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Energy Rating of Buildings to Promote Energy-Conscious Design in Israel

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Abstract: Improving the energy efficiency of existing and new buildings is an important step towards achieving more sustainable environments. There are various methods for grading buildings that are required according to regulations in different places for green building certification. However, in new buildings, these rating systems are usually implemented at late design stages due to their complexity and lack of integration in the architectural design process, thus limiting the available options for improving their performance. In this paper, the model ENERGYui used for design and rating buildings in Israel is presented. One of its main advantages is that it can be used at any design stage, including the early ones. It requires information that is available at each stage only, as the additional necessary information is supplemented by the model. In this way, architects can design buildings in a way where they are aware of each design decision and its impact on their energy performance, while testing different design directions. ENERGYui rates the energy performance of each basic unit, as well as the entire building. The use of the model is demonstrated in two different scenarios: an office building in which basic architectural features such as form and orientation are tested from the very beginning, and a residential building in which the intervention focuses on its envelope, highlighting the possibilities of improving their design during the whole design process.

Keywords: energy rating; green buildings; design tools; energy-conscious design

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1. Introduction

In recent years, there has been a significant increase in interest in subjects concerning sustainable design and construction of buildings that save energy and emissions, while ensuring comfortable conditions inside and outside of them.

In order to evaluate the energetic performance of buildings, different methods and rating systems have been developed in various places in the world, such as LEED [1] in North America and EPBD [2] in Europe. In this work, we introduce the model ENERGYui as a tool for design and rating buildings in Israel. The paper significantly expands upon two previously published conference papers, where an early limited version of the model was introduced, and demonstrates its use not only for rating buildings but also as a design tool [3,4]. These methods can help enable consumers and businesses to make more informed choices and decisions to save energy and money. Despite the development of these methods, there is still uncertainty about their relationship to property value and the understanding of the meaning of the energy performance certificates by the general public [5]. As part of these directives, various methods were developed, which can be used by designers and advisors for evaluating the green performance of buildings in general, and their energy performance in particular [6]. The complexity involved in these evaluations and the special requirements of each method has led to the development of a large variety of tools with different levels of difficulty. A comprehensive list has been featured and evaluated according to various criteria by the United States Department of Energy [7,8]. Although there are tools to evaluate the implications of design changes with an emphasis on architectural parameters, there is not always clear what are the assumptions that these tools take regarding the rest of the parameters. This is a critical point for a design tool that rates buildings according to the strict requirements of a standard. Different approaches for rating buildings are used; some of them are based on actual performance while others rely on design data. The former reflects the performance of the building after its construction and occupancy, while the latter rate the proposed building before its construction, which poses a significant challenge.

To evaluate the energy consumption and performance of the building, sophisticated dynamic hourly energy simulation models, which require a high degree of detail, are generally used. Expertise is required to define the input needed for simulation as well as for understanding the output produced by the models. Moreover, tedious work is required for defining all the building parameters and details needed to perform the simulation. For these reasons, these simulation tools are generally used late in the design process [9], mainly by external expert consultants and not by architects, and therefore their impact during the design process is limited. At late design stages, it is very expensive and sometimes impossible to propose and implement major design changes in the building, even if they may bring a significant improvement in its performance [10]. Furthermore, using energy simulation tools usually is not aligned with the design process and requires capabilities beyond those commonly available to designers. The tools and knowledge that required setting the proper conditions of the simulation usually deprive architects of using this kind of tool during the design process and prevent the possibility of asking important what-if questions that can encourage them to examine different design directions. As a result, these are generally inappropriate as practical design aids for architects, especially early in the process since they share the following characteristics:

- Demand expertise and specific knowledge;
- Require the definition of multiple variables related to mechanical systems, load, schedules, etc.;
- Produce complicated outputs that are difficult to understand and translate to architectural changes or use for answering "what to do next?" questions.

The Israeli Standard IS5281 "Buildings with Reduced Environmental Impact (Green Buildings)" was approved in November 2005 [11]; it was recently updated [12] after a comprehensive revision and has an important impact on the architectural practice in Israel. It provides a multi-disciplinary approach for the assessment of new and thoroughly renovated buildings, by scoring points and compliance thresholds. The standard was adopted in 2013 by the forum of the 15 main cities in Israel and deemed as compulsory for building permits in their jurisdiction. Following this initiative, the planning authorities have decided that the standard will be mandatory for all construction in Israel starting in 2021. It is worth emphasizing that so far in Israel, the only mandatory requirement for obtaining a building permit has been in compliance with IS1045 "Thermal Insulation of Buildings" [13,14], which determines the minimum required levels of thermal insulation of envelope elements according to the building type and climatic zone in which the building is located. Standard IS5281 is divided into nine main chapters that focus on the different aspects of sustainable design and green architecture: (1) energy, (2) site, (3) water, (4) materials, (5) health and wellbeing, (6) waste, (7) transport, (8) management, and (9) innovation. Among them, the energy chapter is the most significant in terms of its relative weight, and its verification and compliance rely on Standard IS5282 "Energy Rating of Buildings" [15].

Standard IS5282 uses two basic approaches to demonstrate compliance: (1) the prescriptive-descriptive approach [15,16] which defines various pre-set solutions (prescriptions) to achieve energy conservation according to the desired ranking, and (2) the performance approach, which defines the energy performance of the building that should be met, considering site energy. In this case, the energy consumption of the proposed building is compared with a theoretical reference building, which determines the energy budget. The rating of the building is determined according to the ratio of energy savings in relation to the reference building, between level F (worst) and level A+ (best). For the implementation of this approach, the use of a dynamic energy hourly simulation model is required. For residential buildings, Table 1 shows the required improvement percentages for each level in accordance to the climate zone the project is located on. Depending on the level obtained, a grade value ($GradeValue_u$) is assigned for each evaluated unit (apartment, office, etc.). The improvement percentage for each unit is calculated according to Equation (1), while the rating of the whole building is calculated according to Equation (2).

$$IP = 100 \times \frac{EC_{ref} - EC_{des}}{EC_{ref}} \tag{1}$$

where:

IP—Improvement percentage (%) of energy consumption for floor area
EC_{ref}—Reference energy consumption (kWh/m^2 year)
EC_{des}—Unit energy consumption (kWh/m^2 year)

$$Bld_{rate} = \frac{\sum_{u=1}^{m} Area_u \times GradeValue_u}{\sum_{u=1}^{m} Area_u} \tag{2}$$

where:

Bld_{rate}—Energy rating of building
$GradeValue_u$—Energy rating of unit (apartment/office)
$Area_u$—Area of unit (m^2)
u—Unit
m—Number of units

Table 1. Unit energy efficiency rating (residential) with $GradeValue_u$.

Rating of Unit	Grade Value	Energy Efficiency Improvement Percentage by Climatic Zone (%)			
		Climate Zone A	Climate Zone B	Climate Zone C	Climate Zone D
A+	5	≥35	≥35	≥40	≥29
A	4	≥30	≥30	≥34	≥26
B	3	≥25	≥25	≥27	≥23
C	2	≥20	≥20	≥20	≥20
D	1	≥10	≥10	≥10	≥10
E	0	<10	<10	<10	<10
F	−1	<0	<0	<0	<0

In the following sections, we present the conceptual idea and development of ENERGYui, a model that allows designers to understand, evaluate, rate, and improve the design and energy performance of buildings during all the design stages including the early ones, by easily using sophisticated and reliable energy simulation models. The simulation engine of the model is the robust hourly dynamic model EnergyPlus developed by the US Department of Energy [17]. The proposed model provides a graphic user interface (GUI) that includes information that helps with fulfilling the requirements of Standard IS5282 for the energy rating of buildings. It also includes a materials library certified by the Standards Institution of Israel, which provides the definition of the properties of the building's materials easily and efficiently. Hence, the user is required only to provide or choose simple data related to the architectural characteristics of the project, such as location, building type, building geometry (envelope, internal walls, and openings), materials, etc., and during the early stages of design they can rely on pre-set smart default values for non-architectural data such as mechanical systems, schedules, etc., to evaluate the proposed design alternative. The idea behind the model is allowing designers to improve the understanding of the influence of design decisions on the energy performance of the building to improve the decision-making process. In this way, a simple easy-to-use model from the user's point of view is provided, while a reliable and robust one creates and simulates a full-detailed building description.

