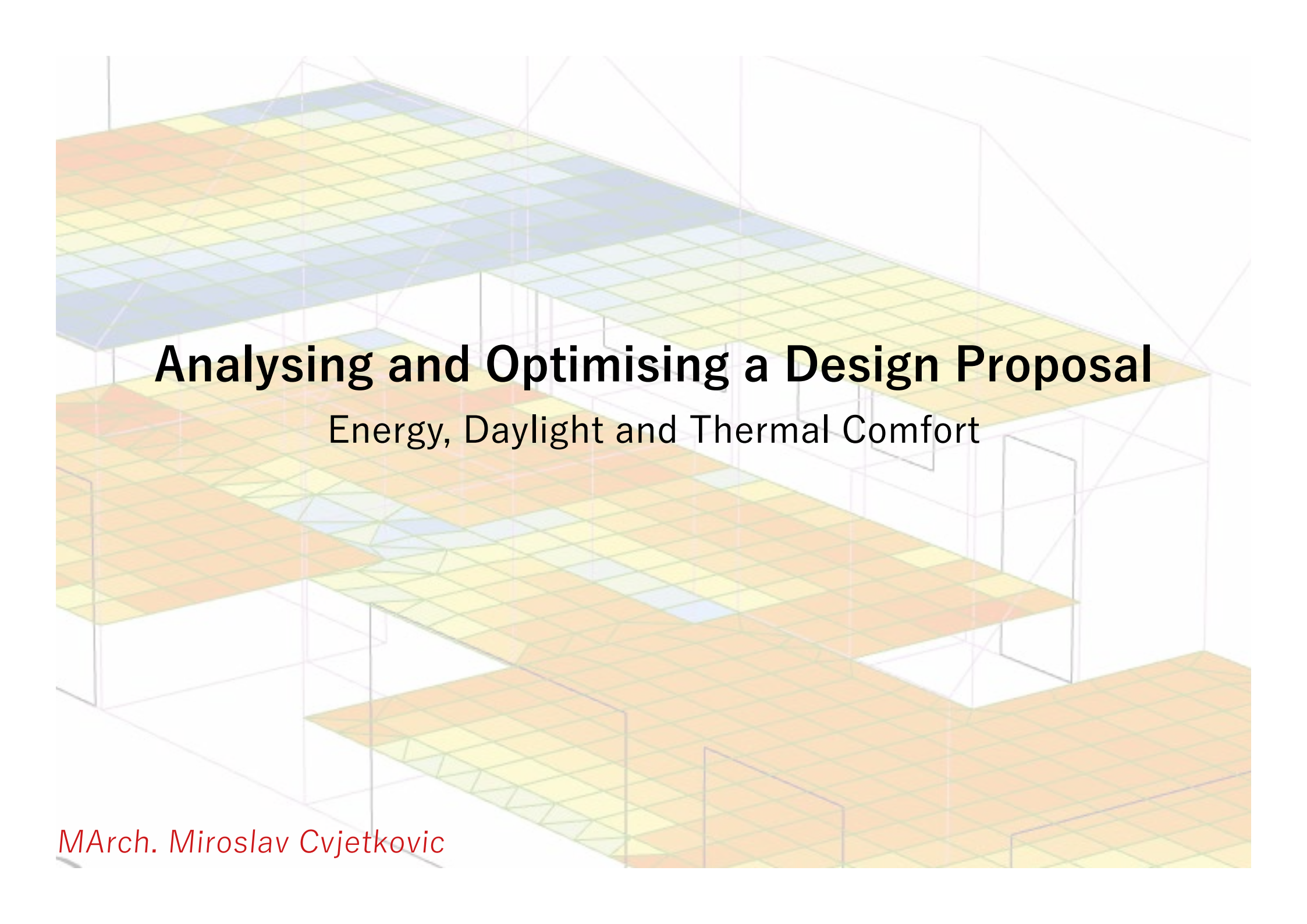


A 3D architectural model of a building with multiple levels. The surfaces are covered with a grid of colored squares in shades of blue, yellow, and orange, representing different material or performance zones. The model is shown in a perspective view, highlighting the spatial layout and the distribution of these zones across the building's footprint and volume.

Analysing and Optimising a Design Proposal

Energy, Daylight and Thermal Comfort

MArch. Miroslav Cvjetkovic

INTRO

This performance analysis serves to evaluate and optimize the energy and daylight quality of a single-family residence design proposal in Sweden.

The goal was to identify targeted improvements with the best cost-benefit balance, and to provide actionable recommendations for the client.

ANALYSIS SCOPE

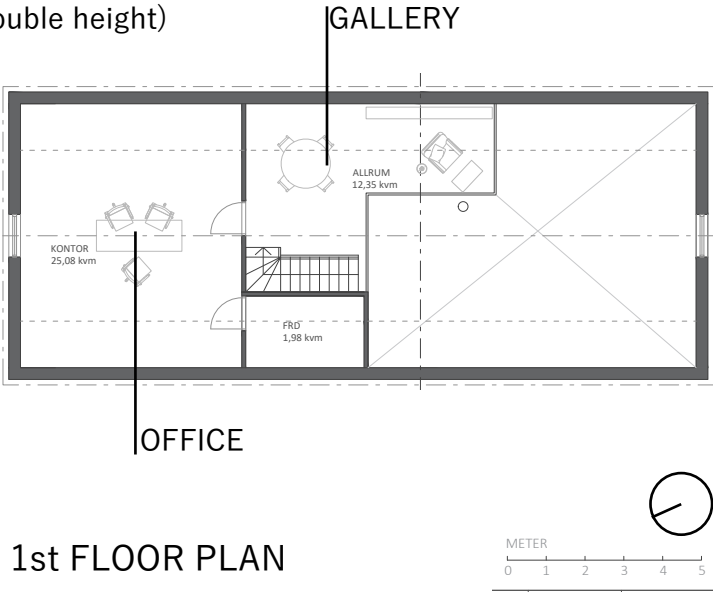
Performance analysis covers:

1. Daylight quality improvement with minimum intervention
2. Envelope upgrade influence on energy demand
3. Cost-benefit analysis
4. Thermal comfort assessment

PROJECT OVERVIEW

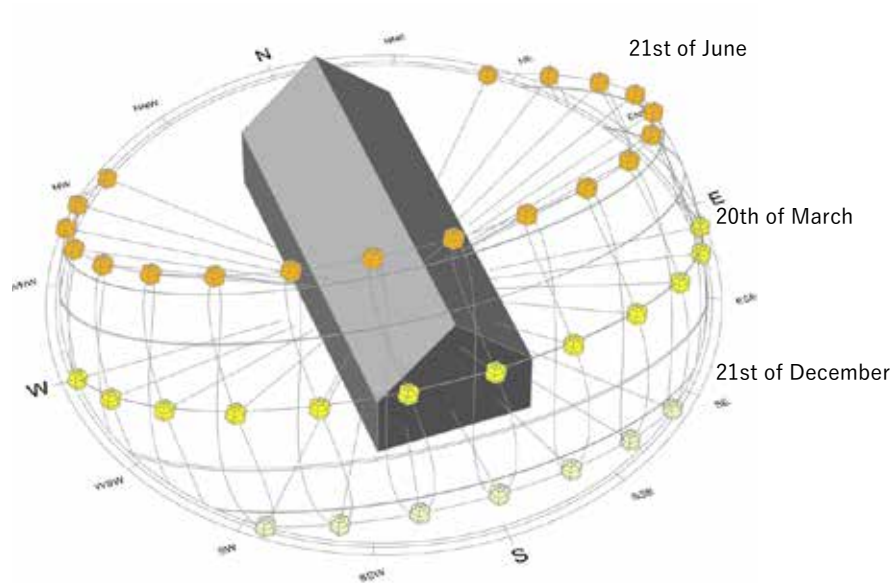


Location: Motala Municipality, SWEDEN
Building Type: Single-Family Residence
Total Floor Area: 210m²
Climate Zone: Dfb (Cold Humid Continental)



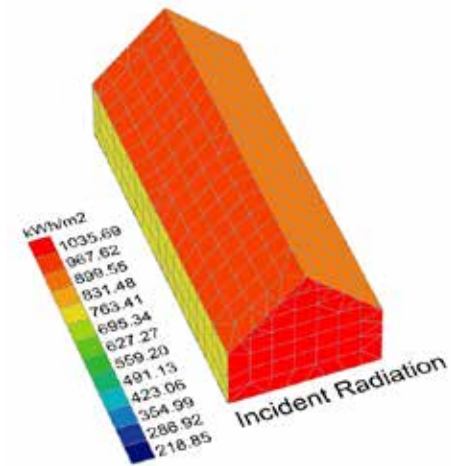
SUN EXPOSURE

ORIENTATION & SUN PATH



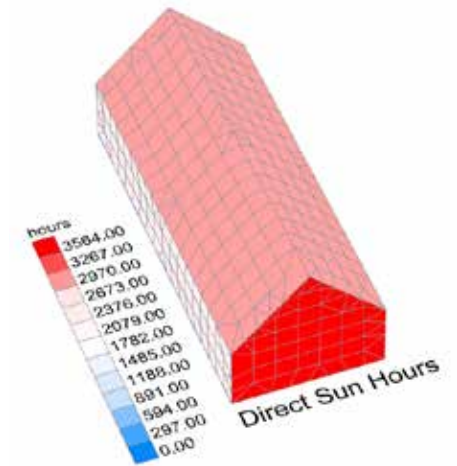
The main living area faces south, while the other rooms are facing east or west allowing balanced daylight in the interior.

INCIDENT SOLAR RADIATION



The west facing roof surface receives 967,62 kWh/m2 - potential for photovoltaic installation.

