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APPLICATION OF AN ADAPTIVE FACADE – CASE STUDY OF A DOUBLE SKIN FAÇADE IN MODERATE CLIMATE

4th International Conference ***"ENERGY in BUILDINGS - Northern Hellas"***
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Outline/Agenda

- Introduction
- History
- Definition and Types
- Experimental analysis
- Numerical Simulations
- Conclusion

Introduction

The envelope (facade) is the part of the building which forms the primary thermal barrier with its environment. It represents the most important factor in determining the level of overall comfort, natural lighting and ventilation ability, and finally how much energy is needed for heating and air-conditioning.

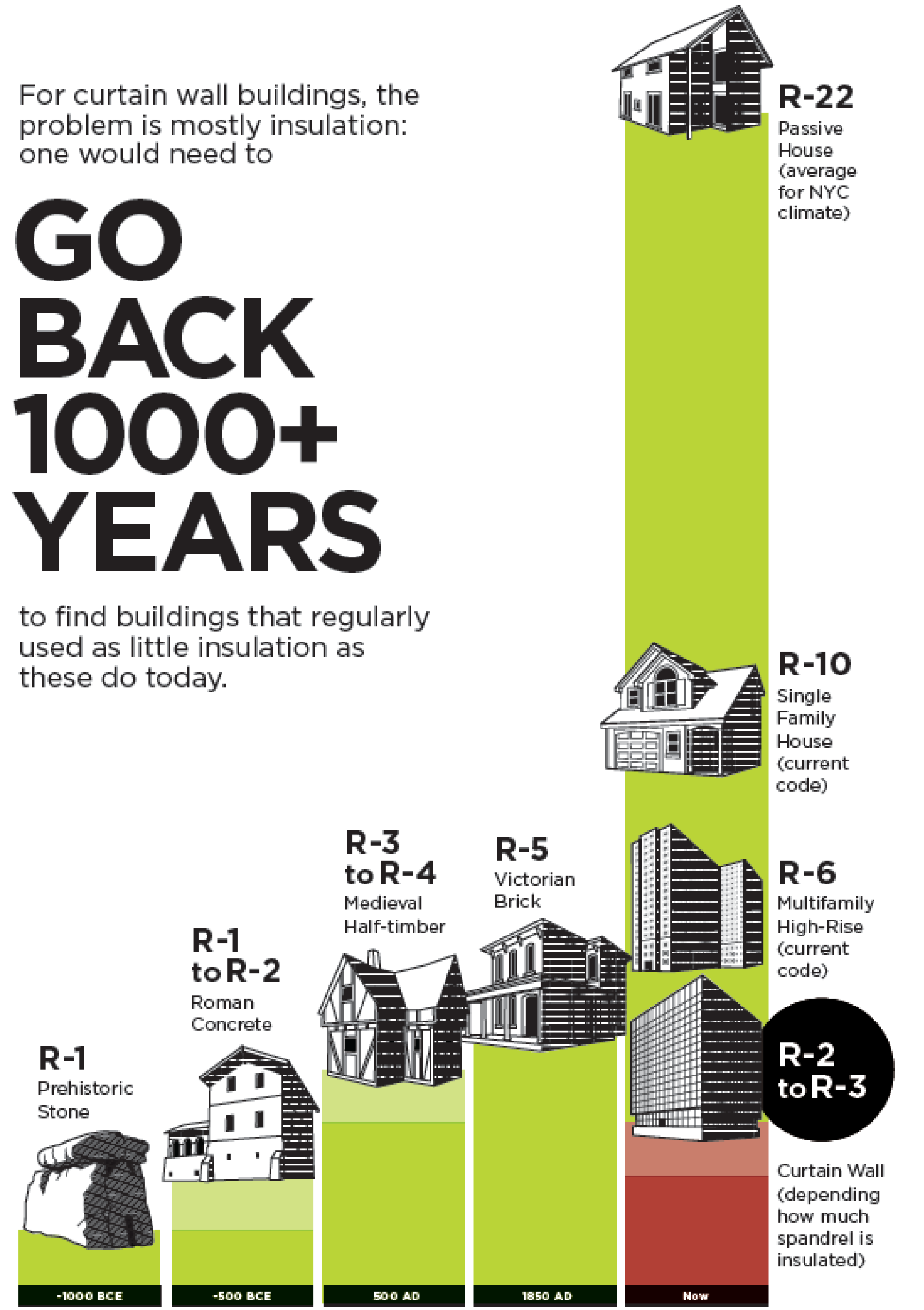
New stricter building codes, regulation and roadmaps, focus on emergency of the use of highly energy efficient technologies and equipment, as well as new adaptive facade solution. The usage of renewable sources to reduce the need for conventional energy become a greater challenge for the engineers.

The question is which building construction can utilize this in order to supply all the needs of the building?

Introduction

Source: Urban Green Council

Introduction



Source: Urban Green Council

Introduction
WHAT TO DO???

✓ Better glass

- The industry can come up with envelope innovations that waste less energy, while keeping the aesthetics and great views that glass provides. There is no question that glass can and will become a better insulator. But windows will never insulate as well as walls. The R-value of the typical New York City curtain wall assembly is R-2.5 to R-3.0; walls are R-30 or better.

✓ Better training

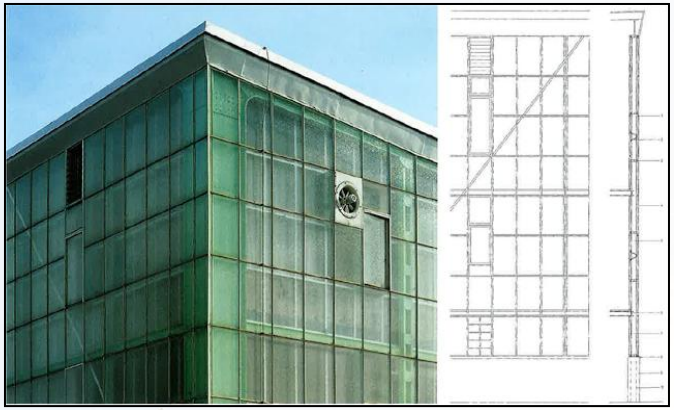
✓ Better codes and standards

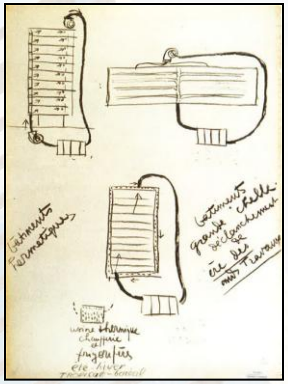
✓ Better design (holistic approach, adaptive facades…)

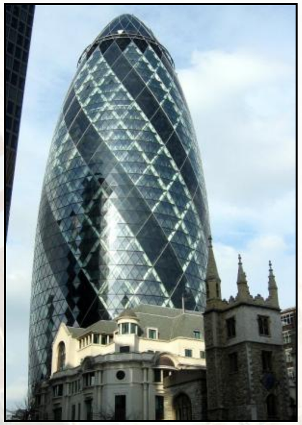
- Communication and discussion between different disciplines, through an integrated and holistic approach to design, leading to achieve the objective – achieving the optimal solution.

