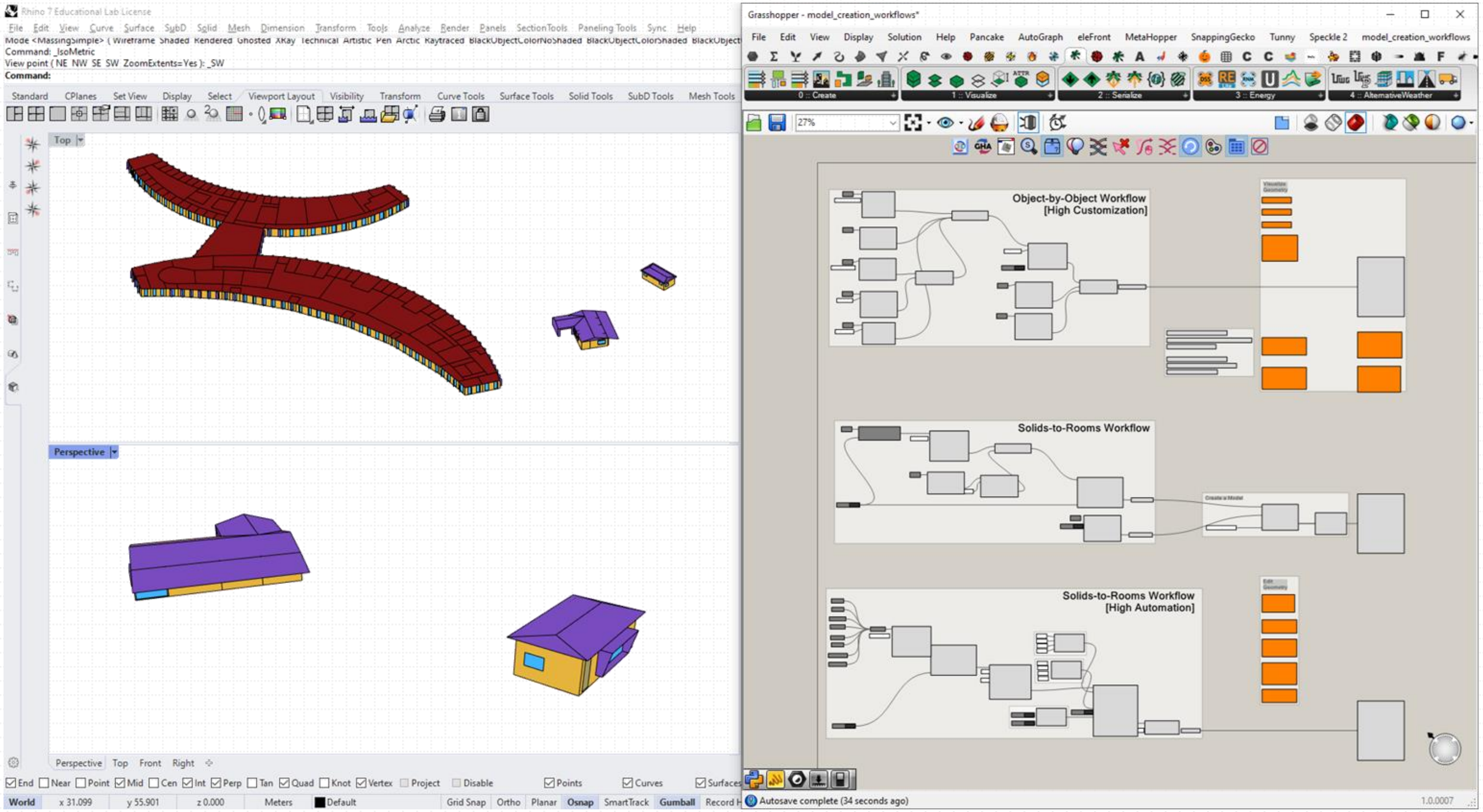

Fig. Modeling creation workflow (with HB).

File no.1: https://drive.google.com/drive/folders/11GoW9I32T6fUeDHj_0kCT5vGLe7Wl0M1

