Multi-angled Façade System for Office Building Renovation

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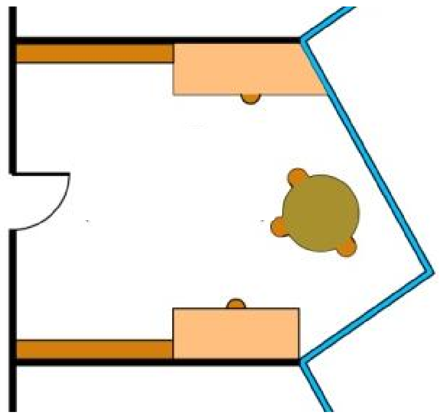
Introduction

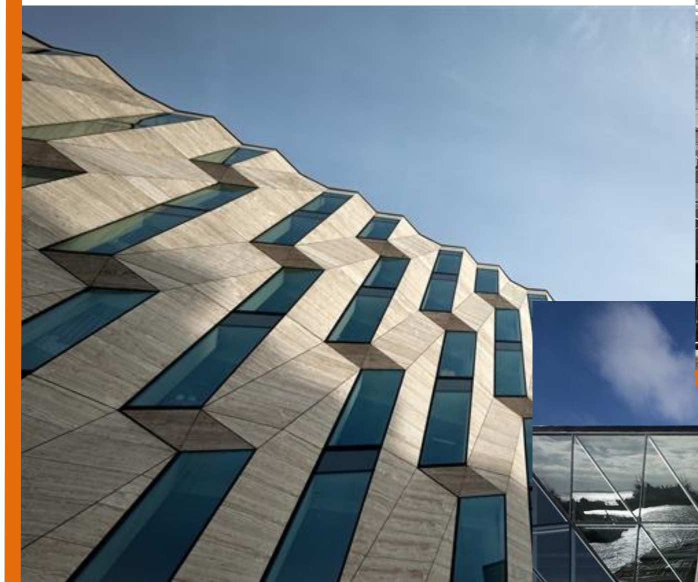
- An interdisciplinary study focusing on the potential of multi-angled façade systems in optimizing indoor climate and energy performance and in creating new architectural qualities.

- Proposing the use of two different orientations of windows in each façade with the appropriate window properties and solar shading control system.



Introduction

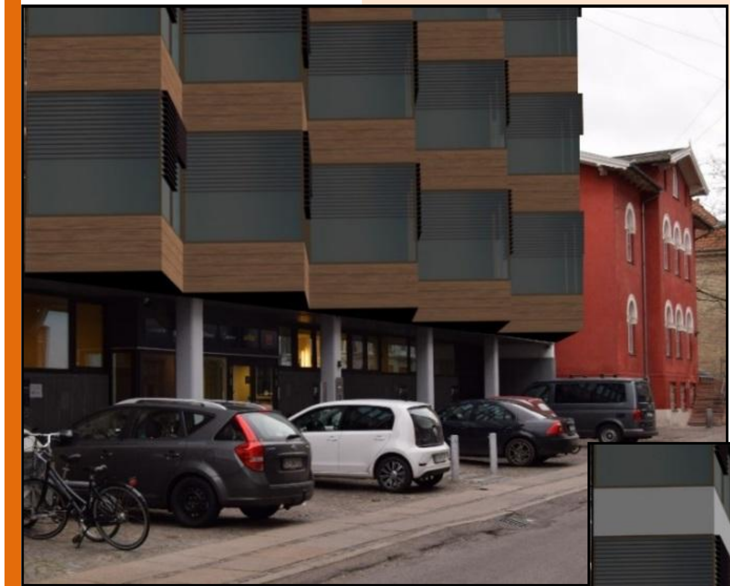
Building: Horten
Architect: 3XN
Hellerup, Denmark