History

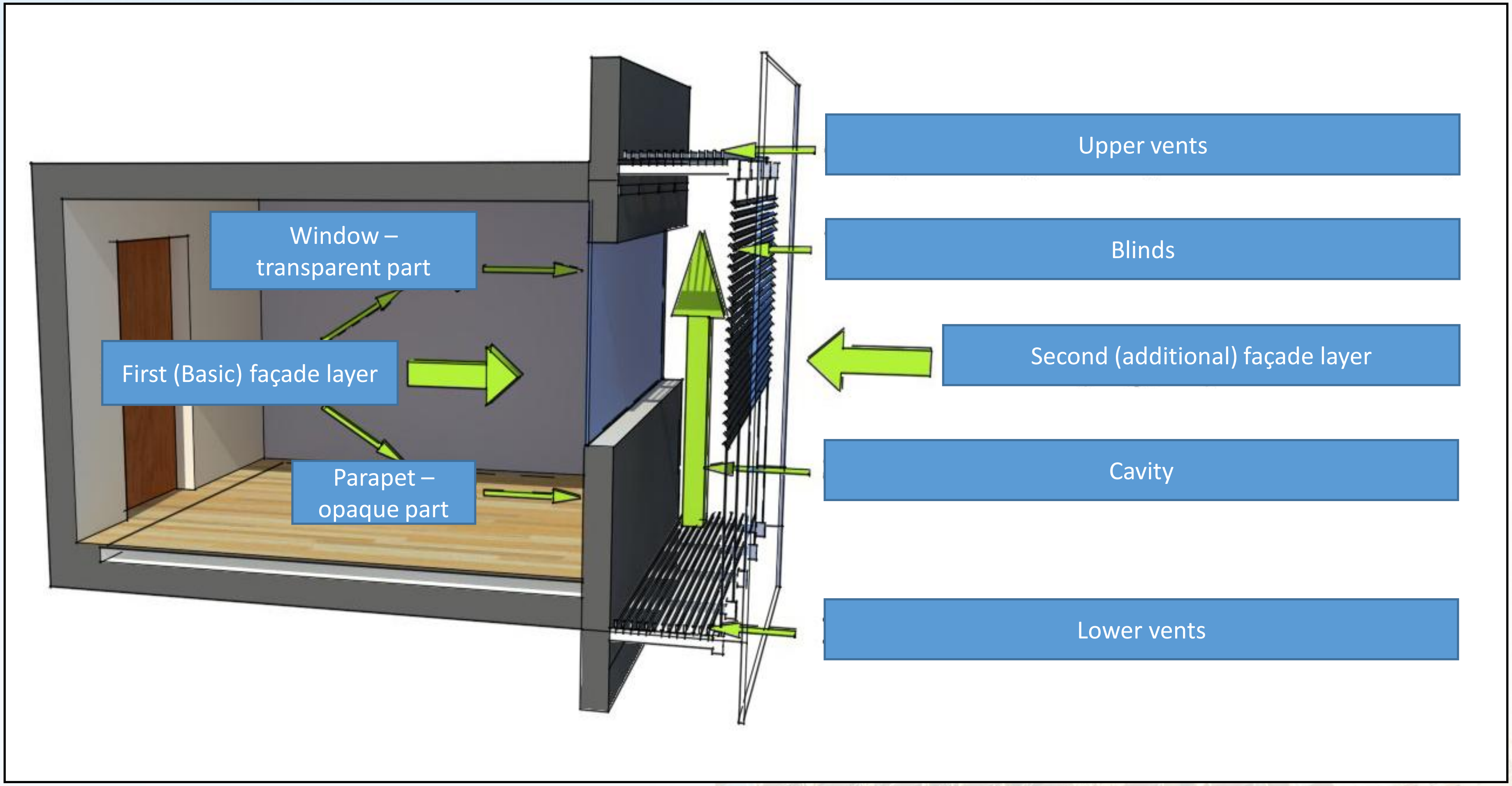
- **Jan-Batist Jobard, 1849**
- **Steiff Factory, 1903**
- **Le Corbusier period from 1926 until 1947**
- **The Ghekin, 2003**
- **The Sydney Tower - 1 Bligh Street, 2011**
- **One Angle Squere 2013**





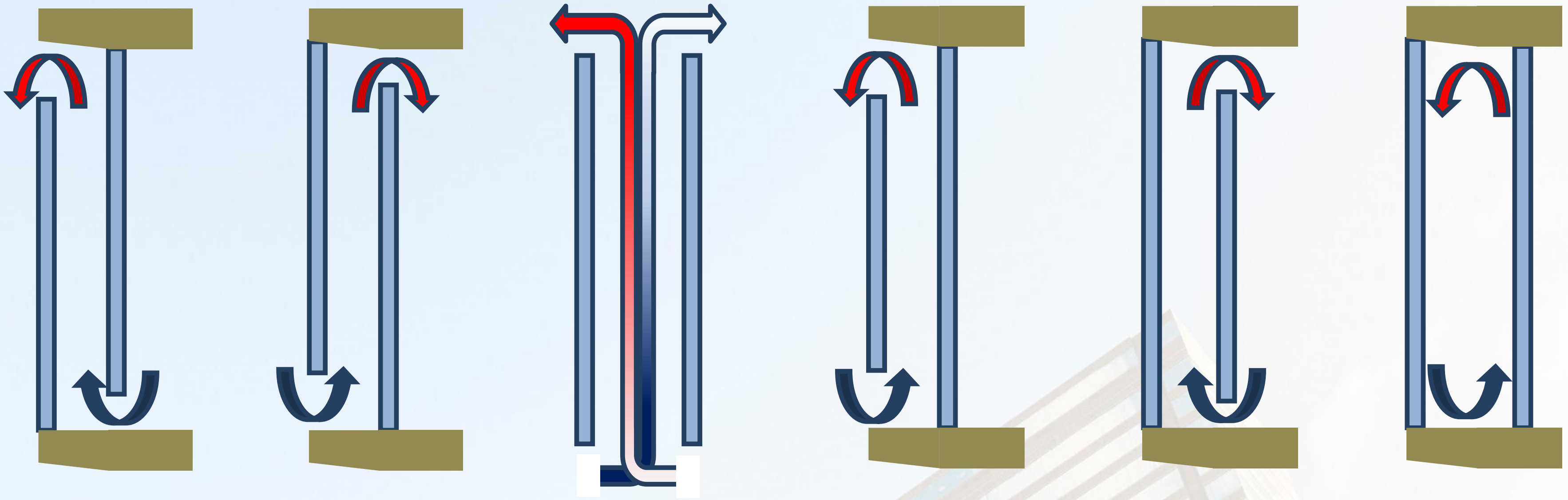


Definition



Upper vents
Blinds
Second (additional) façade layer
Cavity
Lower vents
Window – transparent part
First (Basic) façade layer
Parapet – opaque part

Types



Most of these classifications are essentially based on the geometric characteristics of the facades. Their different modes of working are not always taken into account.

The classification worked out here takes into account the modes of working of the facade and introduces three criteria which are independent of one another:

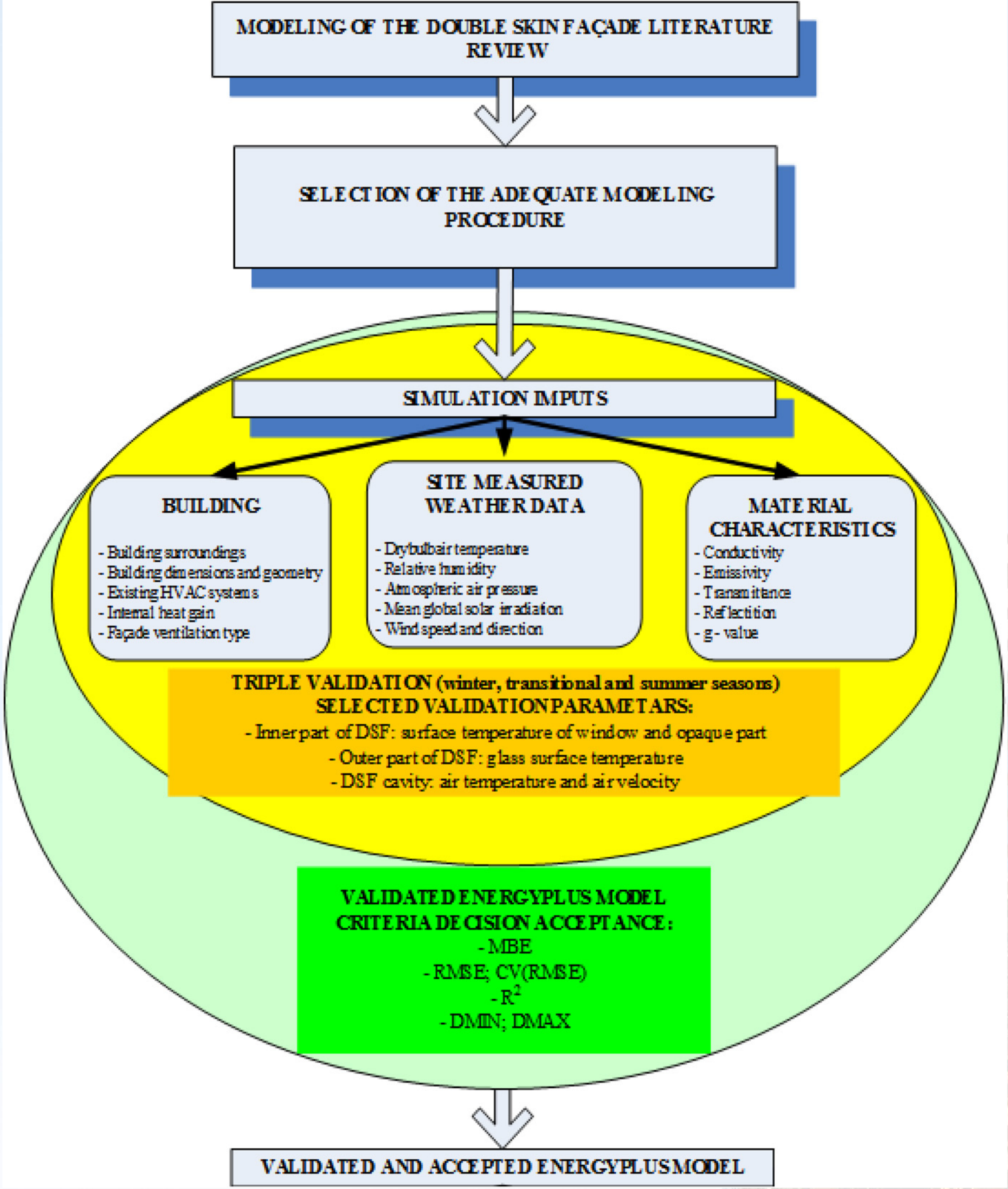
1. **The type of ventilation**
2. **The partitioning of the facade**
3. **The modes of ventilation of the cavity**

Barriers

Differing opinions and experiences have produced problems and doubts among engineers and practitioners. Although current practice has proved great potential of the DSF, designers cannot utilize this concept with confidence. Main reasons for that are:

- Lack of standards, a unique methodology and guidelines on how to design and estimate performance of the DSF,
- Low level of knowledge and experience in design and operation phase,
- For each climate, only a couple of monitored and experimentally tested real building with DSF exist (most results comes from laboratory test cells),
- There is no systematically organized documentation of the energy and environmental performance of existing DSFs.

Research algorithm

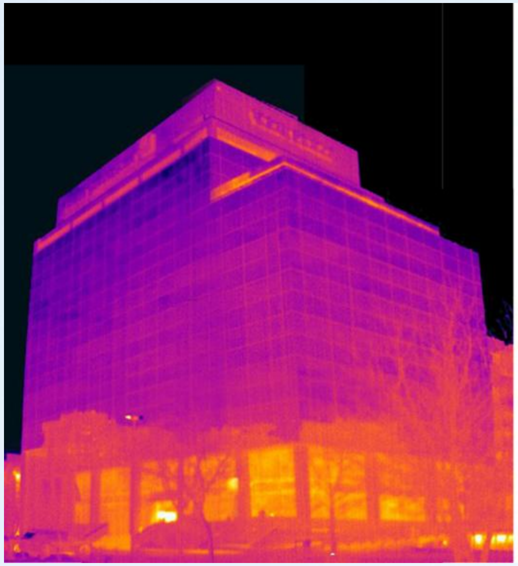


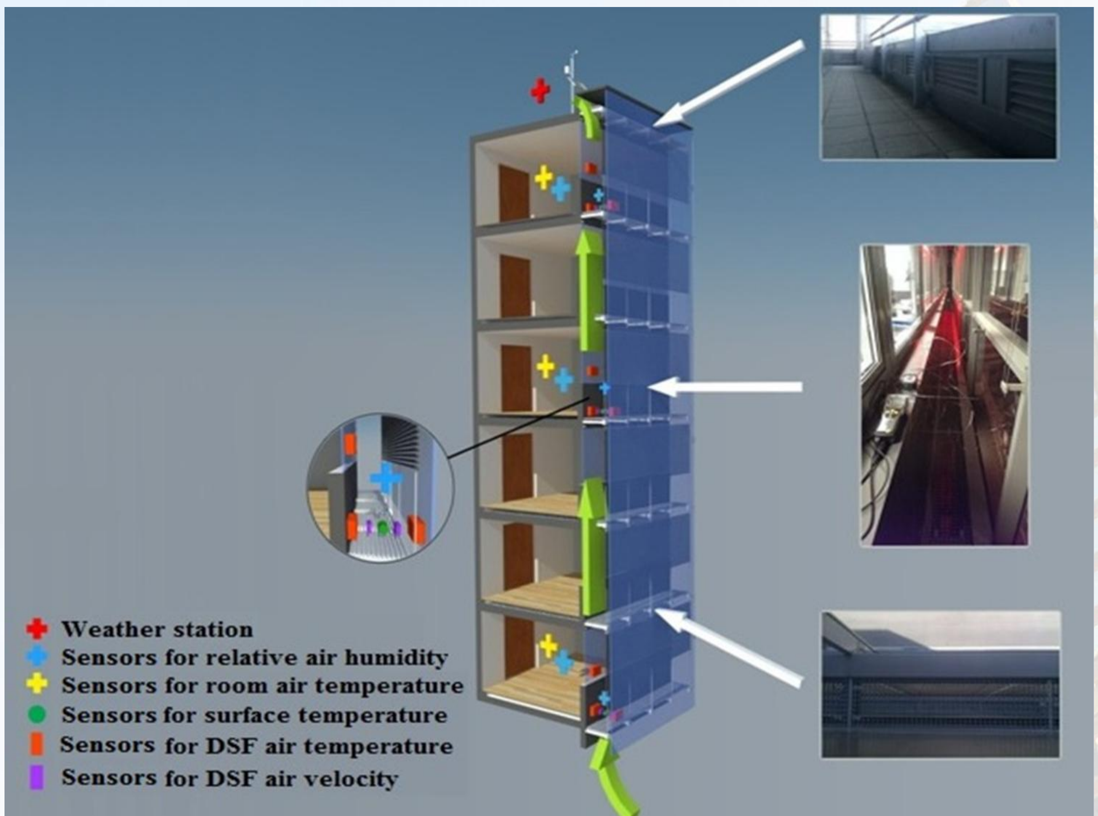
Experimental analysis

Governed by lack of experimentally measured data, a field of detailed measurements were performed during the 2013/14 season in the office building located in Belgrade, Serbia. The uniqueness of this building is that the first facade layer is made in the tradition manner.

The test office building was VIG Plaza, located in Belgrade, Serbia (latitude 44.5°N, longitude 20.3°E, +1h GMT). Climatic conditions in Serbia can be described as moderate-continental with more or less pronounced local characteristics.