Demo (2): Honeybee\
Rhino + Grasshopper + Honeybee + HB-Radiance

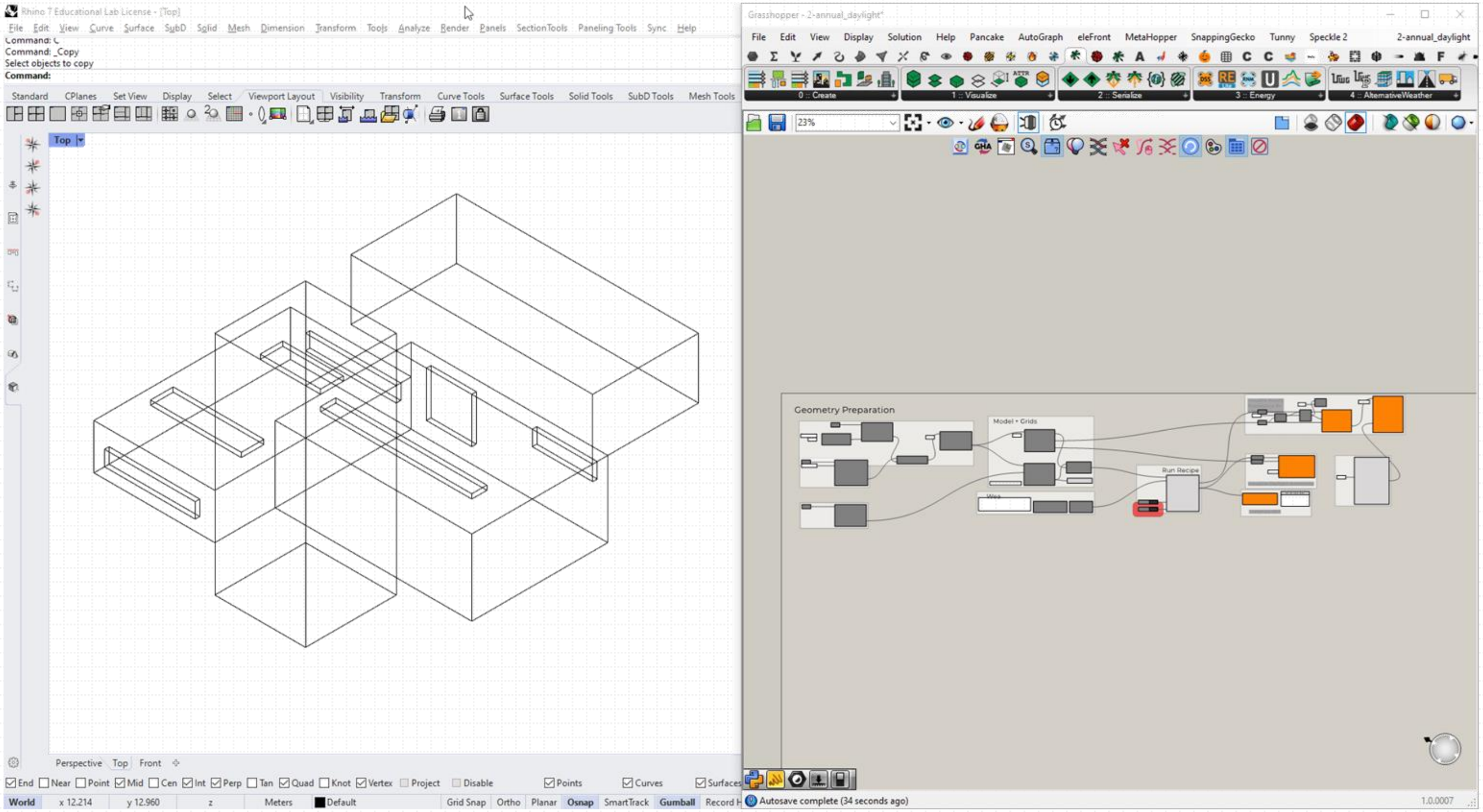

Fig. Annual daylight (with HB-Radiance).
File no.2: https://drive.google.com/drive/folders/11GoW9I32T6fUeDHj_0kCT5vGLe7WI0M1