Building: Niels Bohr
Architect: Vilhem-Lauritzen
Copenhagen Denmark

Building: Kulturværftet
Architect: AART
Helsingør, Denmark

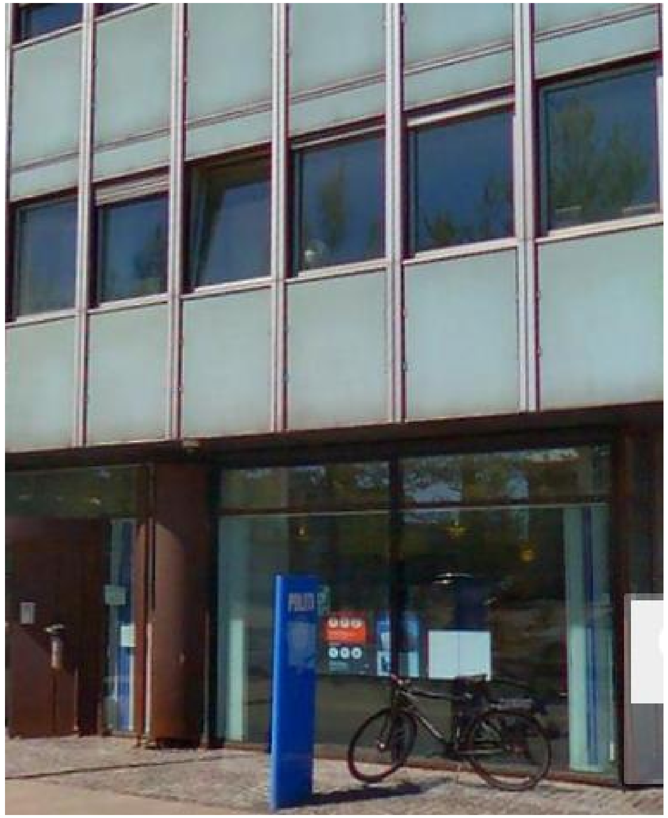
Introduction



Background

- A large number of office buildings in Denmark are facing problems regarding high energy consumption, poor indoor climate and problems with durability.
- The Danish government has announced a strategy for renovation of buildings in Denmark.

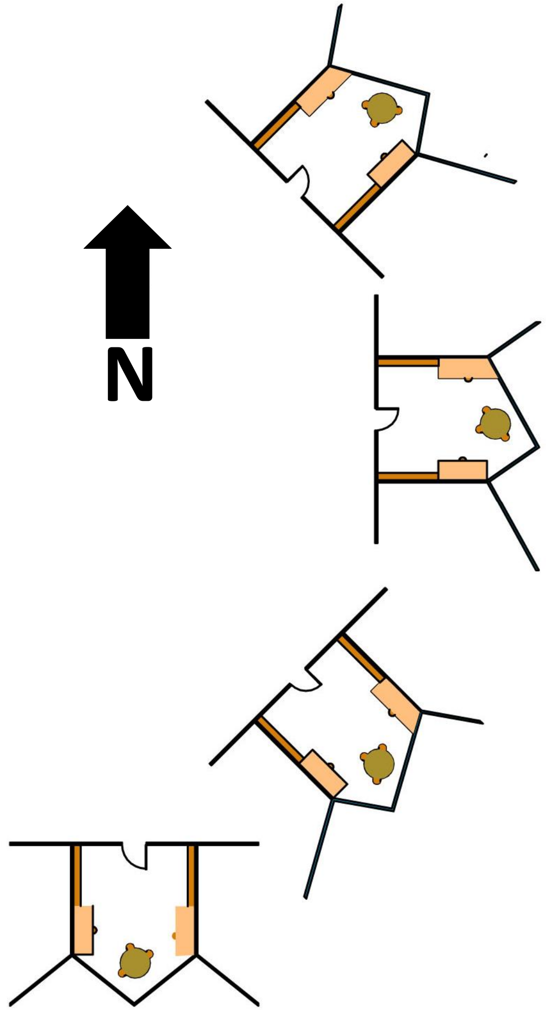
  Large part of The renovation will be on buildings constructed between 1960 and 1980.



An office building built between 1960 and 1980

The technical concept

- The proposed façade is a multi-angled façade consisting of two parts:
  - A larger part oriented more to the north to provide with daylight,
  - A smaller part oriented more to the south to provide with solar heat gain (as shown in the figure to the right for different façade orientations).
- The distance of the extension from the original façade, the solar shading system and the window properties will be evaluated in different scenarios.



