Optimizing the design of retirement homes concerning the indoor environment, energy efficiency, and climate change resiliency

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SUMMARY

This study explored the design optimization possibilities for Danish retirement homes while considering an increased risk of overheating due to elevated temperatures imposed by climate change. The focus was on combinations of design features and technical components ensuring thermal comfort and daylight. The study used a dynamic simulation tool to consider the current Danish design reference year and future climate predictions. The results indicate that using predicted climate data for 2050 could reduce overheating degree hours by 80% due to predicted direct solar radiation discrepancies. The study suggests using heatwave data to assess occupants' heat exposure. Design measures such as solar control coating on glazing reduced overheating by up to 53% while reducing daylight and increasing heating energy consumption. Ventilation hatches provided increased airflow and mitigated overheating without increasing energy consumption. A combination of static shading, solar control coating, and natural ventilation was sufficient for south-facing windows, but dynamic shading was necessary for east and west-facing windows.

KEYWORDS

Thermal comfort, daylight autonomy, elderly home, design optimization, climate change

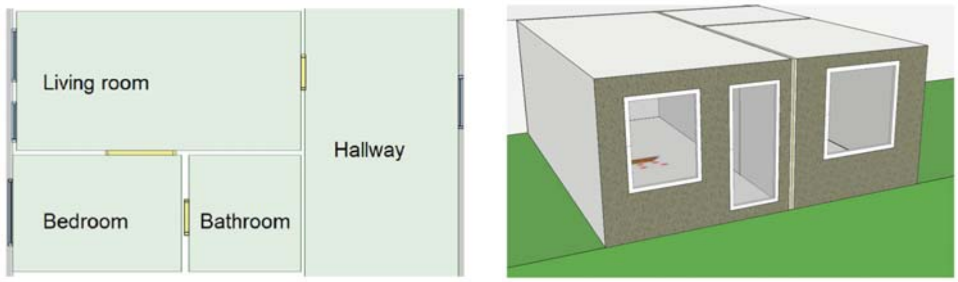
1 INTRODUCTION AND OBJECTIVES

Climate change is one of the biggest challenges facing modern society. One expected consequence in Northern Europe is longer-lasting summers with more frequent and intense heat waves (Meehl, Tebaldi 2004). Denmark and other northern European countries have ambitious goals regarding reducing CO_2 emissions and energy efficiency. At the same time, they require high indoor environmental quality (IEQ), including daylight. The consequence is highly airtight and insulated buildings with pronounced glazed areas that tend to overheat (Simone et al. 2014). The climate change with heat waves and prolonged warm periods, together with buildings that have a tendency to overheat, mean a significant danger for the most sensitive members of the society- young children and the elderly Bundle et al. (2018).

Our objective was to investigate how future weather conditions can be considered during design of retirement homes. We explored combinations of building design and design of building services (e.g. ventilation, heating, solar shading) that would be able to ensure high IEQ.

2 METHODS

The study design and investigated technological solutions were based on interviews with construction professionals working on retirement home projects. We conducted a typology study of 57 buildings to identify representative typical geometry and other characteristics of Danish elderly homes. Based on that, we modelled a two-bedroom nursing home apartment using a dynamic building simulation tool (Figure 1). The constructions were following current Danish building regulations (BR18 2024).



a) b)

Figure 1: a) Floorplan of a simulated apartment in the retirement home, b) 3D representation of the model

For yearly simulations, we used the current Danish design reference year (DRY2013) and Typical Meteorological Year data for years 2050 and 2090 (RCP 8.5), according to Witchen et al. (2021). We added an extra heat wave scenario using historical weather data to ensure that the overheating risk was not underestimated. We used weather files for extremely high temperatures and extremely high solar radiation levels by (Witchen et al. 2021) but simulated only two weeks in August. Table 1 summarizes the modelled technical solutions.