Demo (2): Honeybee\
Rhino + Grasshopper + Honeybee + HB-Radiance

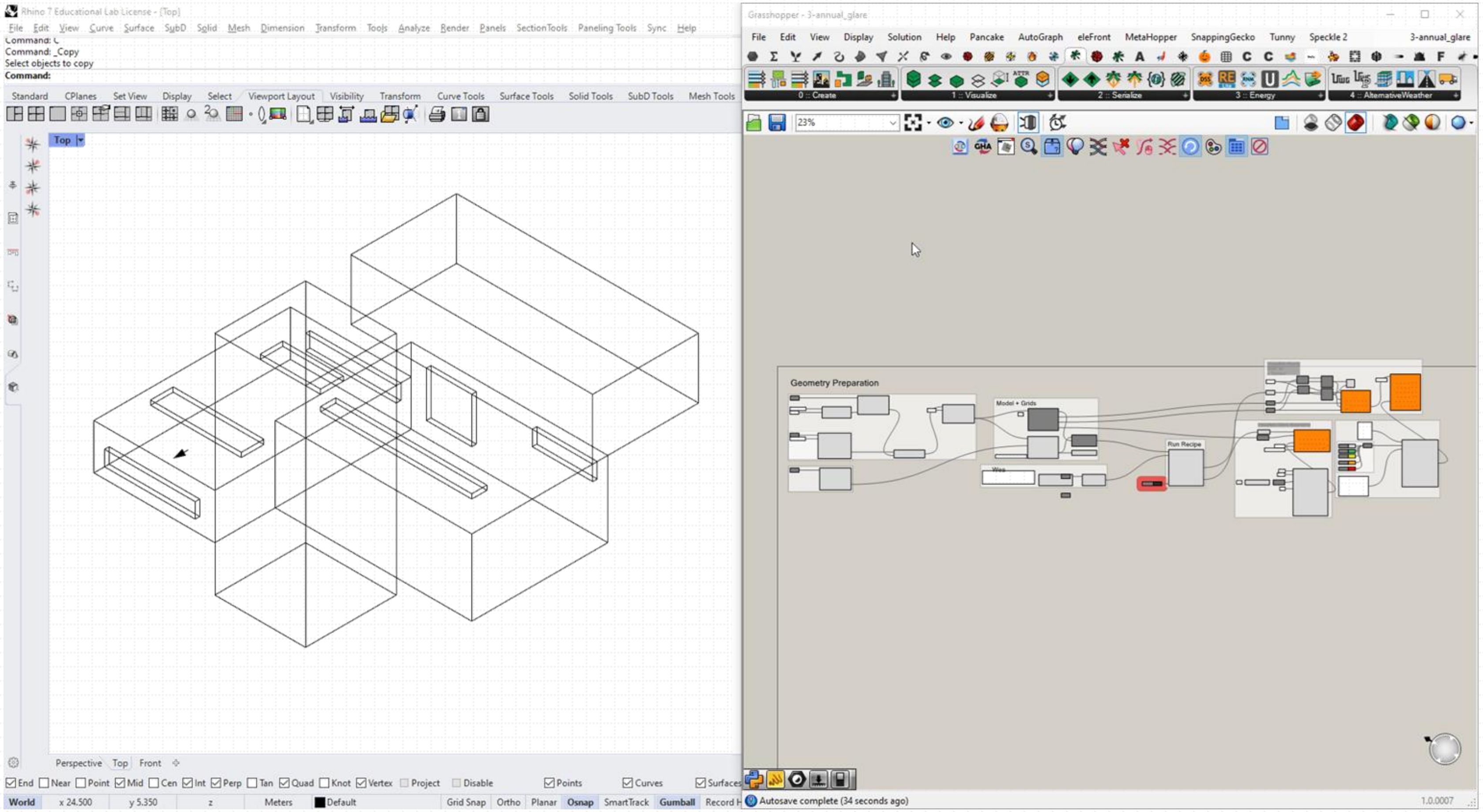

Fig. Annual glare (with HB-Radiance).

File no.3: https://drive.google.com/drive/folders/11GoW9I32T6fUeDHj_0kCT5vGLe7WI0M1