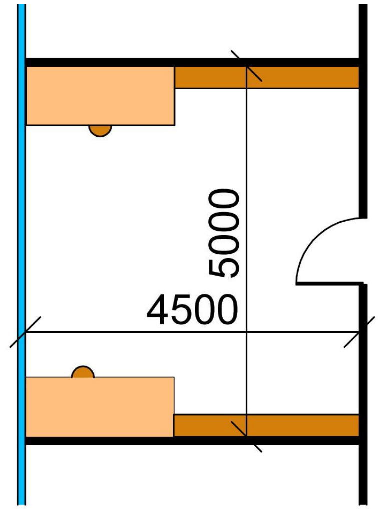
Method

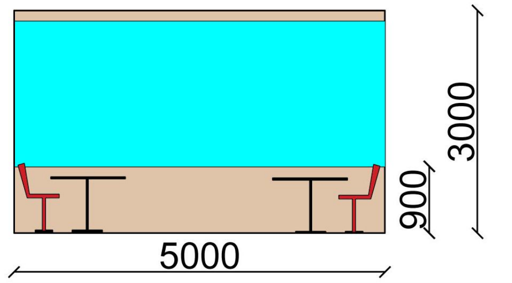
- The architectural potential is presented with the help of AutoCAD 3D MAX and Photoshop software to visualise the façades after the proposed renovation

- The energy efficiency and indoor climate are investigated and evaluated by using simulation research method with the software IDA ICE

Simulation of existing building

- 2 occupants in the room (activity level 1.2 met, occupancy 80%)
- Mechanical ventilation system VAV during working hours, heat exchanger efficiency 80%.
- Mechanical night ventilation in July and August.
- Heating set point is 21°C during working hours, the rest 16°C
- Infiltration is 0.45 l/(s. m^2)
- Window U-value is 3.14 W/(m^2. K), LT_g 0.71, g_g 0.75.
- Wall U-value is 0.61 W/(m^2. K)

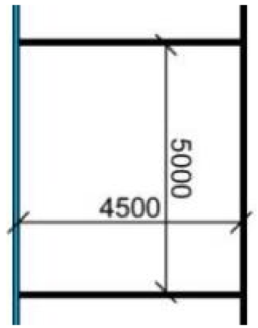




Simulation after renovation

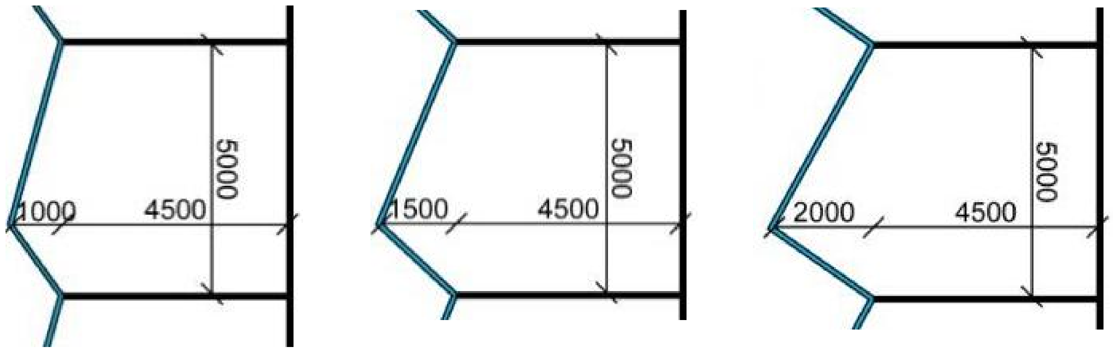
Scenario (2-A):

- The window facing west: (U_g, 0.51 W/m^2 K, LT_g 0.71, g_g 0.5, U_f 1.56 W/m^{2}K).
- U-value of the external wall is 0.125 W/m^2 K.



Scenario (3-B), (4-C) and (5-D):

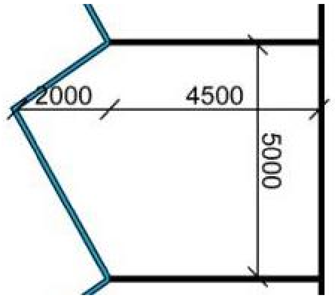
- The window facing southwest: (U_g (W/m^2.K), g_g (%), Lt_g (%)) (0,62, 0,63, 0,74).
- The window facing northwest: (U_g (W/m^2.K), g_g (%), Lt_g (%)) (0,51, 0,5, 0,71).