2. Description of the ENERGYui Model

A scheme describing the workflow of ENERGYui is shown in Figure 1. One of the advantages of the proposed model is that it requires users to only provide the available information related to architectural characteristics and features of the project. Among them, variables such as project location, building type, geometry, windows, shading elements, materials, and ventilation, are selected or defined by the user. Non-architectural parameters are defined by the model behind the scenes (see Table 2 for a list of architectural and non-architectural parameters for residential building type). Hence, this avoids confusion for the users regarding the information they are supposed to provide for the simulation to be performed on the one hand, and it avoids errors or manipulation of different simulation settings in obtaining reliable results on the other hand. In this way, the proposed model adapts to the way architects work and allows for performing sophisticated simulations without the need of dealing with complex definitions. Accordingly, this allows them to correct and improve the design to meet the architectural objectives on the one hand and obtain the desired ranking on the other. Moreover, it provides authorities a way of controlling the correctness of the input data and the reliability of obtained results, which result in the rating of the building.

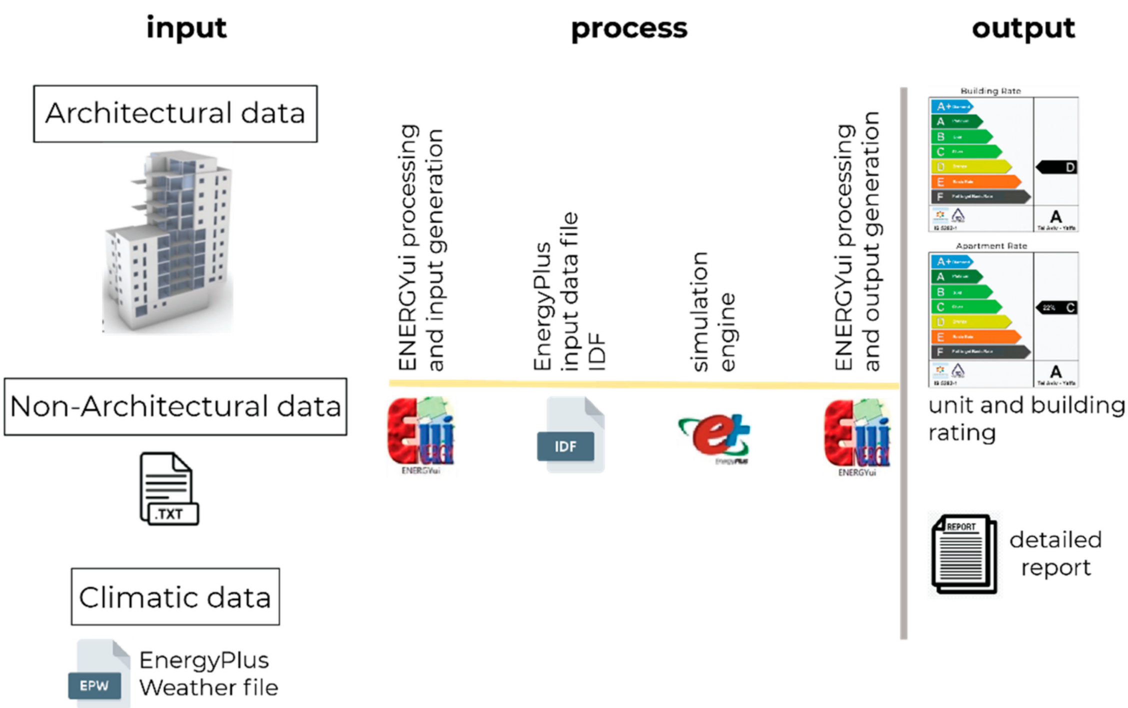

Figure 1. ENERGYui workflow.

ENERGYui is controlled and organized by a command tool chest that guides and advises the user concerning the information and input required or missing to perform the simulation (Figure 2), as will be demonstrated in the following sections.

Table 2. Architectural and non-architectural parameters for residential building type.

Info	Parameters		Variation		
Architectural (user-defined)	Location		Set by user *		
	Geometry	Opaque	Set by user * (See Figures 3 and 4)		
		Windows	Set by user * (See Figures 3 and 5)		
		Blinds		Shading Coefficient Winter	Shading Coefficient Summer
			No Blinds	1.0	1.0
			2/3 opening	0.6	0.4
			1/2 opening	0.5	0.4
			Full opening	0.8	0.4
		Sunshades	Set by user * (See Figure 5)		
	Materials		Set by user * (See Figures 4 and 7)		
	Ventilation		Night Crossed, Comfort		
Non-Architectural (Tool defined)	Loads	People	From 4 to 8—According to apartment size		
		Constant	From 1 to 0.5 W/m^2—According to apartment size		
		Non-constant	From 8 to 4 W/m^2—According to apartment size		
		Lighting	5 W/m^2		
	Mechanical system		Ideal system—Heating/Cooling Loads Calculation		
	Setpoint	Heating	20 °C		
		Cooling	24 °C		
	Infiltration		1 ach		
	Seasons		According to location climatic zone		

Set by user *—User is not constrained by requirements for each parameter.

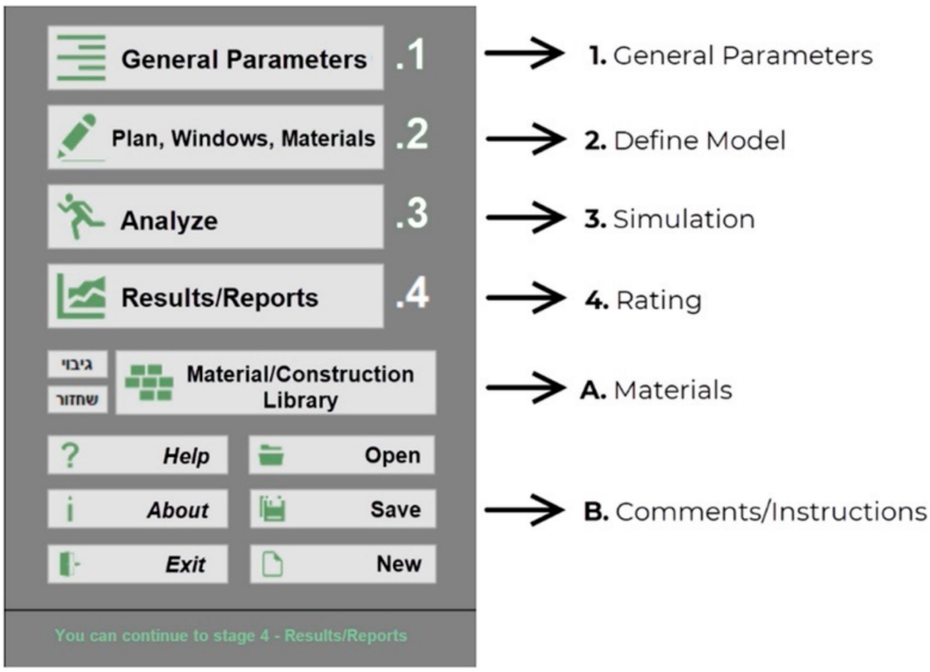

Figure 2. Command tool chest.