Demo (2): Honeybee\
Rhino + Grasshopper + Honeybee + HB-Radiance

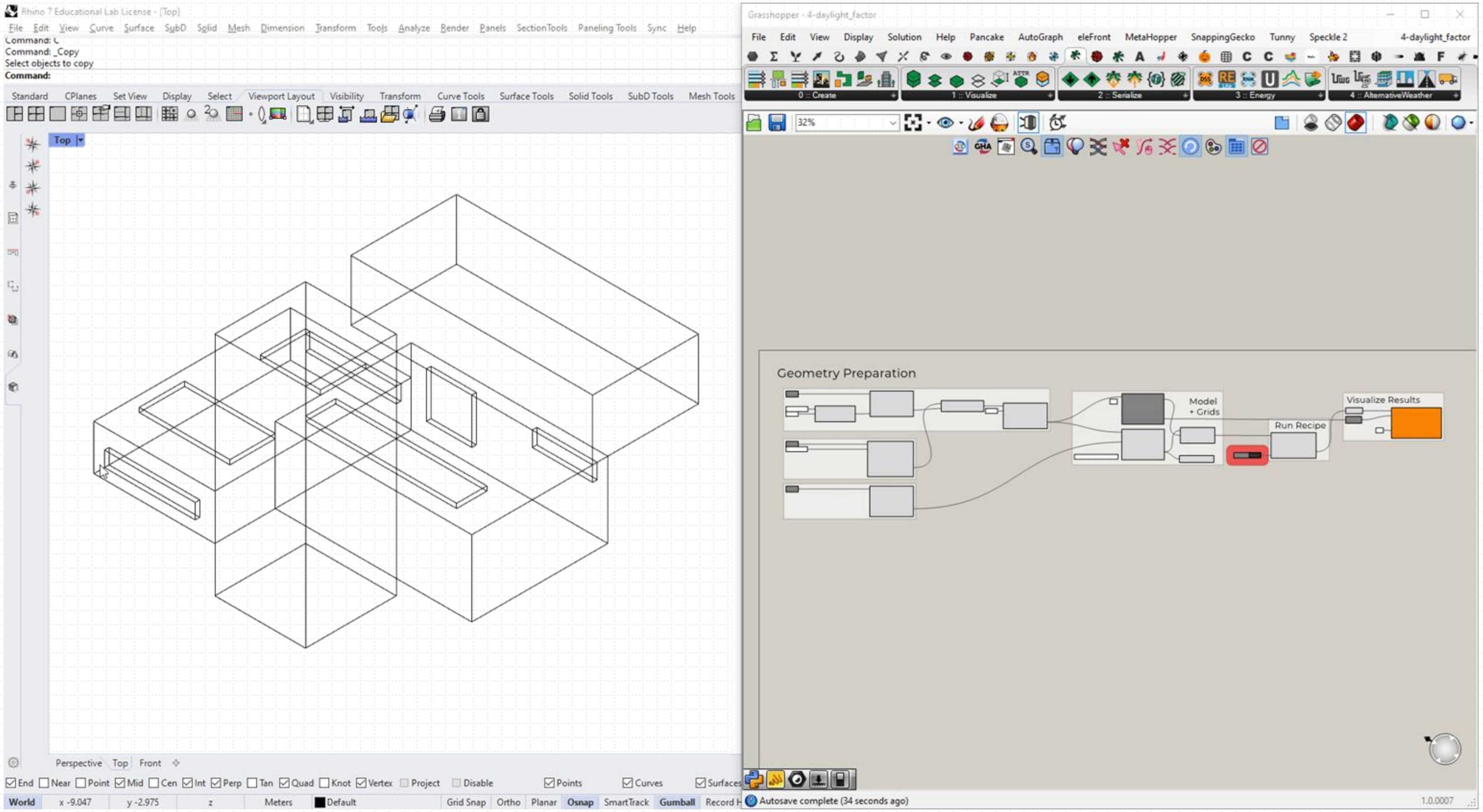

Fig. Daylight Factor (with HB-Radiance).

File no.4: https://drive.google.com/drive/folders/11GoW9I32T6fUeDHj_0kCT5vGLe7WI0M1

Demo (2): Honeybee\
Rhino + Grasshopper + Honeybee + HB-Radiance + Dragonfly

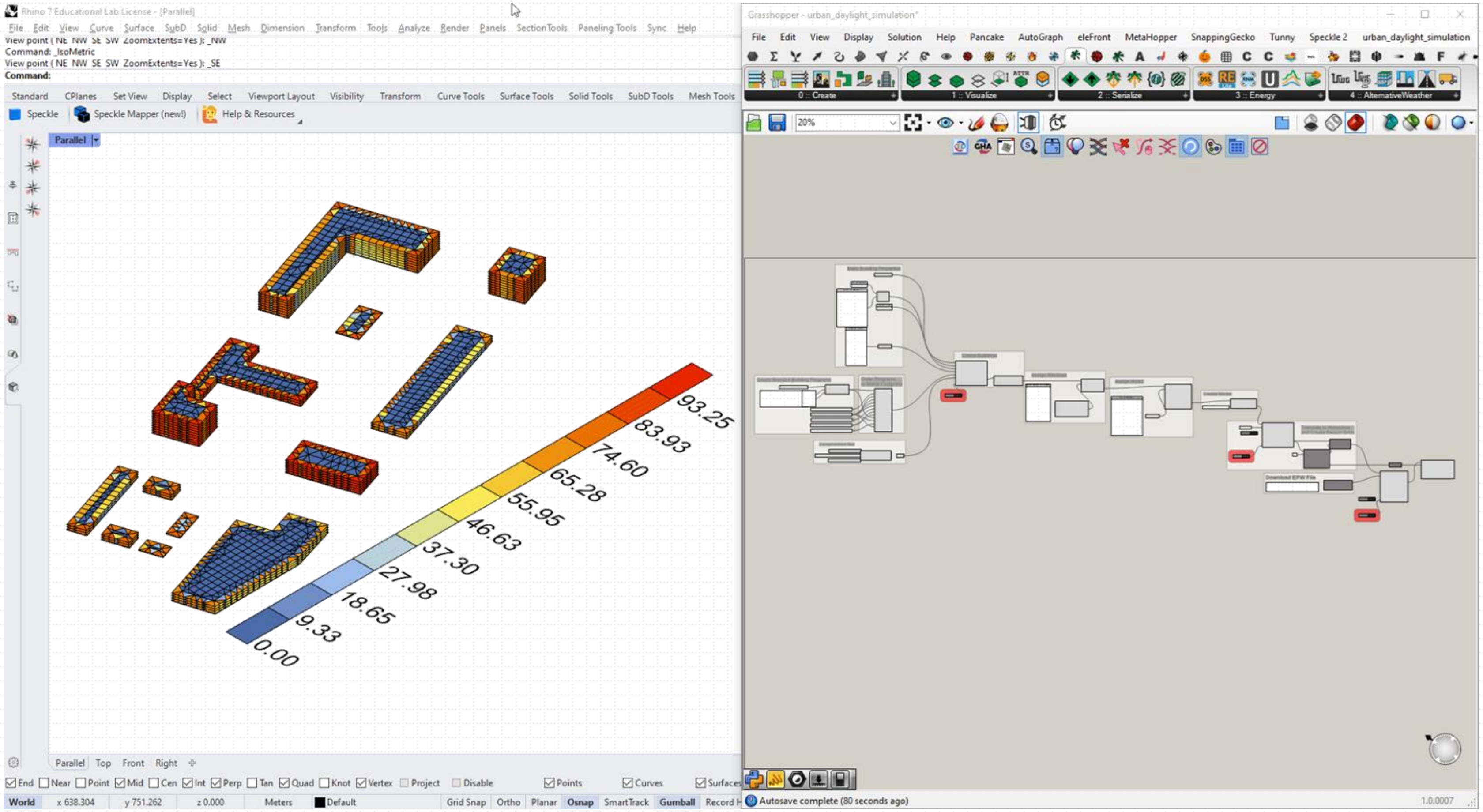

Fig. Urban daylight simulation (with HB-R + DF)

File no.5: https://drive.google.com/drive/folders/11GoW9I32T6fUeDHj_0kCT5vGLe7WI0M1

Recent works

Recent works\
Exploring brute force method for design optioneering in low-cost apartment