Simulation after renovation

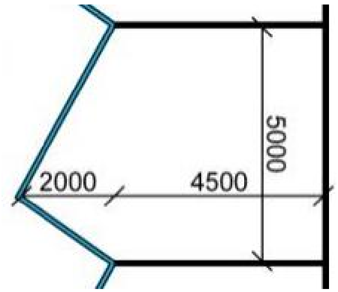
Scenario (6-E):

- The same input data as scenario (5-D).
- The façade configuration is mirrored on an axis in the center of the facade



Scenario (7-D):

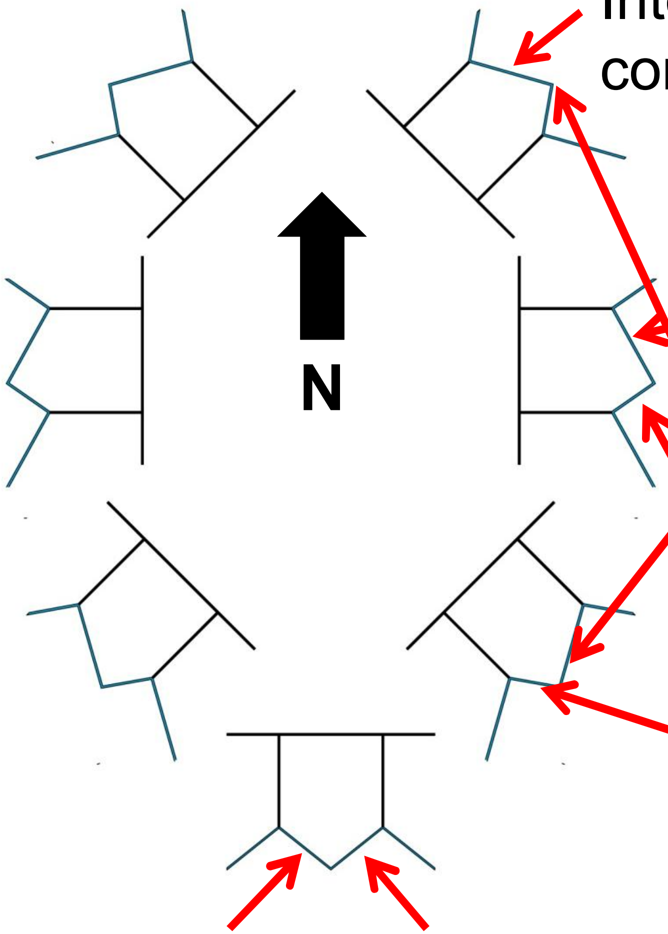
- The same as in scenario (5-D).
- The shading system of both windows depends on solar radiation intensity.



Scenario (8-A), (9-A) and (10-A):

- The same as scenario (2-A) “flat façade”
- The room orientation is toward northwest, southwest and south

Solar shading control systems



Internal shading device controlled manually

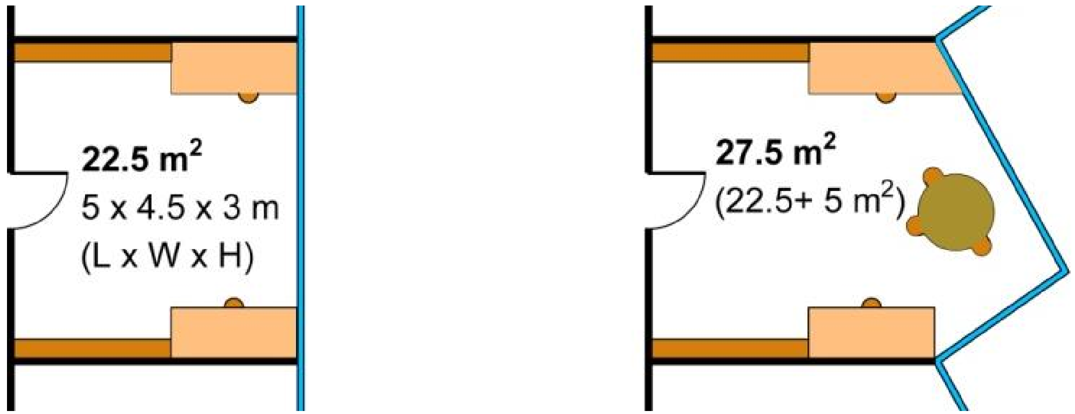
Solar shading control depends on solar radiation intensity. (closes at 125 W/m^2 (measured internally)).