The building was finished in 2011 and it is first example of a multi-storey object with DSF in Serbia. Its design represents one of the unique types of DSF. The first facade layer is made in the traditional manner (with transparent and opaque part, WWR is 45%) and additional second layer that is made fully out of glass.




Weather station
Sensors for relative air humidity
Sensors for room air temperature
Sensors for surface temperature
Sensors for DSF air temperature
Sensors for DSF air velocity

Conclusions form experimental analysis

A field of detailed measurement was conducted and this data was used in order to quantify the effects of the DSF. The experiment results highlight the thermal behaviour of the DSF in winter, transitional and summer conditions.

As the facade inlet and outlet are not regulated, its behaviour is strongly related to the current environment conditions (room conditions can be approximate as constant). The measurement analysis at the VIG Plaza suggests that energy effectiveness is not fully met. The central reasons for this are the main design considerations (only aesthetic and noise reduction purpose) and misunderstanding of the facade working principles.

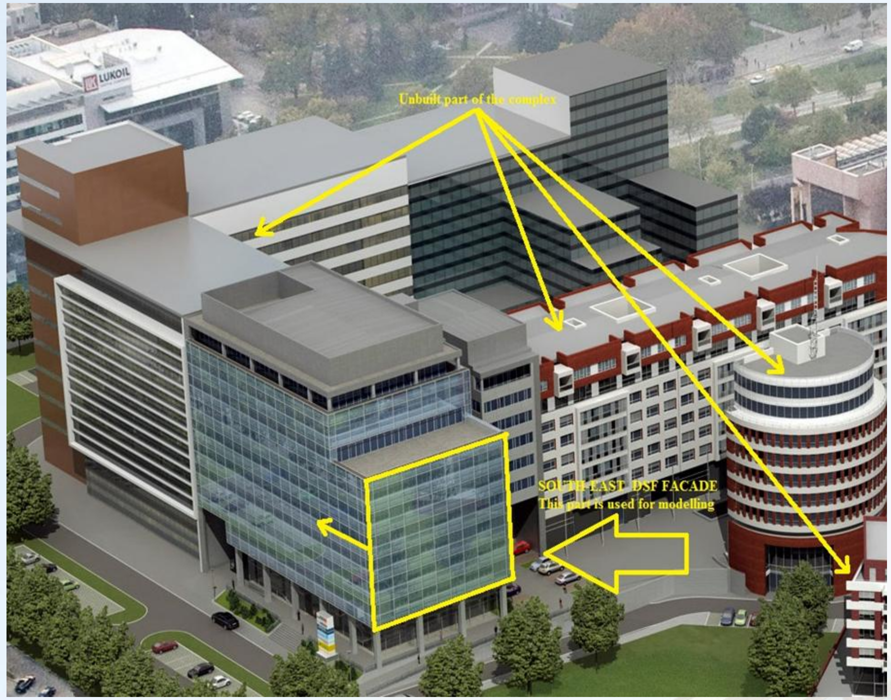
The diversity of the given results for each regime suggests that engineers should recognize that presence of a DSF do not necessarily reduce energy consumption. After all, energy consumption is only one of the many design considerations for DSFs. For this purpose, design processes and future control strategies must be done in a comprehensive manner.

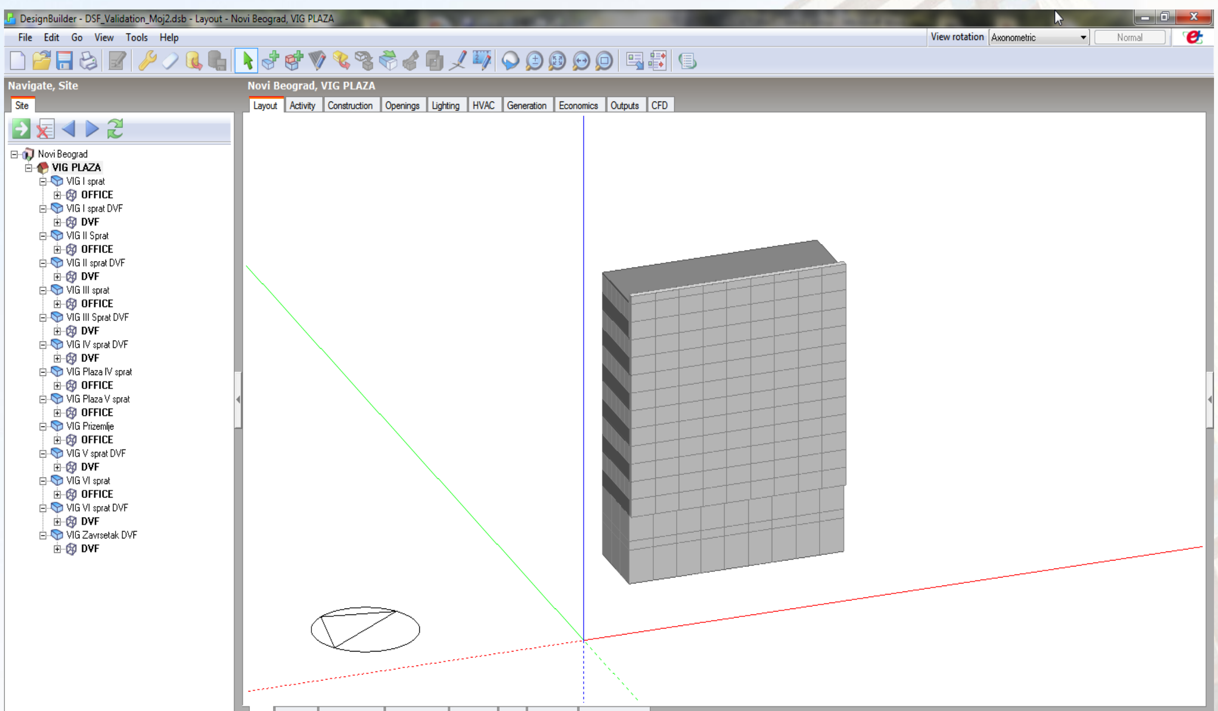
The presented experiment results are very indicative of the best control and operation strategy to optimize and reduce over-all energy consumption.

Experimental validation

For this research part, previously obtained experimental results were used in order to validate simulation model created in software tool EnergyPlus 8.2, combined with Airflow Network Algorithm.

Statistical methods and their indicators are most commonly used to assess the accuracy level of simulation model results. Very important remark is that validation process cannot be just one time activity. Comparatively, for the highest level of reliability, validation process needs to be conducted on a continuous basis. Accordingly, this research will provide triple validation process in three seasons: winter, transitional and summer.


Unbuilt part of the complex
SOUTH-EAST DSF FACADE
This part is used for modelling


DesignBuilder - DSF_Validation_Moj2.dsb - Layout - Novi Beograd, VIG PLAZA
File
Edit
Go
View
Tools
Help
View rotation
Axonometric
Normal
Navigate, Site
Site
Novi Beograd, VIG PLAZA
Layout
Activity
Construction
Openings
Lighting
HVAC
Generation
Economics
Outputs
CFD
Novi Beograd
VIG PLAZA
VIG I sprat
OFFICE
VIG I sprat DVF
DVF
VIG II Sprat
OFFICE
VIG II sprat DVF
DVF
VIG III sprat
OFFICE
VIG III Sprat DVF
DVF
VIG IV sprat DVF
DVF
VIG Plaza IV sprat
OFFICE
VIG Plaza V sprat
OFFICE
VIG Prizemlje
OFFICE
VIG V sprat DVF
DVF
VIG VI sprat
OFFICE
VIG VI sprat DVF
DVF
VIG Zavrsetak DVF
DVF
Edit
Visualise
Heating design
Cooling design
Simulation
CFD
Daylighting
Cost and Carbon

Details about used EnergyPlus and Airflow Network Algorithm simulation parameters