DIRECT SUN HOURS



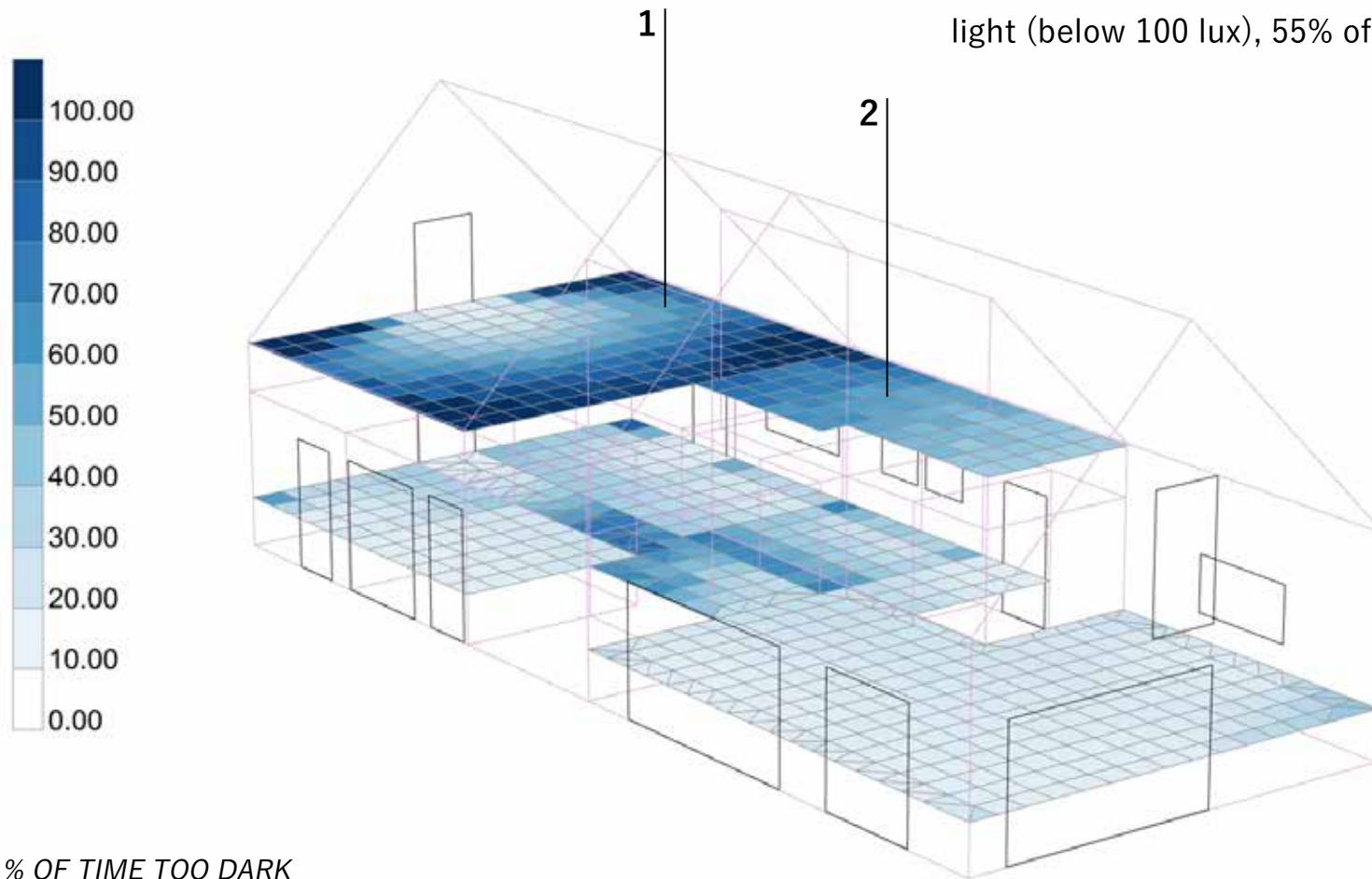
South façade dominates in direct sun hours year-round, offering meaningful passive heating in winter, and potential overheating risk.