2.1. Step 1—General Parameters

The first step relates to the definition of the general information on the project at hand, with the definition of the location (i.e., setting weather conditions for the project) being the most important. Additional information includes designer and developer details and contact, terrain data, etc. After these general parameters are set, the user is allowed to continue to step 2. If information is missing or incorrect in a certain step, the tool chest prompts a notification with details for designers and does not allow the user to continue to the next step, guaranteeing in this way the completeness of the data needed in order to perform the full simulation.

2.2. Steps 2 and 3—Building Model Definition and Simulation

In step 2, the user defines the project geometry: plan, external envelope, openings, materials, number of floors, thermal zoning (offices, apartments, cores, corridors, etc.). The user can start this stage from scratch or can use one of the templates provided by ENERGYui as a starting point. The templates define some of the typical building layouts for various building types in Israel (see Figure 3 for some examples of residential buildings).

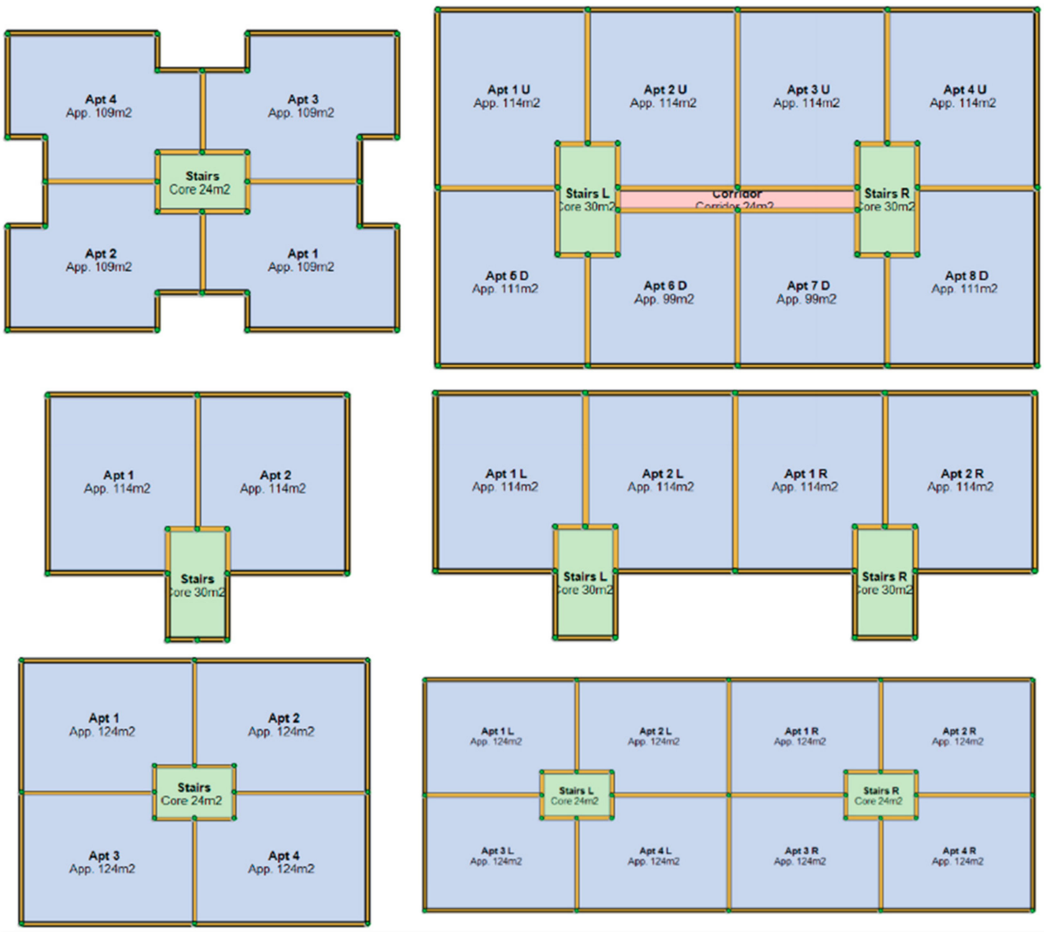

Figure 3. ENERGYui residential templates.

As mentioned above, the definition of the architectural design parameters is done by the designer according to the information available at each design stage, while all non-architectural parameters are defaulted by ENERGYui. The idea behind this setting is to encourage designers to improve the performance of the buildings from the very beginning, based on their basic architectural characteristics, rather than relying on mechanical systems exclusively. Figure 4 shows the range of information needed, aside from the geometry itself, i.e., walls, windows, and thermal zones (see A in Figure 4). The different envelope elements need to be assigned a composite construction, which can be selected from a provided library (Figures 5 and 8) or can be newly created by users according to their needs. These composite constructions can be applied to a specific wall or all walls in the floor or building. In the same manner, for any window, the user needs to choose its frame and glazing material and internal or external shading type, i.e., blinds and/or sunshades (Figure 6). While working on this step, ENERGYui provides graphic feedback on the completeness of the information provided. For instance, a mustard-yellow color element means that a construction definition is still missing and acts to guide the designer to complete it, while a green one indicates that it is fully defined. Additional information that needs to be defined at this step relates to the determination of the north direction, the number of floors, thermal zones, assigning composite constructions for the floor, roofs, internal floors, as well as first-floor type, i.e., on the ground, on columns, or over an unheated space (all seen in B, C, and D in Figure 4). Since some of this information can be unknown in the early stages of design, the user can choose from one of the smart defaults offered by the model (insulation, window size, etc.), which are based on requirements from IS5282.

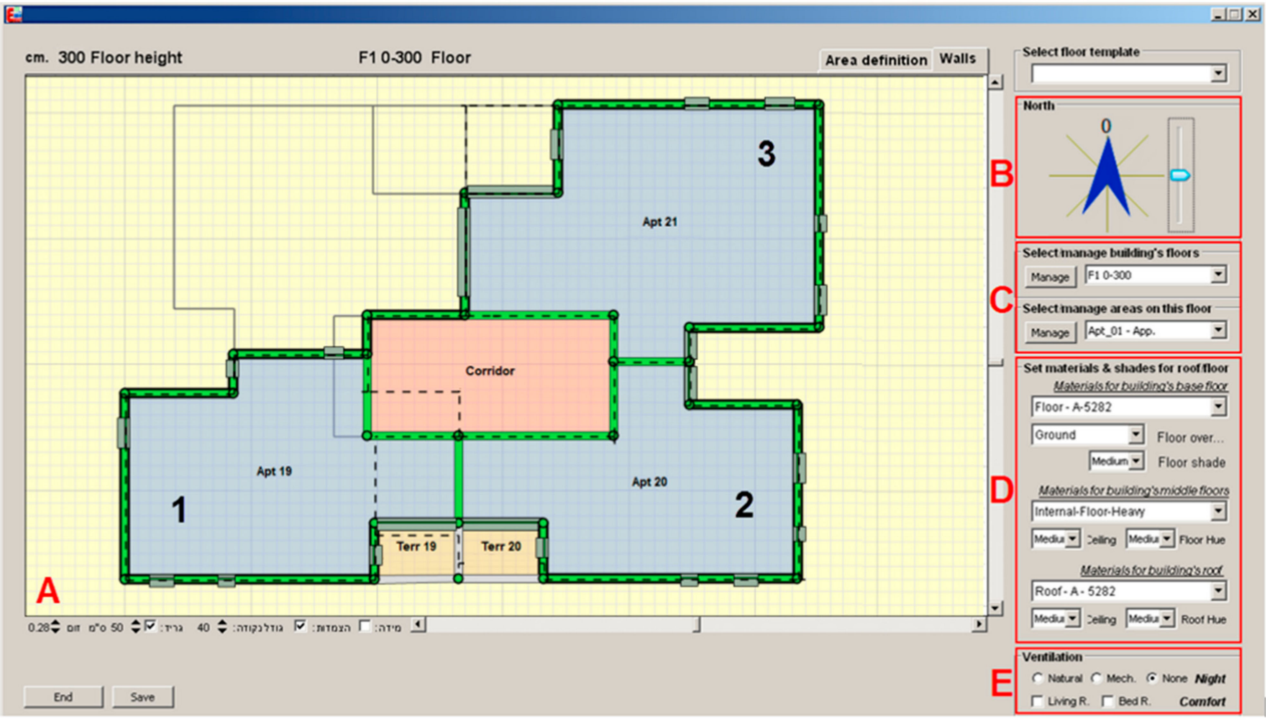

Figure 4. ENERGYui modeling GUI.