SIMULATION SETINGS	SELECTED TYPE
Solar distribution	Full interior and exterior
Surface convection algorithm (inside)	AdaptiveConvectionAlgorithm
Surface convection algorithm (outside)	MoWiTT
Time step per hour	12
Airflow model	AIRNET Network Algorithm
C_p imput values	G_p generator
Discharge coefficient of the openings between the floors	0.51
Crack Flow trough windows and walls	Air mass coefficient (0.00015/0.00025)
Crack Flow trough vents	0.0015
Air mass flow exponent	0.68/0.68; vents 0.64
People	People/Area 0.15
Lights	Watts/Area 12
Electric equipment	Watts/Area 10
Zone Equipment	ZoneHVAC:IdealLoadsAirSystem
Room temperature – winter season	Between 6AM and 7PM, 23°C Other 17°C
Room temperature – summer season	Between 6AM and 7PM, 23.5°C Other 28°C

Cavity air temperature - simulation, °C
Cavity air temperature - measurement, °C
Winter Season
Transitional season
Summer season
Third zone
Second zone
First zone
Outside air temperature, °C
Mean global solar radiation, W/m2
16/2
17/2
18/2
19/2
20/2
20/4
21/4
22/4
23/4
24/4
5/7
6/7
7/7
8/7
9/7
10/7

Numerical simulations – EnergyPlus modelling

Used indicators:

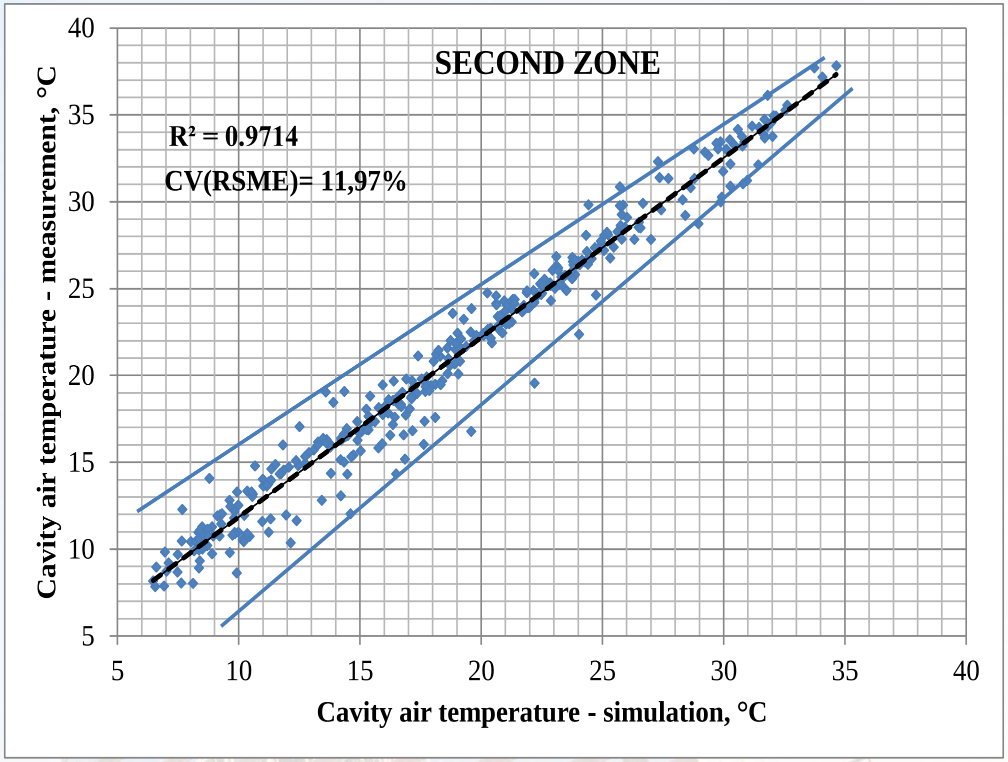
- MBE (Mean Bias Error)
- RMSE (Root Mean Squared Error)
- CV(RMSE) (Coefficient of Variation of the Root Mean Squared Error)
- R^2(Coefficient of Determination)
- DMIN
- DMAX

Conclusions form experimental validation

Ultimate goal for creating a virtual and confirmed model was to further the research of energy simulation studies into the effects of DSF in various scenarios, which were not physically possible as the part of the experimental research.

The combination of software tools EnergyPlus and proved to be a good and reasonable choice when it came to the relation of simulation accuracy and the time required for the simulation. Simulations typically lasted on average 10 min, which can be considered a relatively short time to obtain results.

All of the used statistical indicators have shown a high level of accuracy and matching between the results obtained by the simulation and measurement. Values differ depending on the observed zone and regime.



Numerical simulations – EnergyPlus modelling

The task of this part of the research is a comparative analysis between the current state of a building with DSF and models with traditional envelope type.

The main question that arises is whether and how the DSF may contribute to the decrease in the energy consumption of the building by increasing the quality of the thermal comfort of the occupants.

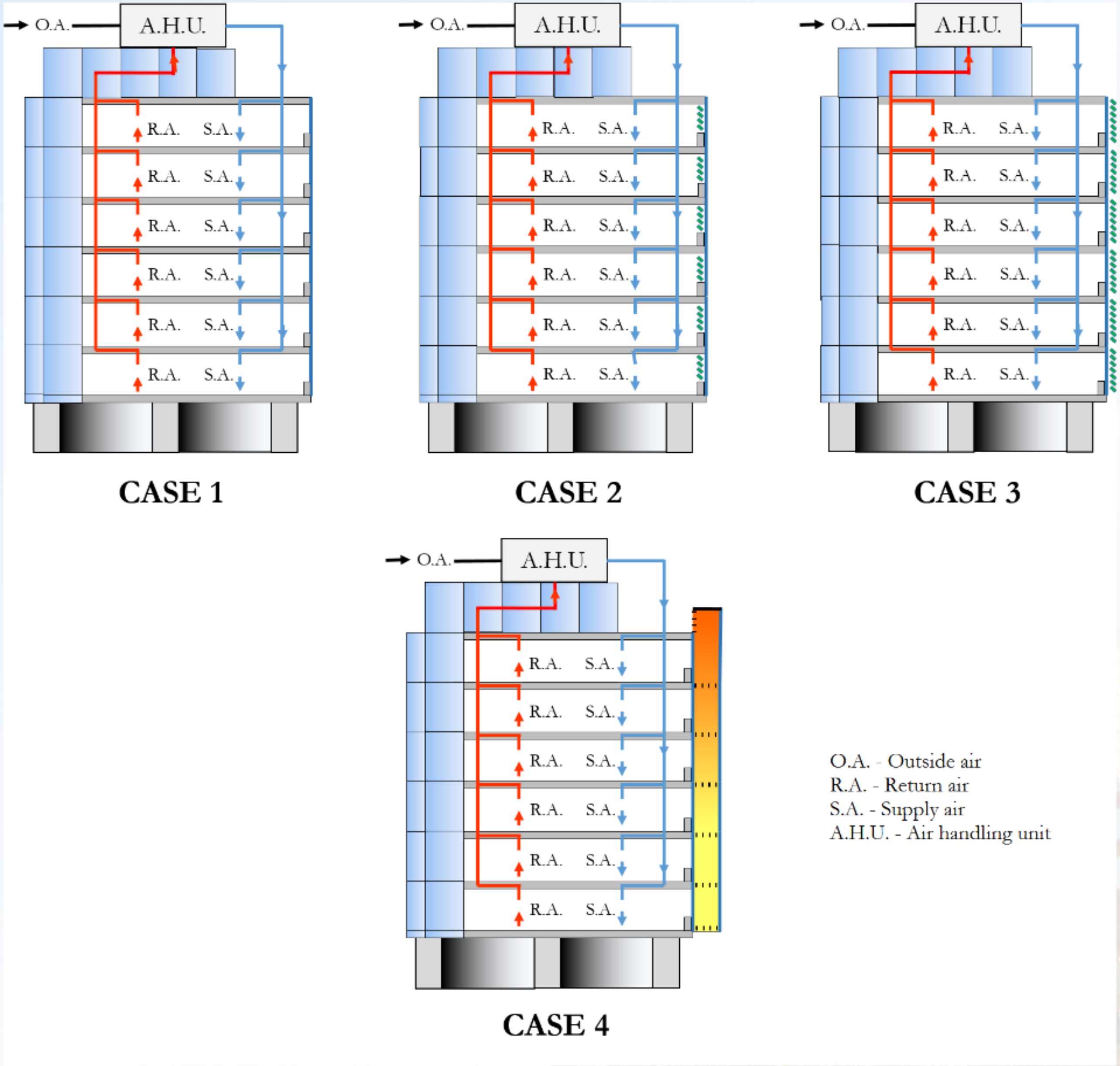
The simulation software tool, EnergyPlus in combination with Airflow Network Algorithm, is used for modelling and all necessary energy calculation.