NATURAL LIGHT QUALITY OPTIMISATION

UNCOMFORTABLE AREAS- too dark

1. Office space receives below 100 lux, 69 % of the time.

2. The gallery space receives insufficient amount of natural light (below 100 lux), 55% of the time annually.

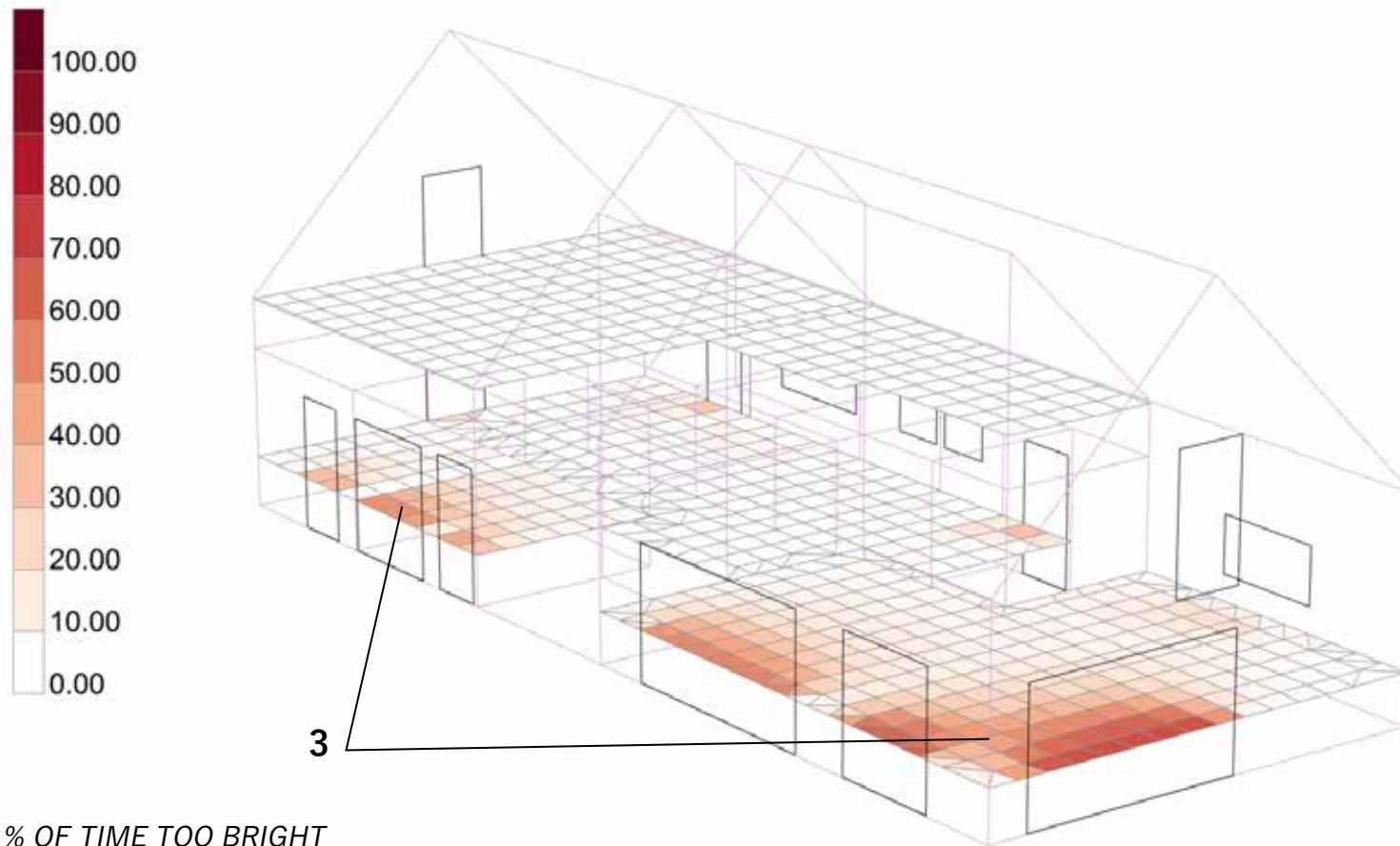


% OF TIME TOO DARK

NATURAL LIGHT QUALITY OPTIMISATION

UNCOMFORTABLE AREAS- too bright

3. Zones around large glazing areas in living room and master bedroom show excessive daylight (above 2000 lux) in up to 60-70 percent of the time annually.



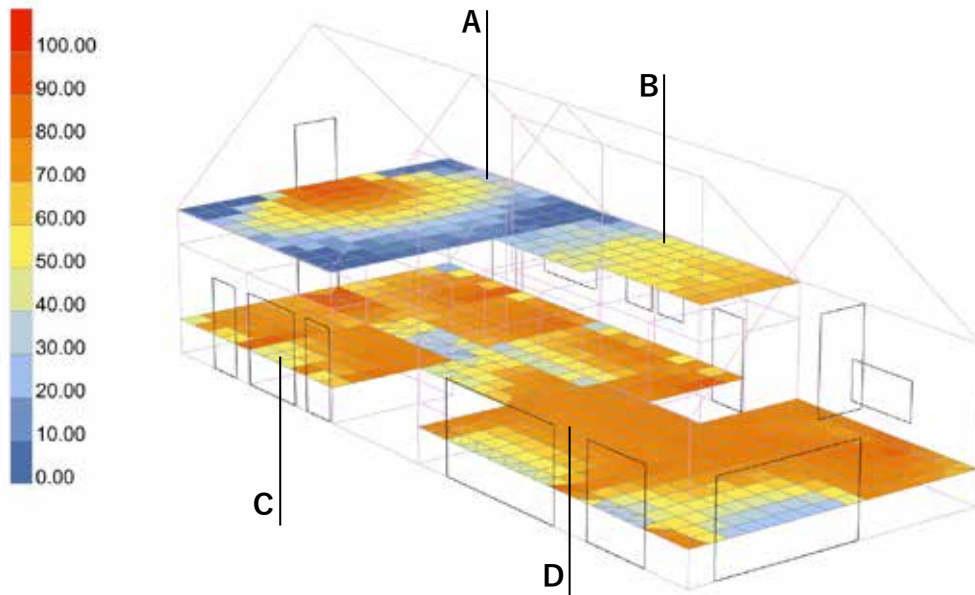
% OF TIME TOO BRIGHT

NATURAL LIGHT QUALITY OPTIMISATION

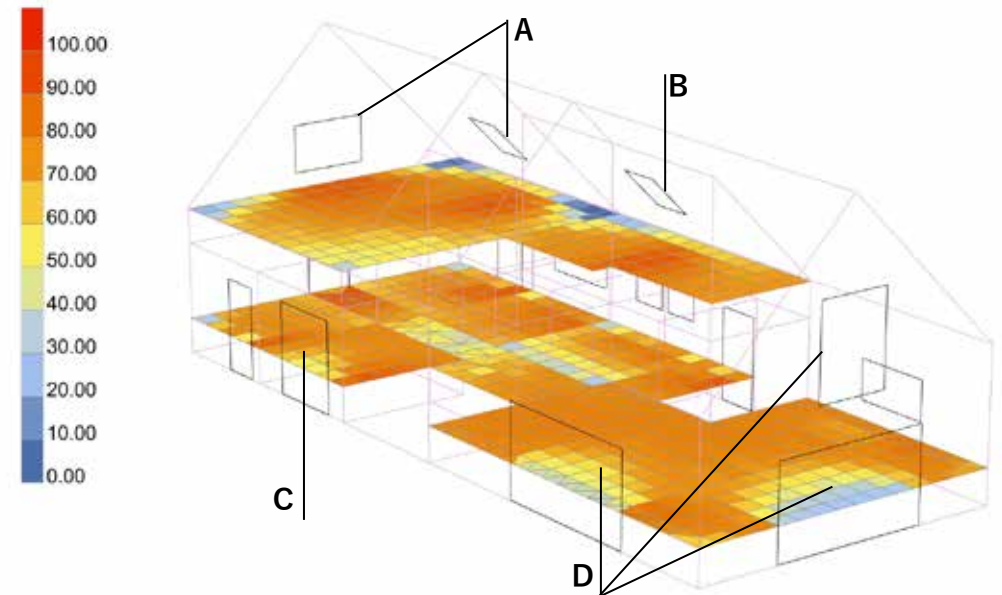
COMFORTABLE AREAS:

EXISTING DESIGN

PROPOSAL:



% OF TIME WITH USEFUL DAYLIGHT (range 100-2000 lux)



% OF TIME WITH USEFUL DAYLIGHT (range 100-2000 lux)

NATURAL LIGHT QUALITY OPTIMISATION

	PROBLEM:	INTERVENTION:	RESULT:
A	OFFICE-Insufficient daylight	Reshaping northern window in the office to maximize daylight and reduce energy loss; Adding a roof window;	Time with useful daylight increased by 32,3%
B	GALLERY- Insufficient daylight	Adding a roof window;	Time with useful daylight increased by 23%
C	M. BEDROOM-Excessive daylight	Cancel one window and reposition the other to optimize the daylight, and reduce excessive light from west;	Time with useful daylight increased by 2%
D	LIVINGROOM- Excessive daylight	Maximizing glazing area on the south façade, reducing glazing area on the west facade;	Time with useful daylight increased by 2%

CONCLUSION:

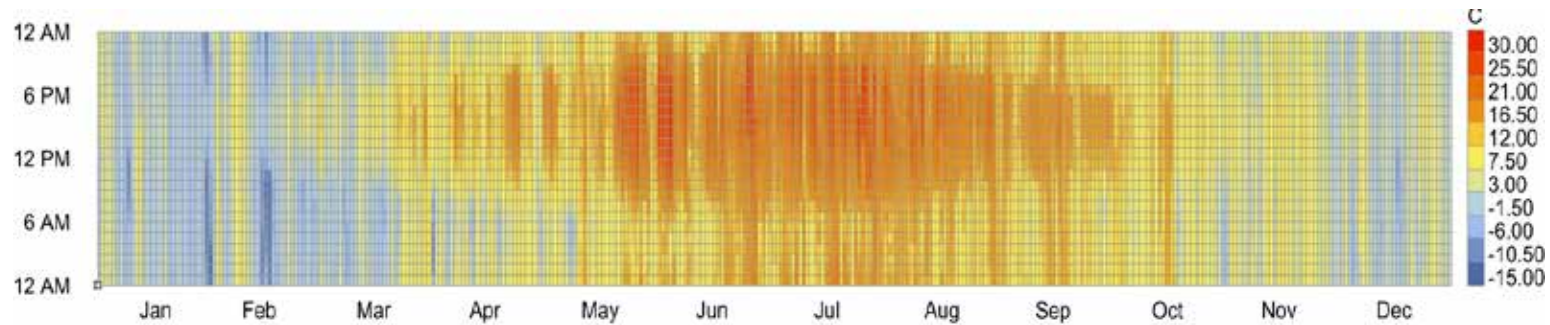
Daylight improved with zero trade-offs;

Comfortable light improved while total glazing area **reduced by 5,6%**;

Energy: 1% saved in energy bills, and also reduced usage of artificial light;

OPTIMISATION OF ENERGY DEMAND

STARTING POINT



Outdoor temperatures fall below zero from late November to March, making heating the dominant energy challenge for this building.



EUI: 99.425 kWh/m²

Heating: 78.233 kWh/m²

Cooling: 4.764 kWh/m²

Lighting: 10.956 kWh/m²

El. equip. : 6.574 kWh/m²

In energy demand breakdown chart, heating by far dominates energy consumption (77%)

OPTIMISATION OF ENERGY DEMAND

STRATEGY:

The goal is to determine how much energy for heating can be saved by improving the building envelope and whether these savings could justify the investment in insulation and windows.

4 scenarios are created, in order to test the performance of the envelope in the following segments:

- 1) wall insulation thickness
- 2) roof insulation thickness
- 3) windows U-Values.

OPTIMISATION OF ENERGY DEMAND

4 TESTED SCENARIOS:

Scenario:	S1- Baseline	S2- Standard	S3- Premium	S4- Walls Only
Wall Ins.Thickness (mm)	150	200	250	250
Roof Ins.Thickness (mm)	250	300	350	250
Glazing U-Value	1	0.75	0.5	1
EUI (kWh/m ²)	99.425	91.599	85.08	94.593
Heating (kWh/m ²)	77.498	69.523	62.826	72.694
Cooling (kWh/m ²)	4.396	4.546	4.723	4.369
El. Lighting (kWh/m ²)	10.956	10.956	10.956	10.956
El. Equipment (kWh/m ²)	6.574	6.574	6.574	6.574

RESULTS:

The Energy demand (EUI) in baseline scenario was reduced by: 5% in S4, 8% in S2 and 15% in S3.

Is the investment in these improvements justified?