Once step 2 is completed and the model contains all the required information for the simulation, the user is allowed to proceed with step 3, which involves running the simulation itself. ENERGYui automatically creates and processes the full input file used by the simulation engine, i.e., EnergyPlus [17].

2.3. Step 4—Rating Individual Units and the Whole Building

After completion of the simulation, ENERGYui rates both the whole building and each of the zones (apartments, offices, etc., according to the building type chosen for evaluation), as seen in Figure 7. Instead of having to deal with a large and complicated number and types of outputs, the building rating and the energy certificate, together with a detailed report for further analysis, are provided. IS5281 requires the whole building to be rated, while IS5282 allows for the rating of both the entire building and individual units. In this sense, the individual rating can help owners or potential buyers to know the energy performance of the specific property and conduct informed decision-making. This information can also be used by planning authorities to stimulate green buildings by providing economic incentives, such as low-interest rates mortgages.

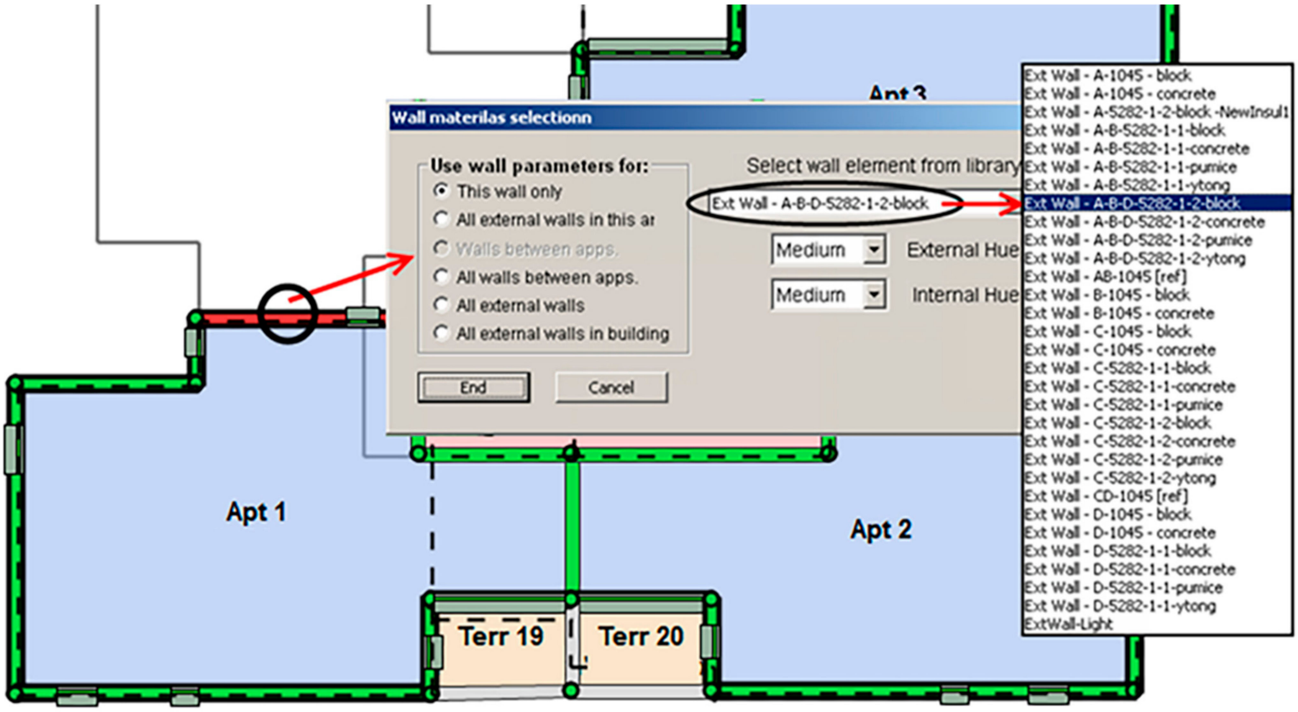

Figure 5. Opaque envelope: Assignment of composite elements.

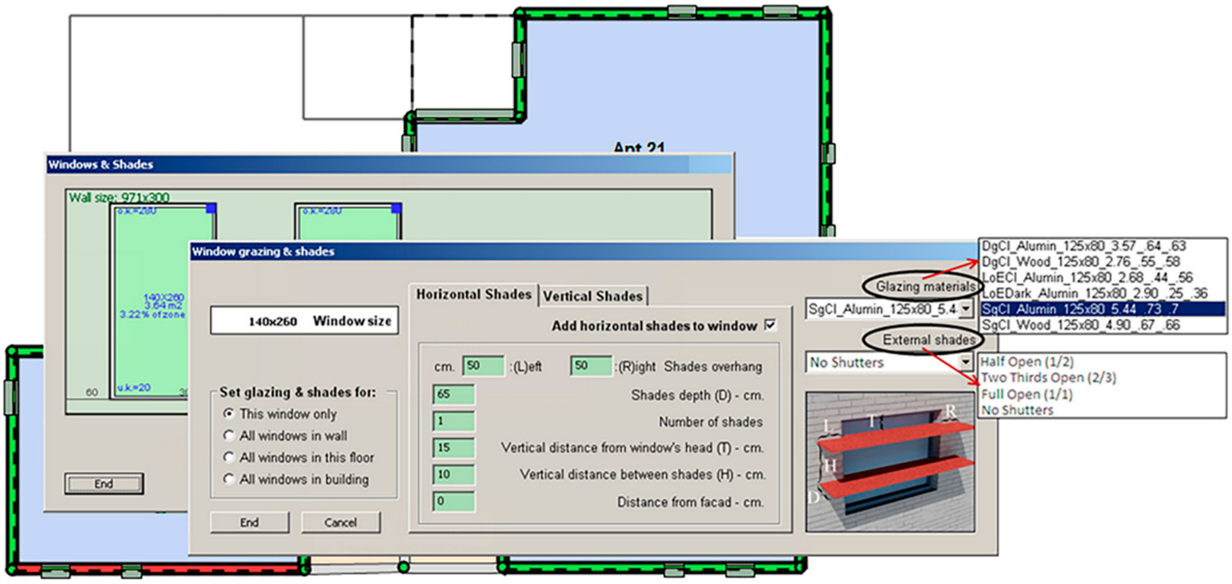

Figure 6. Openings: Assignment of window and shading elements.