Desing explorer: https://tt-acm.github.io/DesignExplorer/?ID=BL_40xRpIT
More: https://www.behance.net/embed/project/142613267

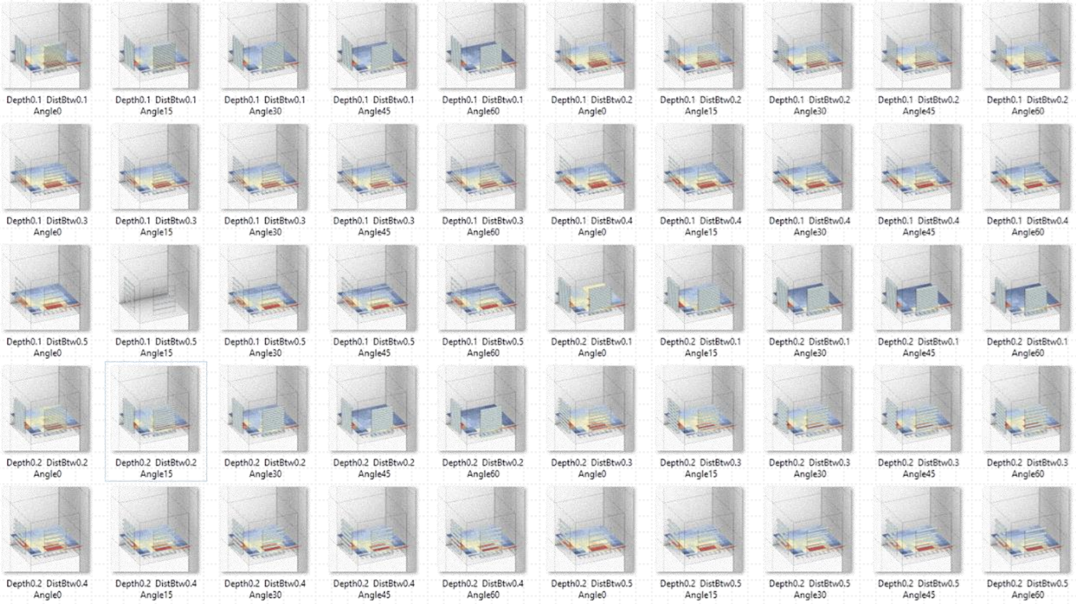

Fig. Brute force method.
https://sites.google.com/view/arnottferels/projects/environmental-analysis-for-low-cost-apartment

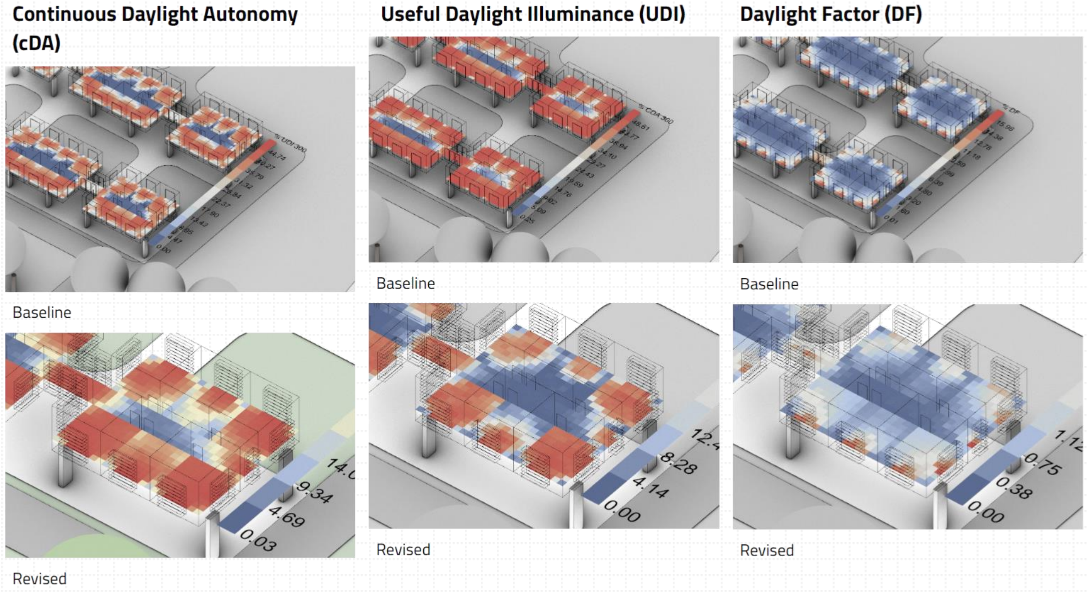

Fig. Baseline v. Revised (cDA, UDI, DF).
https://sites.google.com/view/arnottferels/projects/environmental-analysis-for-low-cost-apartment