OPTIMISATION OF ENERGY DEMAND

COST BENEFIT ANALYSIS:

Scenario:	S1	S2	S3	S4
	Baseline	Standard	Premium	Walls only
Wall Ins. Cost (SEK/m ²):	1150	1400	1650	1650
Roof Ins. Cost (SEK/m ²):	1050	1250	1450	1050
Glazing Cost (SEK/m ²):	6000	9000	15000	6000
Roof win. Cost (SEK/m ²):	14000	20000	35000	14000
Total investment (SEK):	636096.5	838340	1172463.5	717471.5
Annual energy demand(kWh):	20897.25	19235.79	17866.8	19894.53
Annual Savings (SEK):	/	3322.92	6060.9	2005.44
Payback Period (Years):	/	60.86	88.50	40.58

CONCLUSION:

The energy savings in tested scenarios are not enough to justify the investment cost, the payback period is too long.

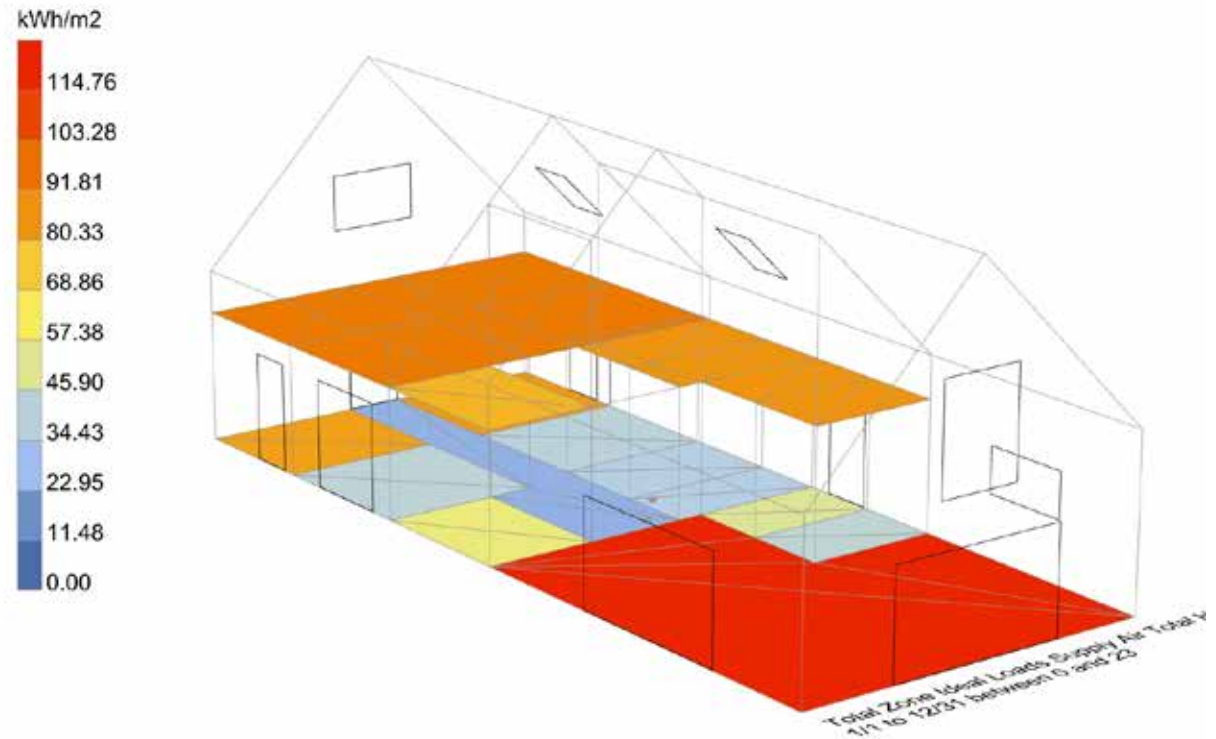
The S1 baseline design envelope gives the best cost-benefit balance compared to the other tested scenarios.

OPTIMISATION OF ENERGY DEMAND

ADDITIONAL CONSIDERATIONS

In addition, heating demand results per room data suggests that the double-height living room area has the highest energy demand per m^2 -114,76 kWh/m^2 .

It is an architectural choice that cannot be compensated through envelope upgrades. It is accepted price for the architectural quality of the space.