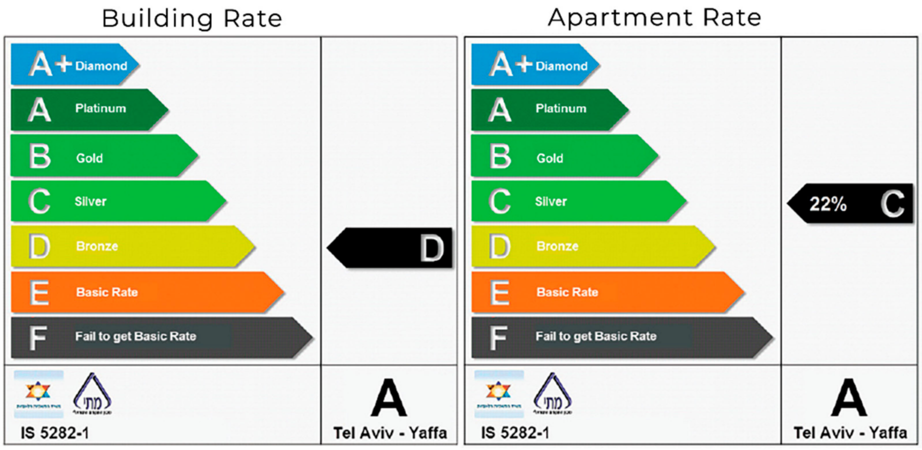

Figure 7. Energy rating for a building (**left**) and an individual unit (**right**).

2.4. Material/Construction Library

ENERGYui contains a library of basic materials and combinations that allows for easy user choice and ensures compliance with requirements as well as the quality and consistency of the data. The materials are categorized according to different types (concrete, wood, glazing, etc.) in a way where users can quickly find the most relevant one for their needs (see Figure 8 part A). Individual materials are used for the creation of composite elements for the building envelope. Those assemblies can be assigned to different geometry elements in the building, as in floors, windows, walls, roofs, etc. (see Figure 8 part B). It is possible to choose from default predefined composite elements or create new ones as shown in Figure 8 part C. New composite constructions can be created based on existing and certified basic materials included in the library, or based on new materials on the market as defined by the user. In the last case, a notice will be printed in the detailed report, meaning that the designer will be requested to provide approved documentation certifying the properties of the new material. The library manager differentiates between certified materials/composite elements and new ones defined by the users by different colors, while the first category is protected and cannot be altered by users.

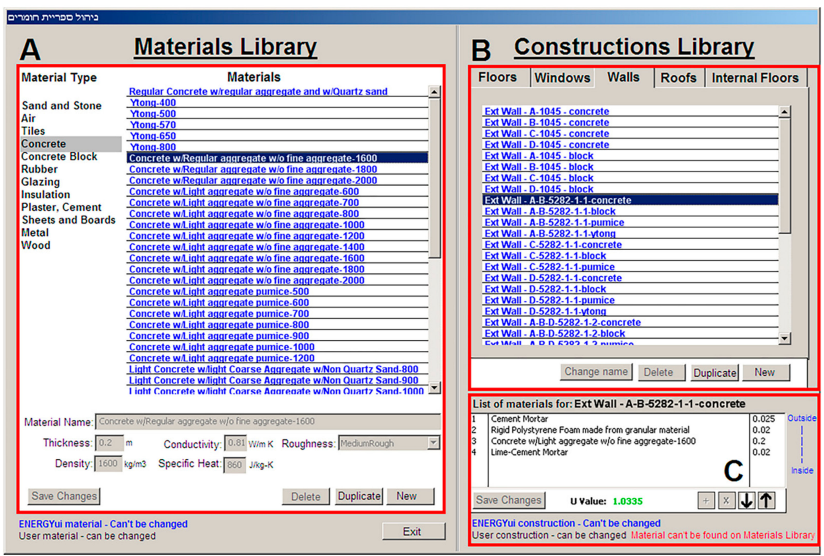

Figure 8. Material/construction library. List of materials (**left**); list of constructions (**right**).

3. Case Studies

In this section, we demonstrate the use of the ENERGYui model through the analysis and exploration of several design alternatives in two different examples. The first case study demonstrates the use of the model for the analysis of alternatives and decision-making in the design of an office building from the first stages of the design process to the detailed design. The second one shows the analysis of a residential building in a more advanced state of design, in which several basic decisions have already been made and therefore the freedom of action is more limited.

3.1. Office Building

This case study demonstrate the design of a theoretical office building in the city of Tel Aviv in the coastal plan zone of Israel. As stated above, this case allows the designer to explore various basic design alternatives for the building from the very beginning, where the criterion for choosing which alternative(s) to continue to develop is the achieved energy rating of the building. The use of the tool at early stages allows for exploring fundamental architectural decisions such as massing and main orientation of the building. Three basic options for the office building proportions were explored based on their depth, going from a deep office space of 14 m, a more typical depth of 8.2 m, and a shallow deep of 5 m. The expected total area is about 4500 m^2 for all buildings, resulting in two 4-story and one 5-story buildings, respectively as shown in Figure 9.

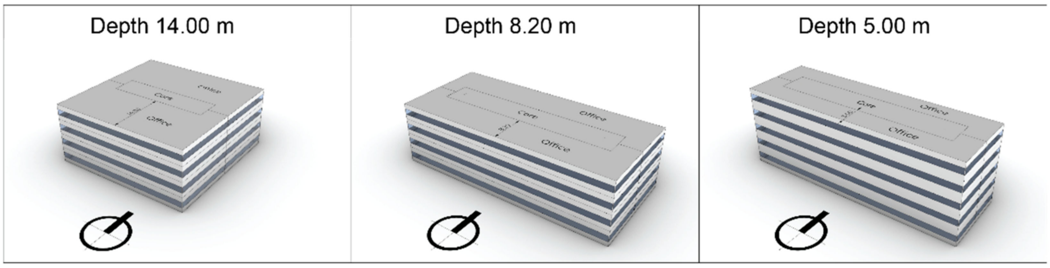

Figure 9. Case study building 1: Basic massing alternatives. **Left**: Deep offices (14 m); **Middle**: Standard depth (8.2 m); **Right**: Shallow depth (5 m).

To allow for the use of the simulation model at this early stage of design, basic properties for this case study were set as smart-default values based on requirements and common practices: A window size is predetermined for all buildings as a strip of 1.40 m on all facades, and double-glazing clear glazing type is used for openings. The opaque part of the façade uses as a starting point a basic level of insulation, meeting the minimum requirements required for heavy construction as set out in IS1045. Although some improvement in insulation levels beyond this minimum value may be beneficial in terms of overall energy consumption and rating (as we demonstrate later), it should be emphasized that in Israel's coastal climate zone there is a balance point between winter and summer. In winter, adding insulation may help lower heating requirements, although during the dominant warm period, adding insulation beyond the recommended level may make it difficult to cool the building and may require night ventilation [18]. Therefore, the insulation requirements in this climate zone are less stringent than in cold regions. No internal or external shading devices and no ventilation were implemented, and the light control was set to one step on/off (LC1S) for the basic set of alternatives. The full set of characteristics of the buildings (basic set and design alternatives) are presented in Table 3.

Table 3. Office building case with design parameters.