The validated model in the analysis is used for comparative evaluation with models with traditional facades.

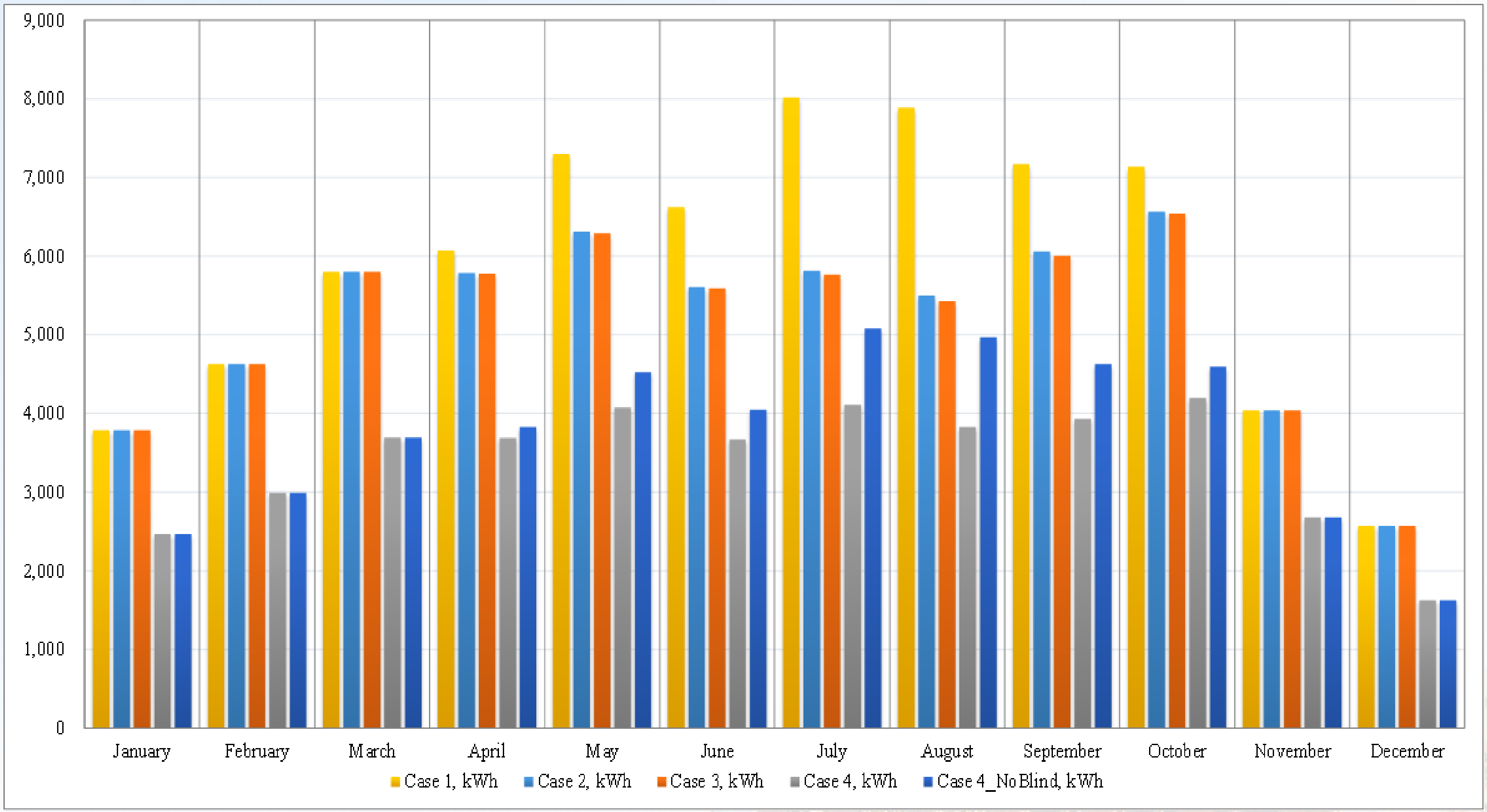
The simulation results for all the models analysed assess what their impact is on the energy consumption for heating and air-conditioning of the building.

When compared to models with traditional facade, the energy analysis shows justification, but also the necessity for an adequate control strategy, for the application of the concept of DSF in the climatic conditions of Belgrade.