Heating demand results per room data

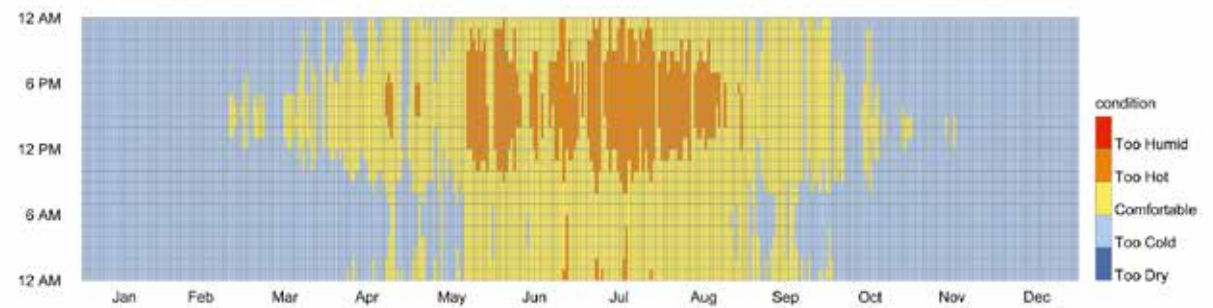
THERMAL COMFORT ASSESSMENT

REDUCING TOO HOT PERIODS

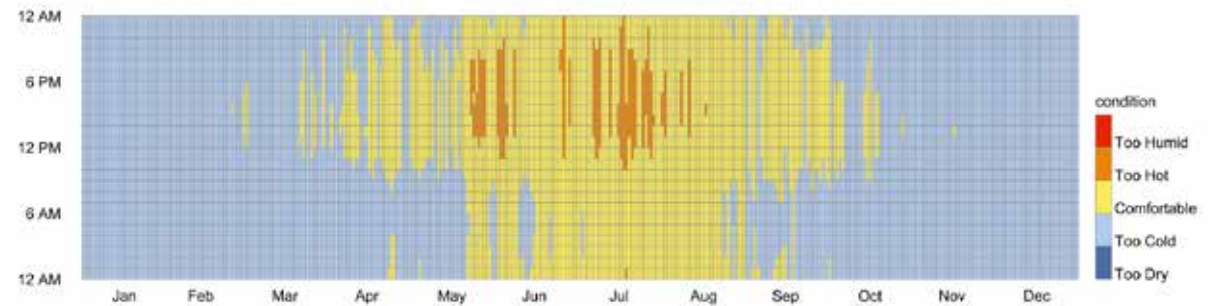
STRATEGY: ADDING LOUVRES TO REDUCE OVERHEATING

Thermal comfort has been simulated for all mentioned scenarios S1-S4.

Simulations show that most of the rooms feel cold October-March and hot in the afternoons June-August.



Thermal comfort map of the livingroom space without louvres



Thermal comfort map of the livingroom space with louvres- Preliminary shading simulation shows significantly reduced overheating

THERMAL COMFORT ASSESSMENT

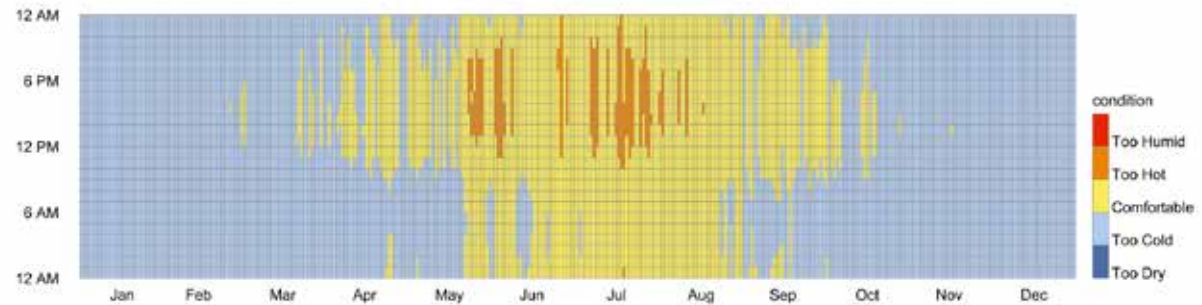
REDUCING TOO COLD PERIODS

STRATEGY: RAISING HEATING SETPOINT TEMPERATURE

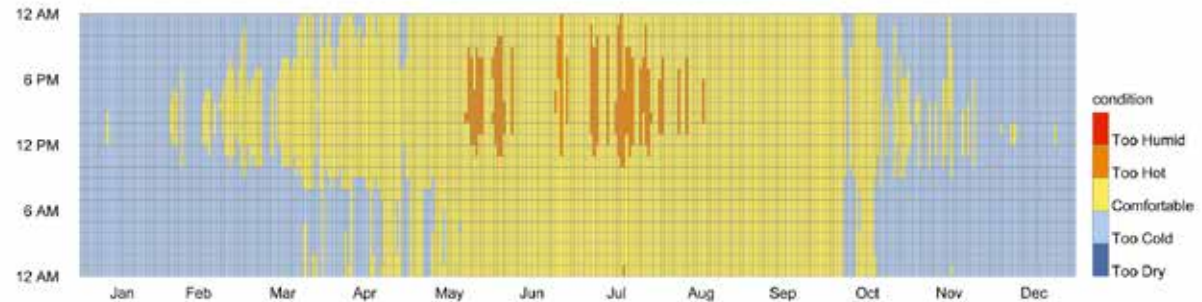
Simulations also showed that improving the building envelope does not meaningfully improve thermal comfort results. The rooms become more comfortable only when the heating setpoint temperature is increased.

Raising the heating setpoint from 20° C to 21° C leads to thermal comfort improvement for 20 percent- average thermal comfort in the house 56%.

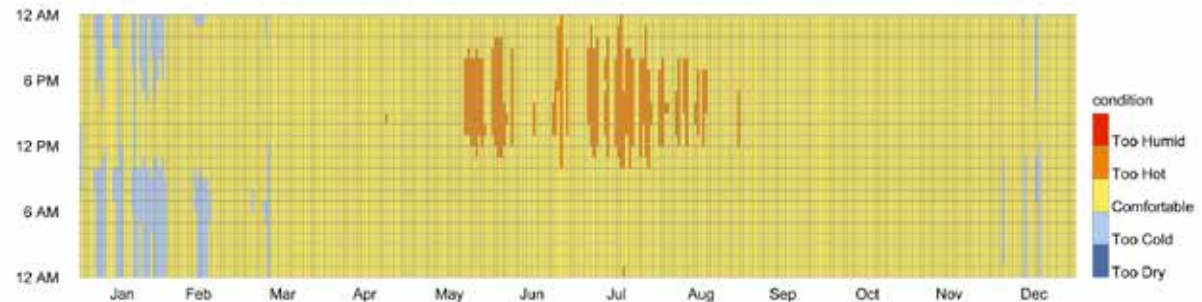
Raising the heating setpoint from 20° C to 22° C leads to almost ideal thermal comfort-97%. However, the heating demand rises for 17%.