Parameter		Acronym	Description	Value
Proportion			Office's depth	5.0 m, 8.2 m, 14.0 m
Orientation	Des_Alt	0 Deg, 45 Deg, 315 Deg	Main façade orientation	-
Insulation	Bsc	StIns	Standard Insulation	U = 1.25 W/m^{2}K
	Des_Alt	ImIns	Improved insulation	U = 0.5 W/m^{2}K
Glazing	Bsc	DgCl	Double Glazing Clear	U = 3.95 W/m^{2}K, SHGC = 0.65, Vt = 0.63
	Des_Alt	LowE	Low Emissivity glazing	U = 3.14 W/m^{2}K, SHGC = 0.52, Vt = 0.6
Shading	Bsc	noShd	No shading	-
	Des_Alt	IntShd	Internal dynamic shading	SC = 0.55
	Des_Alt	ExtShd	External dynamic shading	-
	Des_Alt	BrSol	External fixed shading	-
Window Size	Bsc	MedWin	Medium window size	H = 1.4 m
	Des_Alt	MaxWin	Maximal window size	H = 2.7 m
	Des_Alt	MinWin	Reduced window size	H = 1.0 m
	Des_Alt	MinWinSouth	Reduced window size South	H = 1.0 m
Light Control	Bsc	LC1S	Light control 1 step	on/off (500 lx)
	Des_Alt	LC2S	Light control 2 step	on/off (500 lx)
	Des_Alt	LCdim	Light control dimmer	dimmer (500 lx)
Ventilation	Bsc	noV	No Ventilation	-
	Des_Alt	nNV	Natural night ventilation	3 ach
	Des_Alt	mNV	Mechanical night ventilation	10 ach
	Des_Alt	ComfV	Comfort ventilation	Ceiling fan (Allows to raise summer temperature by 0.5 °C)

Basic alternative (Bsc)

Insulation	Glazing	Shading	Window Size	Light Control	Ventilation
StIns	DgCl	noShd	MedWin	LC1S	noV

Design alternative (Des_Alt): Alternative get value from a set of given parameters or from user defined values.

Table 4 and Figure 10 present the description and results for the alternatives of the theoretical office building. As previously stated for this case study, the exploratory process starts from the most basic design decisions at the first stage, i.e., massing and orientation of the building according to site constraints (0 deg, 45 deg, and 315 deg). The results were assessed at two levels: the whole building and at two typical middle floor offices (north and south). The best results (higher rating and lower energy consumption) for each building depth were kept for the next stages. For the 5 m depth building, all orientations were rated E or above, and hence it was decided to keep them all. For the 8.2 m depth case, 0 deg and 45 deg were kept, and for the 14 m depth, only the 0 deg option was suitable to be kept for further analysis.

Table 4. Office building case with design path showing improvements of design alternatives.

	Description	DEPTH 5.0							DEPTH 8.2							DEPTH 14.0						
		Middle Floor						Whole Building	Middle Floor						Whole Building	Middle Floor						Whole Building
		Office North			Office South				Office North			Office South				Office North			Office South			
	EC_{ref} Offices: 42.38 kWh/m^2 year	Improv %	Rating	EC_{des} (kWh/m^2 year)	Improv %	Rating	EC_{des} (kWh/m^2 year)	Rating	Improv %	Rating	EC_{des} (kWh/m^2 year)	Improv %	Rating	EC_{des} (kWh/m^2 year)	Rating	Improv %	Rating	EC_{des} (kWh/m^2 year)	Improv %	Rating	EC_{des} (kWh/m^2 year)	Rating
Orientation	0 Deg	27	D	31.1	29	C	30.1	C	15	E	35.9	17	E	35.2	E	9	F	38.6	10	E	38.2	E
	45 Deg	15	E	36.2	19	E	34.4	E	8	F	39.1	11	E	37.8	E	6	F	39.8	8	F	39	F
	315 Deg	17	E	35.2	15	E	36.2	E	9	F	38.4	8	F	39.2	F	7	F	39.3	6	F	39.8	F
Window Size	0 Deg_Min Win	17	E	35.2	34	B	28.2	D	3	F	41.2	20	D	33.8	E	6	F	39.9	13	F	37	F
	0 Deg_Max Win	20	D	34	6	F	39.7	E	8	F	38.9	−1	F	42.7	F	−1	F	42.8	−7	F	45.4	F
	45 Deg_Min Win	9	F	38.3	22	D	33	E	−1	F	42.9	12	E	37.2	F							
	45 Deg_Max Win	−3	F	43.6	−8	F	45.8	F	−6	F	45	−9	F	46.2	F							
	315 Deg_Min Win	8	F	39	21	D	33.4	E											-			
	315 Deg_Max Win	5	F	40.4	−17	F	49.7	F				-										
	0 Deg_Min Win South	26	D	31.3	33	C	28.3	C														
Shading	0 Deg_Int Shd	27	D	31	34	B	28	C	16	E	35.5	21	E	33.6	E							
	0 Deg_Ext Shd	26	D	31.2	31	C	29.2	D	16	E	35.4	23	D	32.5	E				-			
	0 Deg_ImIns_LowE_FixExtShd	−3	F	42.3	19	E	27.6	E	−4	F	44.1	21	D	33.6	E							
Detailed Design Parameters	0 Deg_ImIns_LowE	31	C	29.2	38	B	26.3	B	19	E	35.4	24	E	32.5	E							
	0 Deg_LowE_IntShd_MaxWin	28	C	30.3	31	C	29.3	C	15	E	35.8	18	E	34.7	E							
	0 Deg_ImIns_LowE_IntShd	30	C	29.5	40	A	25.3	B	19	E	34.4	26	E	31.5	D							
	0 Deg_ImIns_LowE_ExtShd	29	C	30.2	39	B	25.8	C														
	0_Deg_ImIns_LowE_IntShd_ MaxWin	28	C	30.3	31	C	29.3	C														
	0 Deg_IntShd_Min Win South	27	D	31.1	35	B	27.4	C														
	0 Deg_SI_LowE_Min Win South	28	C	30.6	37	B	26.7	C											-			
	0 Deg_ImIns_Min Win South	29	C	30	35	B	27.5	C				-										
	0 Deg_ImIns_LowE_Min Win South	31	C	29.3	40	A	25.6	B														
	0 Deg_ImIns_LowE_IntShd_ Min Win South	30	C	29.5	40	A	25.6	B														
	0 Deg_ImIns_LowE_Min Win South_nNV	38	B	26.3	48	A+	22.1	A														
	0 Deg_ImIns_LowE_Min Win South_mNV	32	C	28.9	43	A	24.3	B														
	0 Deg_ImIns_LowE_Min Win South_mNV_ComfV	37	C	26.5	49	A+	21.8	A														
	0 Deg_ImIns_LowE_Min Win South_LC2S	34	B	28	41	A	24.9	B														
	0 Deg_ImIns_LowE_Min Win South_LCdim	39	B	25.8	46	A+	23	A														