Recent works\
Integrating energy modeling into algorithmic modeling

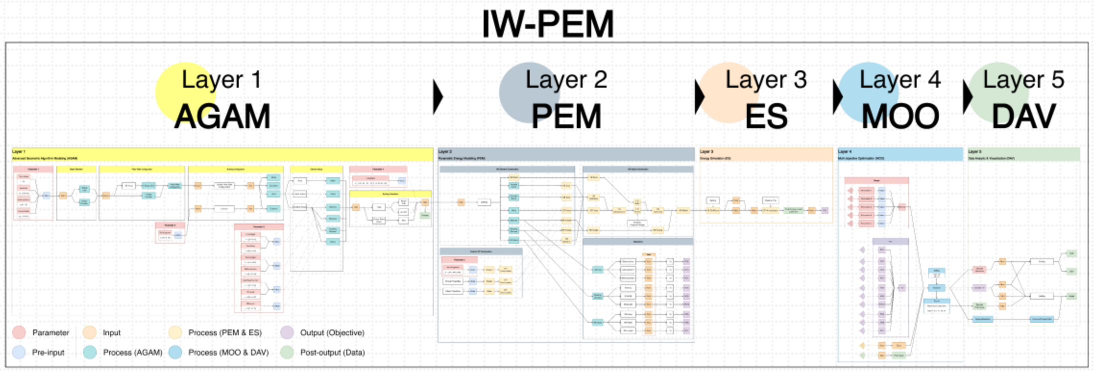

Fig. Integrated Workflow for Parametric Energy Modeling (IW-PEM)

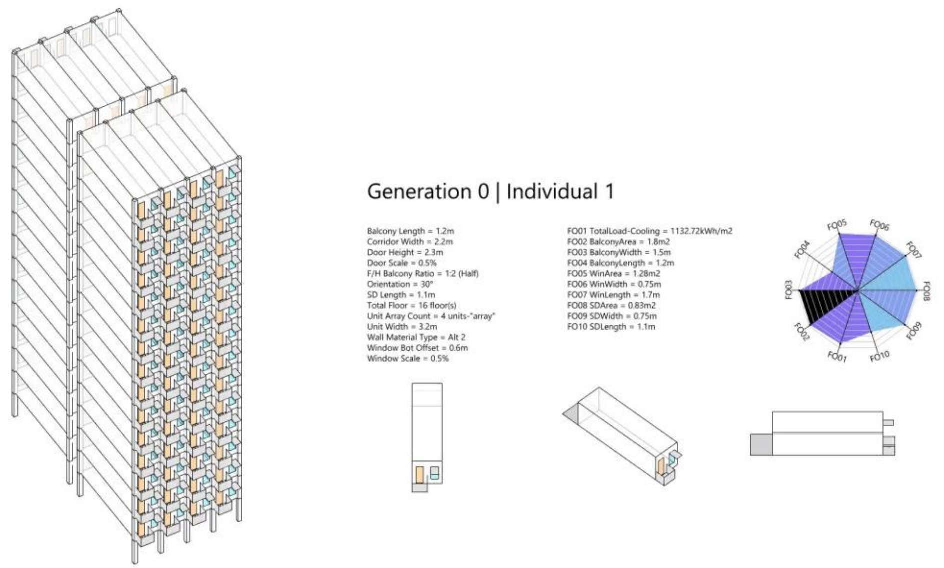

Fig. Multi-objective Optimization.

Extras

Extras\
DA, cDA, UDI, DF

- **Daylight Autonomy (DA)**: The primary metric in the annual daylight series, now acknowledged a "dynamic daylight metrics". It indicates the percentage of yearly daytime hours when a specific point in a space exceeds a user-defined illumination level.
- **Continuous Daylight Autonomy (cDA)**: An adaptation of Daylight Autonomy introduced by Zach Rogers in (2006). It assigns partial credit linearly to values below the user-defined threshold. For example, with a DA threshold set at 300 lux, if a point exceeds 300 lux for 50% of the time annually, cDA might yield a value of around 55-60% or more.
- **Useful Daylight Illuminance (UDI)**: A modification of Daylight Autonomy formulated by Mardaljevic and Nabil (2005). It categorizes hourly time values into three illumination ranges: 0-100 lux, 100-2000 lux, and over 2000 lux. Full credit is granted only to values between 100 lux and 2,000 lux.
- **Daylight Factor (DF)**: Developed in the early 20th century in the United Kingdom, it denotes the ratio of indoor to outdoor illumination under overcast skies. The calculation involves dividing indoor horizontal work plane illumination by outdoor horizontal roof illumination and multiplying by 100.

https://patternguide.advancedbuildings.net/

Extras\
Integrating parametric design and simulation for daylight optimization

Design environment: Grasshopper, a parametric modeling plugin in Rhino, is utilized for algorithmic design without coding.

Ladybug tools plugin: Integrated into Grasshopper, Ladybug Tools enables daylight (using Radiance) and thermal/energy (using Energy Plus) simulations.

Simulation components: Daylight simulations in Grasshopper utilize Radiance algorithms, with key parameters like -ab (number of ray bounces) set for optimal results; Wallacei X is employed as a multi-objective optimization engine for the second optimization workflow.

Simulation strategy: The focus of the simulation is optimizing daylight efficiency, particularly in central light-wells, using the NSGA-II algorithm for optimization.