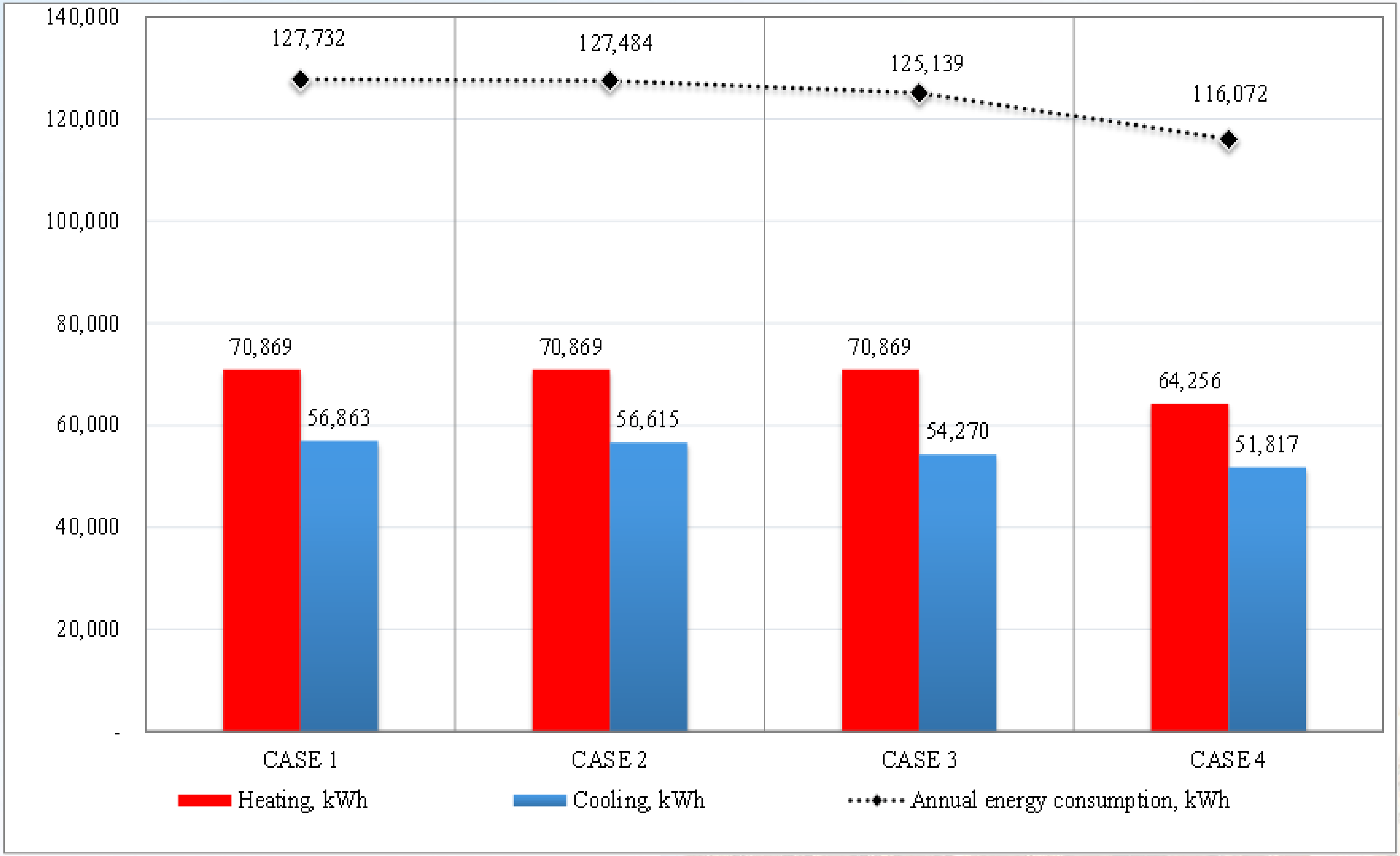
Case studies



Comparative analysis of the solar radiation transfer in air-conditioned areas



Comparative analysis of annual energy consumption



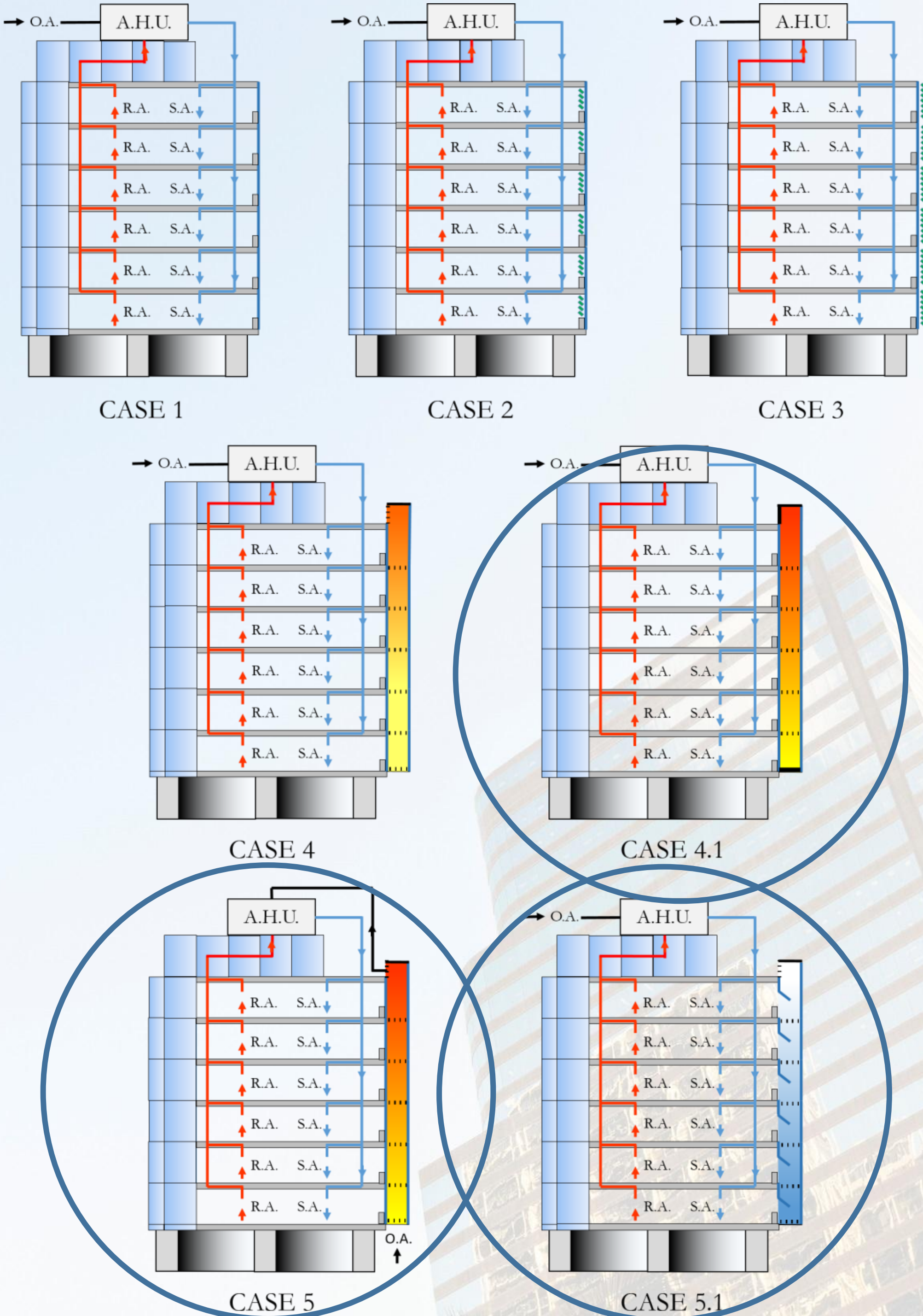
Conclusions and future work from EnergyPlus modelling

As for the cases with traditional facade, the energy consumption for heating is the same, because the blinds are always in the raised position during the heating season. Comparative analysis showed minimal differences between cases 1 and 2, and saving is achieved in energy consumption for cooling (0.4%) due to the presence of internal blinds in case 2.