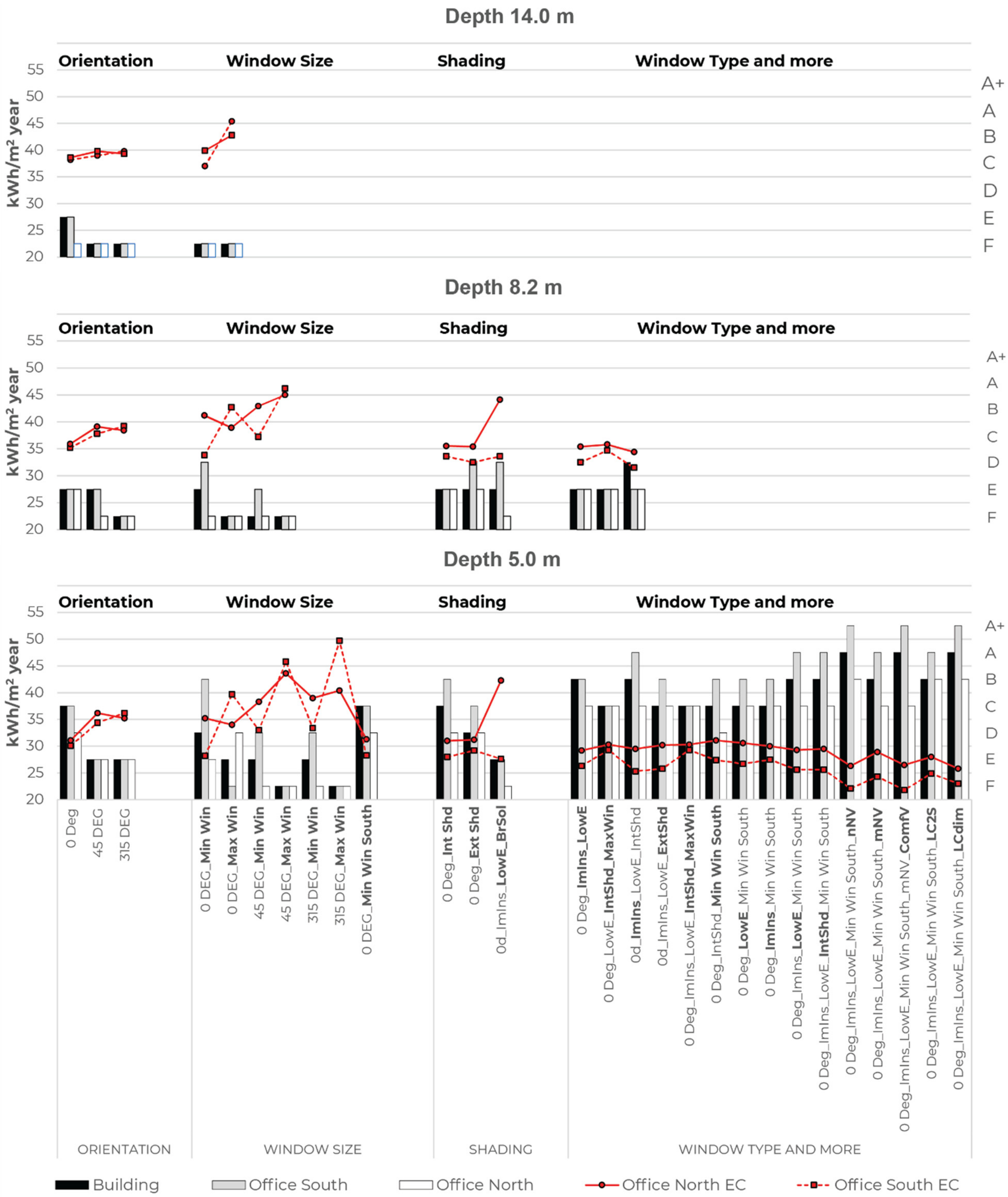

Figure 10. Case study building 2: Energy consumption and rating of design alternatives and decision making during the design process. **Top**: Deep offices (14 m); **Middle**: Standard depth (8.2 m); **Bottom**: Shallow depth (5 m). In bold: parameter changed in each alternative.

The second stage of the exploration tests the influence of window sizing on the performance of the building. This is a stage in the design process where basic decisions still need to be taken, as in the previous one. Three strategies for window size were evaluated, i.e., reducing the size to a minimum, enlarging the size to a maximum, and reducing the size only for the south-oriented offices (denoted as "min win", "max win", and "min win south", respectively). At this stage, the main improvements in the rating were obtained with the clean north-south orientation (0 deg), especially on the 5 m depth option. The 8.2 m depth shows a slightly better performance compared with the previous stage and the 14 m depth shows no improvement at all. This is probably due to the fact that the lighting consumption is heavily affected by the deep spaces, and therefore it was decided not to further pursue this design option. For the next stages, only the north-south options were kept for further exploration.

Once the more basic decisions were made, the third stage implements the use of shading strategies for the openings. They included dynamic shading devices, internal, and external (IntShd and ExtShd) activated when the amount of solar radiation reaching the office space overcomes a predetermined threshold. Fixed devices were also considered as a design option (FixExtShd). The internal shading performed better for the shallow building while the external was slightly better than the internal for the 8.2 m depth. The fixed shading type did not represent any improvement compared to the previous stage and was discarded. As a result, both dynamic shades were kept for the next design stage.

The fourth stage is intended for a more detailed level of decision-making in advanced stages of design. Improving the glazing type or using dynamic shade led to significant performance improvement in the 5 m depth office building. For the 8.2 m depth case, however, it showed no significant rating and performance improvement from the previous stage, maybe even worsening at the single office level. For this reason, it was decided to drop this building option and to pursue only the shallow-depth office. Significant improvement in the performance of the building and midfloor offices occurs when using low-emissivity (LowE) glazing, reducing the window size in the south-oriented offices, and improving the insulation of the opaque envelope. With one or more than those parameters, the building reached an overall B grade and the offices C (north) and A (south). Implementing some sort of ventilation (natural/mechanical night ventilation or comfort ventilation, provided by ceiling fans) or dimmer light control led to an A rating for the building and A+ for the south-oriented offices, which is the best one achieved for this case study (see Table 4 and Figure 10).

3.2. Residential Building

The second case study presents a residential tower building, 11-floor height (Sanhedrin Building), designed in the city of Ramat Gan, as well in the coastal plan climatic zone. Figure 11 shows two different design alternatives for this building.

In this building, due to design limitations and programmatic constraints, several fundamental design parameters were fixed and cannot be considered for change during the process, as building orientation. Therefore, the exploration path focused on design parameters related to the external building envelope. The case study assesses two design alternatives that allows for understanding the impact of the proposed changes on the performance of both the whole building and the apartments on a typical middle 2-apartment floor (dark grey in Figure 11). The first alternative shows a conservative approach, where the building uses the more common construction technologies available in the Israeli market, and the aesthetics are guided by modern traditional customs (Figure 11 top). The second alternative shows a more "fashionable" aesthetics of the building envelope, where constructors, entrepreneurs, and even users prefer to have larger windows with extensive use of glazing, mainly in the social areas of the residential units (Figure 11 bottom).

Table 5 presents a description of the different simulated stages for both design alternatives, a total of 4 for both alternatives. The table shows the summary of the results obtained in the simulations while changing different design variables for Apartments 1 and 2 and for the whole building.