Solar shading control depends on operative temperature (closes at 23°C)

Solar shading control depends on solar radiation intensity (closes at 125 W/m^2)

Architectural qualities

- Functional quality: Increases the area of the office room by about 19%



- Optical quality:

  More daylight to the office room, which has a better colour rendering quality.

- Visual quality:

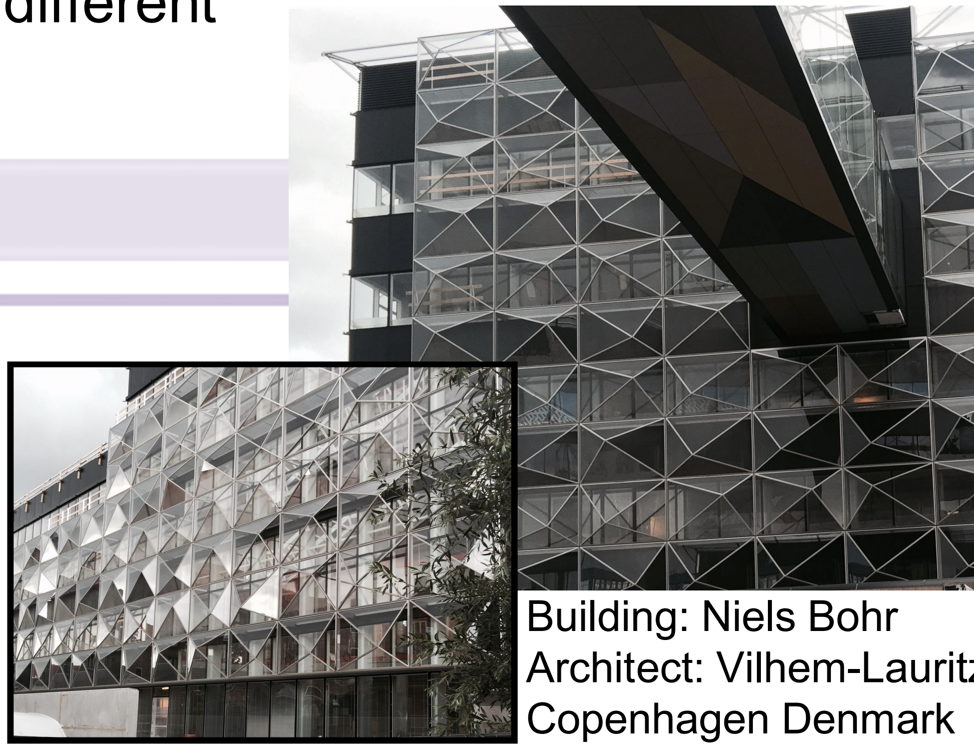
  While having solar shading shut down on one part of the façade, another part of the façade may have no shading

Architectural qualities

Aesthetic quality:

- An interesting façade with a dynamic form from the outside.
- The room façade is divided into two parts or more, which can be enhanced by implementing different façade cladding concepts.

Building: Kulturværftet
Architect: AART
Helsingør, Denmark



Building: Niels Bohr
Architect: Vilhem-Lauritzen
Copenhagen Denmark

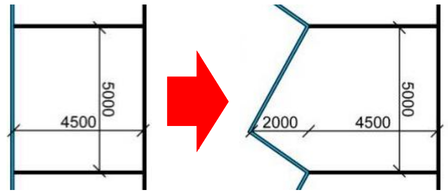
The simulation results

	Scenarios												
	1-A	2-A	3-B	4-C	5-D	6-E	7-D	8-A	9-A	10-A	11-D	12-D	13-F
The room area (m^2)	22.50	22.50	25.00	26.25	27.50	27.50	27.50	22.50	22.50	22.50	27.50	27.50	27.50
Lighting (kWh/(m^2·year))	6.7	5.7	4.9	4.6	4.3	4.3	4.2	6.0	5.9	5.8	4.5	4.2	3.9
HVAC Aux (fans & pump)kWh/(m^2.year)	8.3	12.7	10.5	9.8	9.2	12.0	12.2	12.4	11.9	11.0	8.6	8.9	11.1
Heating (kWh/(m^2.year))	83.5	29.4	27.9	28.1	28.3	31.3	30.9	31.2	27.6	26.8	31.9	25.7	26.3
Total (kWh/(m^2.year)) (According to BR15)	98.4	47.9	43.3	42.5	41.8	47.7	47.3	49.6	45.4	43.6	45.0	38.9	41.3