Livingroom heating setpoint temperature 20° C.



Livingroom heating setpoint temperature 21° C. Heating demand increases 7%



Livingroom heating setpoint temperature 22° C. Heating demand increases 17%

THERMAL COMFORT ASSESSMENT

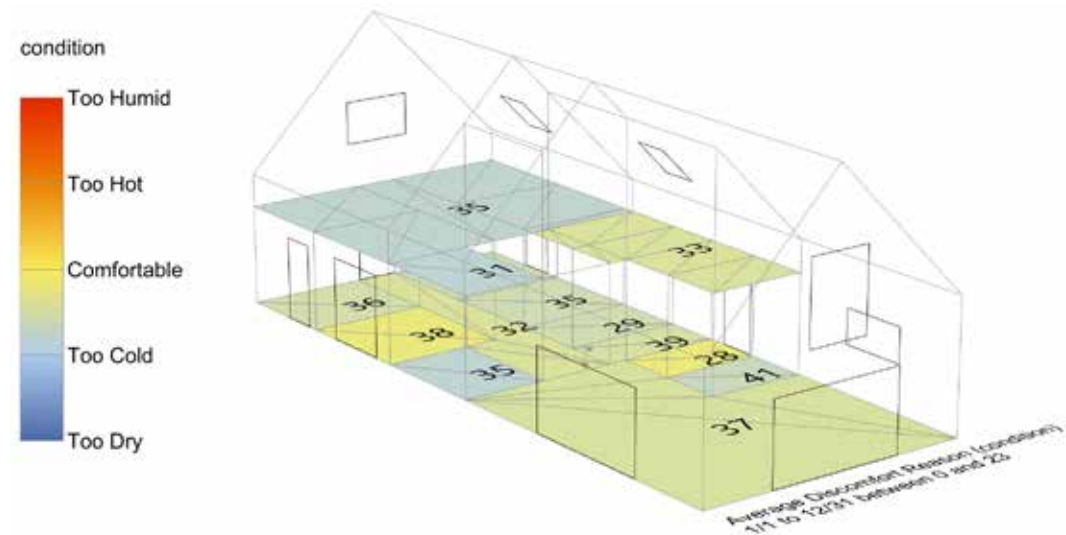
Thermal comfort results can be also shown per room. The comfort condition is indicated with colors and numbers that show the percentage of time when each room is comfortable.

CONCLUSION:

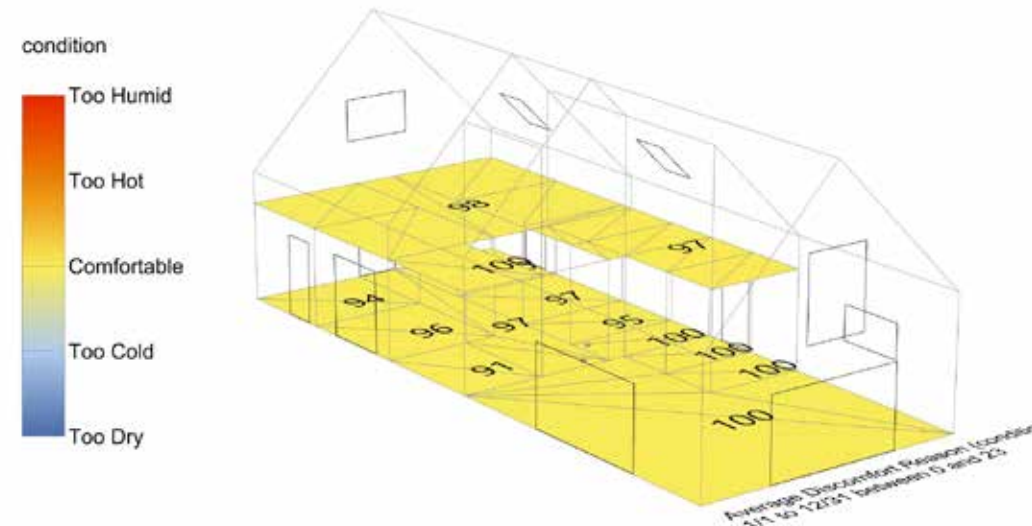
Envelope upgrades do not meaningfully improve thermal comfort — baseline performance is sufficient.

Optimal comfort requires a higher heating setpoint, increasing energy demand. This is a matter of occupant preference, not envelope performance.

THERMAL COMFORT RESULTS PER ROOM:



Baseline design- heating setpoint temperature 20° C- average thermal comfort 36%



Baseline design- heating setpoint temperature 22° C- average thermal comfort 97%

FINAL RECOMMENDATIONS

Daylight

- Implement proposed window modifications — 32% daylight improvement in office, 23% in gallery, at minimal construction cost, and without compromising energy demand.

Energy

- Retain baseline envelope — investment in upgrades is not justified. Pay-back periods range from 40 to 88 years.
- The double-height living area carries an inherent energy cost of 114 kWh/m². This is an architectural quality worth preserving — its impact is understood and accounted for in this analysis.

Thermal Comfort

- Consider external shading on south and west glazing to reduce afternoon overheating. Preliminary simulation confirms effectiveness.
- Optimal comfort is achieved at 22° C setpoint. This increases energy demand by 17% but delivers 97% comfort across all rooms — a conscious trade-off for the occupant.