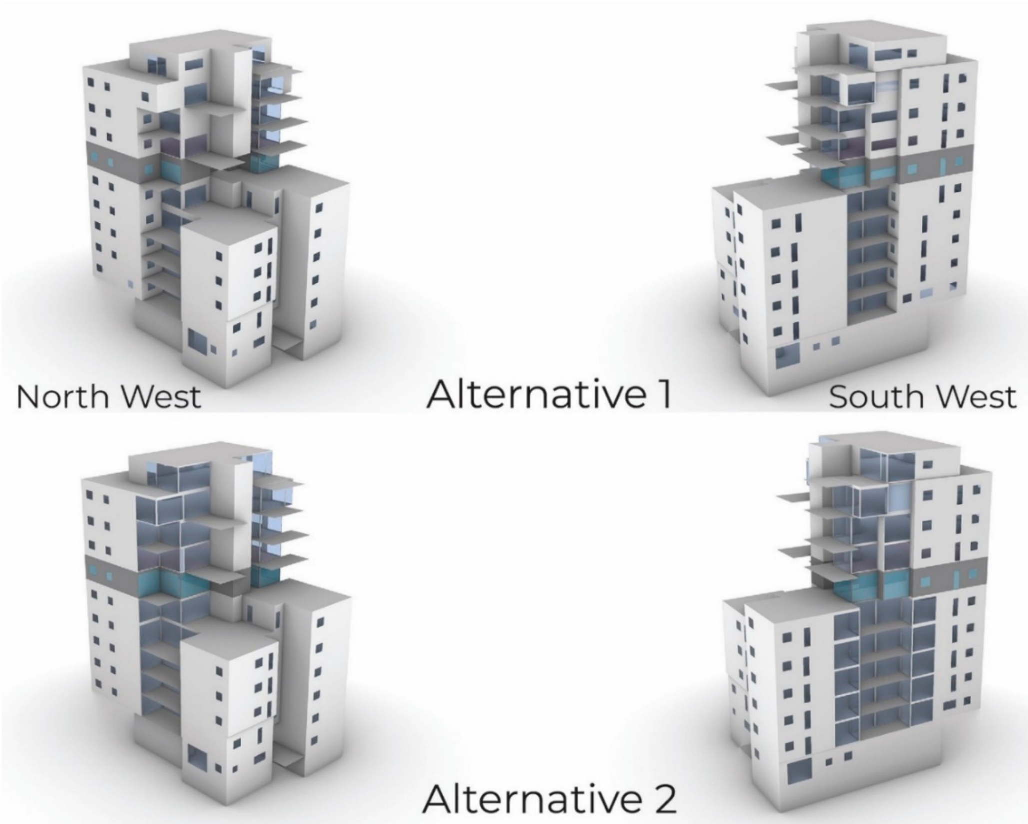

Figure 11. Case study building 2. View from northwest (**left**) and southwest (**right**). Top: Design Alternative 1; Bottom: Design Alternative 2 with larger windows.

Alternative 1: The building was first analyzed by implementing basic requirements for the insulation of the building's envelope (roof, walls), as currently required by local standards (Figure 11 top and Figure 12 left). In addition, windows with clear single glazing were designed at the beginning without any solar protection. This is despite the design tradition in Israel, which applies roller shutters to windows in residential buildings for privacy, allowing dynamic shading as needed as well as improving window insulation at night. According to IS5282, this building ranks the lowest rating possible F, as well as apartment 1, while Apartment 2 rates E (Alternative 1, Stage 1).

As a way to improve the rating, it was proposed to improve the insulation of the opaque envelope and to use double glazing clear in the windows instead. These changes led to the improvement of the rating of the whole building to the basic level of D, while Apartments 1 and 2 rate E and D, respectively (Alternative 1, Stage 2). Both apartments remain low-rated despite the improvements, probably due to the relatively large opening towards the south, west, and north directions, the lack of any shading protection for the windows, and a relatively large external surface area.

Adding dynamic external shutters that can be fully open and close as well as providing dynamic shading and improving night insulation proved to be a very efficient and important factor for energy savings. These changes changed the building rate to B, while the apartments rated C (Alternative 1, Stage 3).

Table 5. Design path showing improvements of two design alternatives.

Description			Typical Middle Floor						Whole Building
			Apartment 1			Apartment 2			
EC_{ref} Residential: 41.78 kWh/m^2 year			Improvement %	Rating	EC_{des} (kWh/m^2 year)	Improvement %	Rating	EC_{des} (kWh/m^2 year)	Rating
Alternative 1	1	Basic Insulation Single Glazing Clear No Shading	−6	F	44.3	5	E	39.9	F
	2	Improved Envelope Insulation IS5282-Level 2 Double Glazing Clear	6	E	39.3	16	D	35	D
	3	Full Opening External shutters	24	C	31.7	24	C	31.7	B
	4	Night Ventilation	32	A	28.2	31	A	28.6	A
Alternative 2	1	Increase Glazing—social areas	−9	F	45.7	−24	F	51.9	F
	2	LowE Glazing	5	E	39.7	−10	F	45.9	F
	3	Full Opening External shutters	23	C	32.2	14	D	36.1	C
	4	Night Ventilation	31	A	28.7	22	C	32.6	A

Allowing for night ventilation during summer nights (when the outside temperature is lower than the inside temperature) improved the final rating of the building and both apartments to A (Alternative 1, Stage 4). Further improvement could have been achieved on its energy performance by updating geometry, window size, or orientation; these changes were not tested in this alternative.

Alternative 2: As noted above, this alternative reflects design choices related to market preferences, namely in encouraging window enlargements mainly in the public areas of the apartments. For this alternative, the glazing ratio was significantly increased for the social areas of each apartment (Figure 11 bottom and Figure 12 right). This substantial change affected the performance of the apartments and the whole building for the worst. The apartments and the building rated F (Alternative 2, Stage 1). To deal with the enlargement of the windows, in the next stage we tried to improve the quality of the glazing, both in terms of insulation and solar heat gain coefficient (U value = 3.14, SHGC = 0.2). Changing the glazing type to LowE slightly improved the overall results (% improvement) but not the ratings. Only Apartment 1 is rated now at E (Alternative 2, Stage 2). In the next stage, as in Alternative 1, the addition of dynamic external shutters proved to be especially important to improve the performance of the building. This led to the building being rated at C and the apartments at C and D (Alternative 2, Stage 3). Lastly, implementing night ventilation, which is beneficial in this climate, contributed to bringing the final rating of the building and Apartment 1 to A while Apartment 2 received a C rating (Alternative 2, Stage 4).

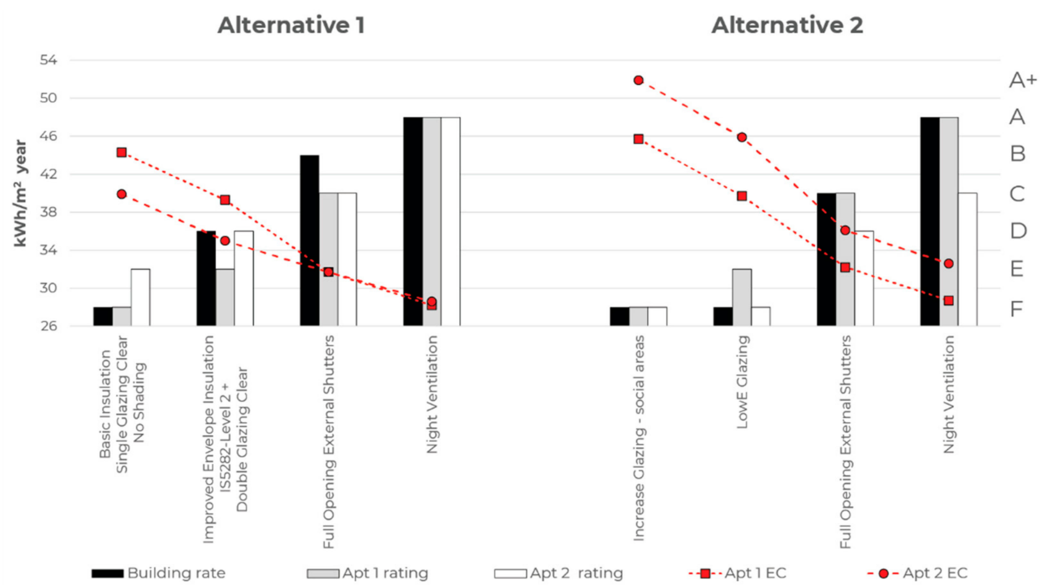

Figure 12. Case study building 2: Energy consumption and rating of design alternatives during the design process.

4. Conclusions

A simple model ENERGYui that allows for the use of the simulation program Energy Plus for improving design performance during the process of the rating of buildings was demonstrated. The model was applied at different stages through the design process of an office and a residential building. Significant improvements were obtained in the final ranking in both cases studied. With the help of the model, beyond obtaining the rating of the building, which is its main objective, it was possible to explore different alternatives at all design stages, including the early ones, and make decisions according to the qualities of each one of them. In this way, the model allows for increased awareness of energy implications regarding design decisions, and it diversifies the available design options. The proposed model focuses on information from designers related mainly to architectural parameters. The non-architectural ones are suggested by the tool itself based on smart default values. ENERGYui is expected to make a great impact not just among green building consultants, but also among practitioners in their architectural practice since it is the recommended tool to be used for checking compliance with IS5282.

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