- The number of overheating hours that exceed 26^0C was kept below 100 hours and the hours that exceed 27^0C was kept below 25 hours in all the scenarios.

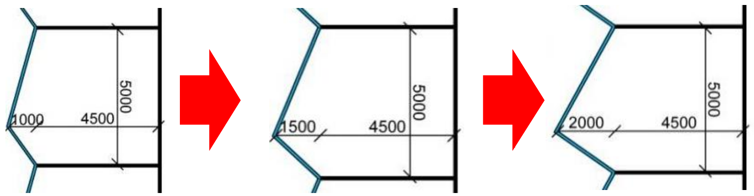
Results analysis

Scenario (2-A) and (5-D)



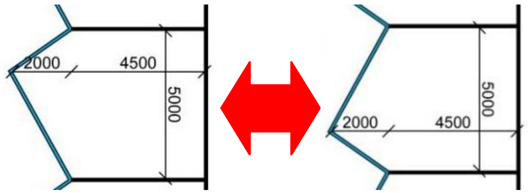
- The area-weighted primary energy consumption for heating and lighting are higher in scenario (2-A), while it is lower for heating and higher for lighting when it is un-weighted.
- The total primary energy consumption is lower in scenario (5-D) by 6.1 kWh/(m^2.year).

Scenario (3-B), (4-C) and (5-D)



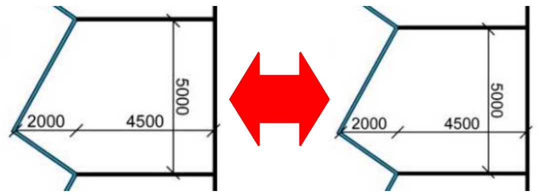
- The primary energy for heating (un- weighted) is higher in scenario (5-D) and lower when it is weighted.
- The total area weighted primary energy consumption is lower in scenario (5-D) compared to scenarios (4-C) and (3-B), respectively.

Results analysis



Scenario (6-E) and (5-D)

- The energy consumption for HVAC Aux and and heating is higher in scenario (6-E) than in scenario (5-D) with a high number of overheating hours.
- The primary energy consumption is higher in scenario (6-E) by 5.9 kWh/(m^2.year).



Scenario (7-D) and (5-D)

- The energy consumption for heating is less by 2.6 kWh/(m^2.year) in scenario (5-D). while for HVAC Aux, is higher in scenario (7-D) by 3 kWh/(m^2.year).
- The total primary energy consumption for scenario (7-D) is higher by 5.5 kWh/(m^2.year)

Discussion

- The research implemented an interdisciplinary study which provided architectural and technical solutions for facade renovation.

- Many architectural qualities like functional and optical by increasing the daylight in the room

- provided the possibility for daylight penetration and a view to the outside from one part of the facade while the other part might be blocked by a shading device.

  Thus avoiding a case where the shading device is totally shut down over the whole facade.

Discussion

- Different orientations, glass properties, size and controled shading devices work together to optimize daylight and ratio between heat loss and heat gain in the room

- Energy consumption for lighting is lower due to the large window oriented more to the north

  It is also lower for ventilation because of less heat gain in the hot season

- A good control of the energy gain and loss through the two facade windows.

  The heat gain from the window oriented more to the south help to reduce energy consumption for heating.

Conclusion

- The multi-angled façade system has many architectural qualities like functional, optical, visual and aesthetic.

- Saving in the primary energy consumption when renovated with a flat facade is about 50 kWh/(m^2.year),

  The saving with multi-angled facade about 4.9- 6.5 kWh/(m^2.year) higher than the saving in a flat façade.

- Multi-angled facades provide more daylight penetration and a view to outside from one part of the facade while the other part might be blocked by a shading device.