Table 1: Modelled technical solutions

Component	Description
Ventilation hatches	C_d = 0.3, effective opening area 74%, U = 0.3 W/m^{2}K
Low energy glazing	g = 0.54, U = 0.61 W/m2K, Tvis = 73%
Solar control glazing	g = 0.31 and 0.28, U = 0.58 W/m^{2}K, T_{vis} = 63% and 53%
Static solar shading	Overhang (0.25-2.5 m), vertical fins (0.25-1.6 m), loggia (2 m deep)
Active solar shading	External blinds: T_{vis} = 0%, R = 0.67 and external screen: T_{vis} = 3%, R = 0.09, controlled by the solar radiation on the façade (threshold range 100-250 W/m^2)
Mechanical ventilation	CAV at 15 L/, 20 L/s and 30 L/s, VAV 11.6 (0.3 L/s·m^2)-30 L/s, controlled by CO_2 and temperature

3 RESULTS AND DISCUSSION

First, we evaluated all technical solutions separately. Consequently, we evaluated their combination. Figure 2 shows an example of the results evaluation design scenarios using dynamic shading and VAV ventilation.

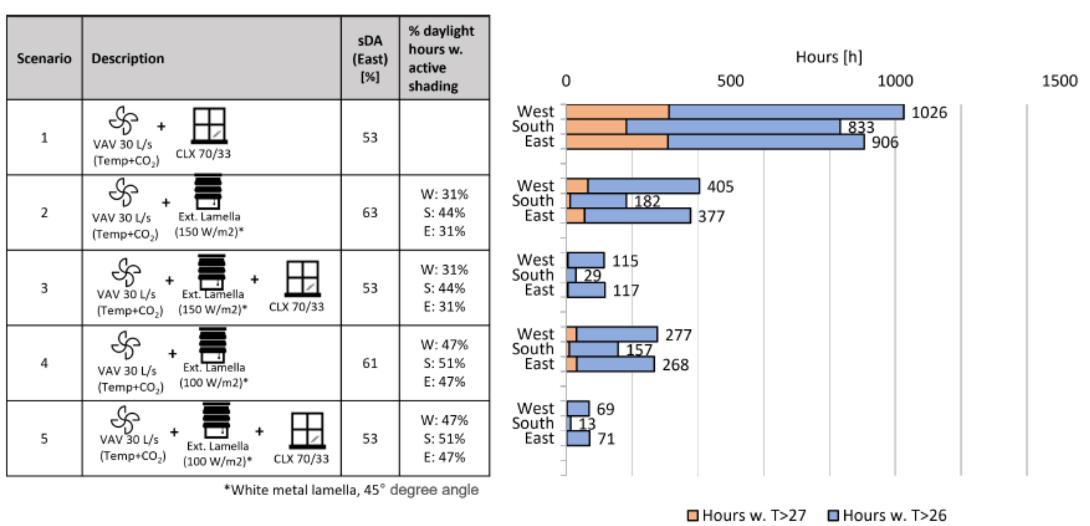


Figure 2: Example of results evaluating combinations of technical solutions. CLX is solar control glazing, T is operative temperature; sDA is spatial daylight autonomy.

Figure 3 shows the optimum set of design scenarios towards the south evaluated according to DR2013 and heat wave weather data.

Scenario	Description	[°C h] DRY2013	[°C h] Extreme heat	Δ[°C h]	HWP
S1	H: 1.15m + CLX 70/33 + Temp. Ctl. + Summer open at T_{amb} >16°C	3	19	15	0.4
S2	H: 1.15m + CLX 70/33 + CAV 20 L/s	9	54	46	1.3
S3	2m Int. balcony + Temp. Ctl. + Summer open at T_{amb} >16°C	8	35	27	0.8
S4	MS-F 60/14 + CLX 70/33	9	91	82	2.3
S5	Ext. Lamella (150 W/m2)* + CLX 70/33 + VAV 30 L/s (Temp+CO_2)	4	14	11	0.3

Figure 3: Example of results evaluating combinations of technical solutions. °C·h - degree hours according to EN 16798; HPW is heat wave performance index – lower number indicates better performance during heat waves.

4 CONCLUSIONS

- Future weather conditions could be considered by assessing the heat exposure of building occupants during a heatwave instead of using projected future weather data.
- The solar control glazing was an effective solution to reduce overheating by up to 53%. However, it also reduced spatial daylight autonomy by up to 13% and increased heating demand by up to 6%.
- Natural ventilation through ventilation hatches could increase airflow by up to 10 L/s, averaged over a month during summer, helping to mitigate overheating without increasing ventilation energy consumption.
- A combination of static horizontal shading, solar control coating, and natural ventilation was sufficient for South-facing windows. However, dynamic shading was necessary for East and West-facing windows to reach the thermal comfort target.

5 REFERENCES

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