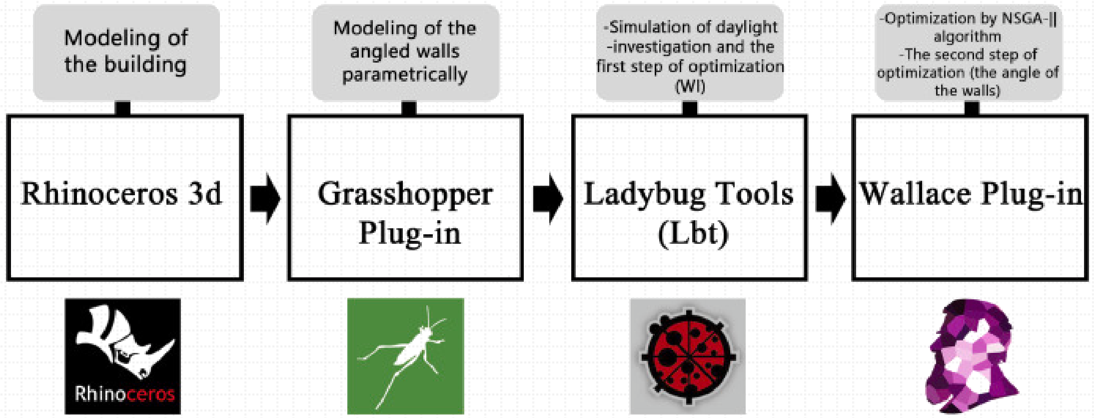

Fig. The four main steps of the research workflow in the simulation environment.

Goharian, A., Daneshjoo, K., Shaeri, J., Mahdavinejad, M., & Yeganeh, M. (2023). A designerly approach to daylight efficiency of central light-well; combining manual with NSGA-II algorithm optimization. Energy, 127402. https://doi.org/10.1016/j.energy.2023.127402

Extras\
Enhancing building performance and comfort through external shading

Energy efficiency and comfort: Incorporating external shading on building facades significantly cuts energy use and enhances visual comfort by efficiently managing sunlight on both exterior and interior walls.

Design and control advancements: Recent progress in design tools, controls, and manufacturing empowers architects to create innovative static and kinetic external shading systems, improving building performance and occupant comfort.

Challenges in simulation models: It's hard for architects to widely use models that help with external shading. The models are complicated, take a lot of time, and architects might not have enough knowledge or ways to fit them into their designs easily.

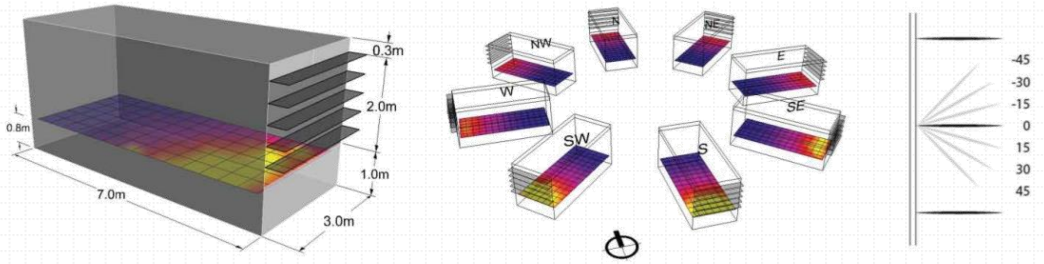

Fig. Case study setup. Left – office dimensions. Middle – room orientation. Right – louver positions.

Grobman, Y. J., Capeluto, I. G., & Austern, G. (2016). External shading in buildings: comparative analysis of daylighting performance in static and kinetic operation scenarios. Architectural Science Review, 60(2), 126–136. doi:10.1080/00038628.2016.1266991

Extras\
Overcoming challenges in performance-based design

Sustainable building design: Designing sustainable buildings uses parametric and evolutionary optimization in mass design to make them more energy-efficient.

Challenges: The parametric approach limits design variations, and creating these models takes a lot of time, disrupting the design process.

Solution: A subtractive-based algorithm helps by generating diverse mass variations without needing additional models.

Benefits: This algorithm can be used in different scenarios without extra work, helping architects optimize building performance.

Case studies: Two studies on improving natural lighting show that this algorithm enhances exploring building design potential for better energy efficiency.

Fig. Generated building massings based on different numbers of subtractors: V indicates vertical subtractors, H indicates horizontal subtractors.

Fig. Generated building massings with different target gross areas.

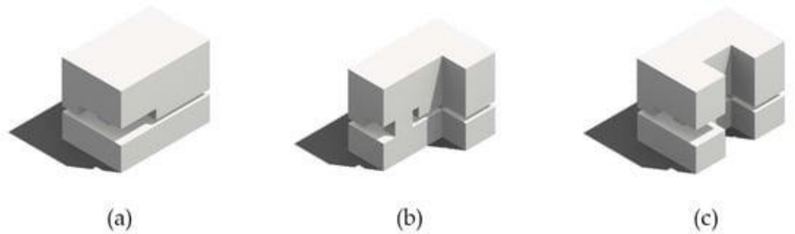

Fig. Generated building massings with different footprints: (a) rectangular footprint, (b) L-shaped footprint, and (c) U-shaped footprint.