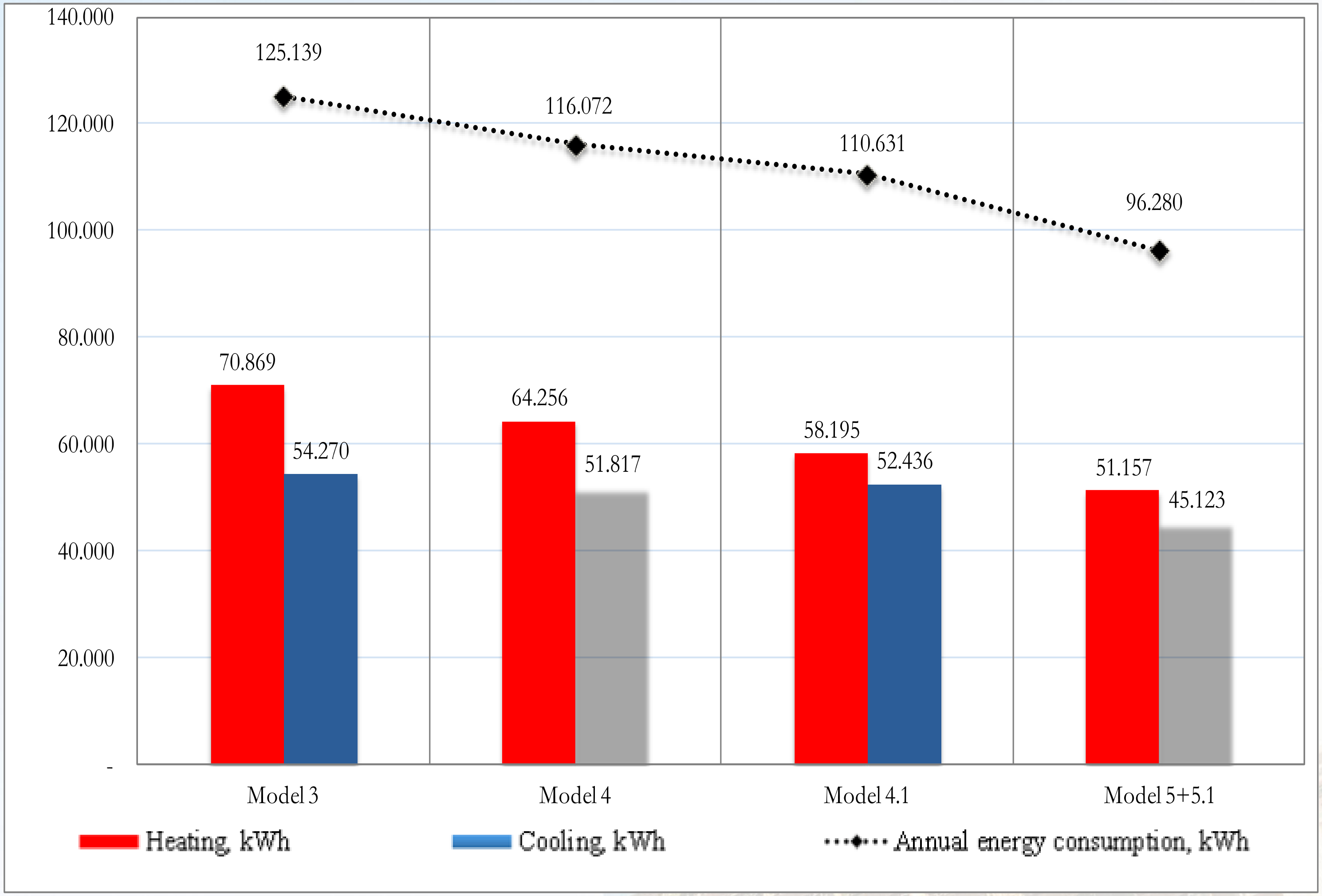
In further comparison, case 3 has seen even greater savings in energy consumption for cooling (5%) compared to case 1, which confirms the assumption that the external position of blinds is the most effective in reducing heat gain.

Comparing the existing building model (case 4) and the most efficient model with traditional facade (case 3), the conclusion is that the DSF concept achieves savings in energy consumption for heating (9%) and for cooling (5%).

However, it was also concluded that there is still more potential for savings if adequate seasonal operational control and management strategies for the facade are applied. This direction is the main goal of future research.

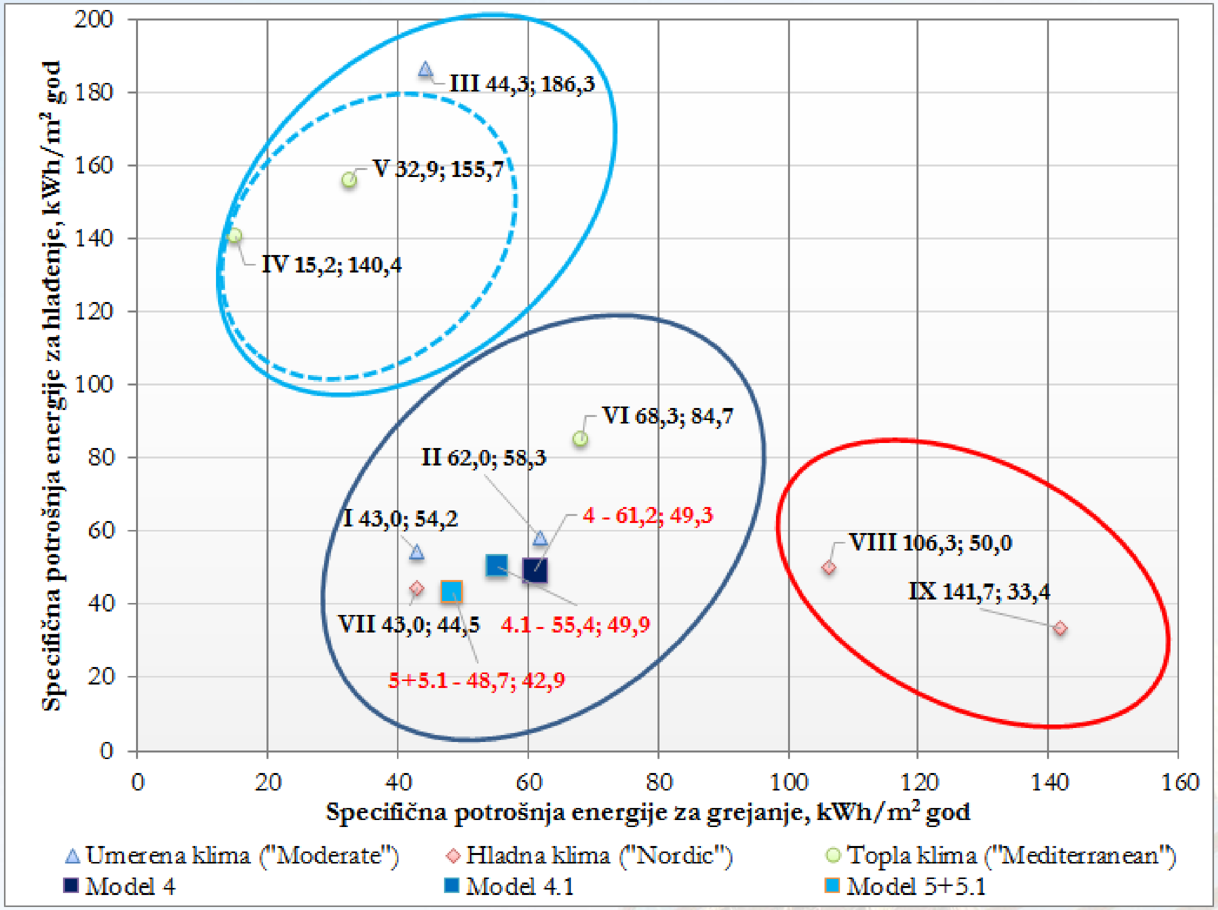

O.A.
A.H.U.
R.A. S.A.
R.A. S.A.
R.A. S.A.
R.A. S.A.
R.A. S.A.
R.A. S.A.
CASE 1
O.A.
A.H.U.
R.A. S.A.
R.A. S.A.
R.A. S.A.
R.A. S.A.
R.A. S.A.
R.A. S.A.
CASE 2
O.A.
A.H.U.
R.A. S.A.
R.A. S.A.
R.A. S.A.
R.A. S.A.
R.A. S.A.
R.A. S.A.
CASE 3
O.A.
A.H.U.
R.A. S.A.
R.A. S.A.
R.A. S.A.
R.A. S.A.
R.A. S.A.
R.A. S.A.
CASE 4
O.A.
A.H.U.
R.A. S.A.
R.A. S.A.
R.A. S.A.
R.A. S.A.
R.A. S.A.
R.A. S.A.
CASE 4.1
A.H.U.
R.A. S.A.
R.A. S.A.
R.A. S.A.
R.A. S.A.
R.A. S.A.
R.A. S.A.
O.A.
CASE 5
O.A.
A.H.U.
R.A. S.A.
R.A. S.A.
R.A. S.A.
R.A. S.A.
R.A. S.A.
R.A. S.A.
CASE 5.1

Comparative analysis of annual energy consumption



Model 3	Model 3	Model 4	Model 4	Model 4.1
Model 4.1	Model 5+5.1	Model 4.1	Model 5+5.1	Model 5+5.1
18%	28%	9%	20%	12%
4%	17%	-1%	14%	13%
12%	23%	5%	17%	13%

Comparative analysis of energy consumption per m² of floor area for different climatic conditions of Europe



Acknowledgments

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Questions?

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