Wang, L., Janssen, P., Chen, K. W., Tong, Z., & Ji, G. (2019). Subtractive Building Massing for Performance-Based Architectural Design Exploration: A Case Study of Daylighting Optimization. Sustainability, 11(24), 6965. https://doi.org/10.3390/su11246965

Extras\
Challenges in simulating natural light

Challenges in simulating natural light: Predicting natural light in buildings becomes tricky because materials like fabric roller blinds and Venetian blinds are hard to describe with regular models.

Complexity of light materials: Fabrics and blinds are challenging to predict due to their intricate light-scattering properties, going beyond standard models.

Impact on accuracy: Materials with complex light properties, like those in natural light enhancement systems, can significantly affect how accurately we predict natural light in buildings.

Ward, G. J., Bueno, B., Geisler-Moroder, D., Grobe, L. O., Jonsson, J. C., Lee, E. S., ... Wilson, H. R. (2022). Daylight simulation workflows incorporating measured bidirectional scattering distribution functions. Energy and Buildings, 259, 111890. doi:10.1016/j.enbuild.2022.111890

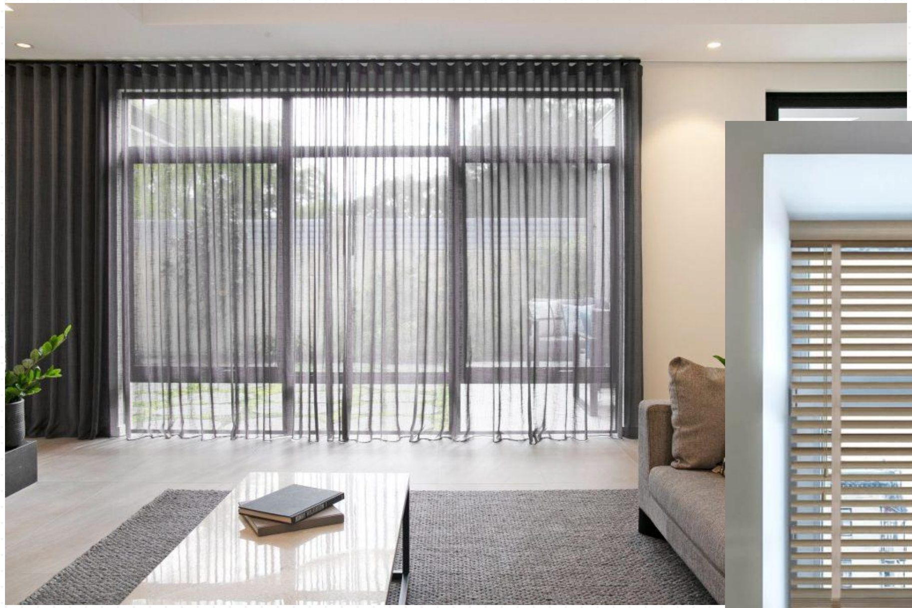

Fig. Blinds. https://theblindsgallery.com.au/which-blinds-let-in-most-light/ (left), https://www.orderblinds.co.uk/buy/warm-grey-wood-grain-faux-wood-venetian-blind-with-tapes_10239.htm (right)

Extras\
Optimizing building massing; natural lighting; urban planning codes

Optimizing building massing and its impact on natural lighting: Optimizing building massing has a significant impact on natural lighting, with notable achievements showing an average increase of 96% compared to reference massing.

Sensitivity of massing design to natural lighting: Findings indicate that the performance of natural lighting is highly sensitive to changes in building massing design. There is substantial potential in optimizing building massing for improved lighting; however, inappropriate design choices can lead to more intensive energy consumption for lighting.

The importance of urban planning codes: Designing building massing with tower-like forms may not be suitable if there are strict regulations in urban planning codes regarding building height. However, this can potentially be addressed by adjusting the building massing for better lighting while adhering to code requirements.

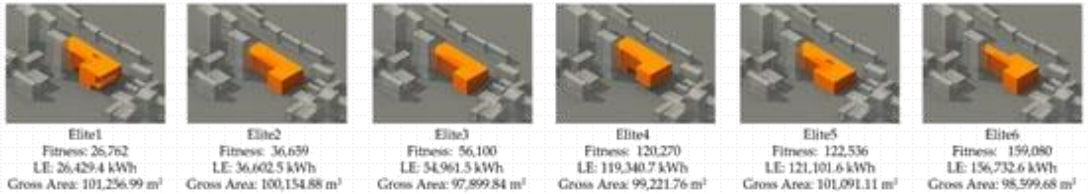

Fig. Elite individuals of daylighting (south-east aerial view).

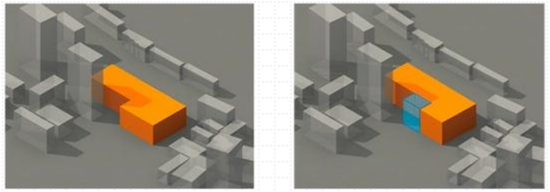

Fig. Set-back in the south wing of the building massing (south-east aerial view).

Wang, L., Janssen, P., Chen, K. W., Tong, Z., & Ji, G. (2019). Subtractive Building Massing for Performance-Based Architectural Design Exploration: A Case Study of Daylighting Optimization. Sustainability, 11(24), 6965. https://doi.org/10.3390/su11246965

Thank you