ENERGY OPTIMIZATION OF OFFICE BUILDING IN PRAGUE

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Summary

Dynamic simulation is a comprehensive tool for all design stages. The earlier it is introduced, the more significant energy savings it can bring. This paper is focused on a case study of an office building project in Prague – Anděl. We started on this project with evaluation of internal comfort criteria using dynamic simulation software. Then we were asked by project management to make more complex study about energy efficiency related to thermal comfort.

Keywords: Energy efficiency, Office Building, Thermal Comfort, Optimization

1 Optimization

The subject of the optimization is an administration building with 9 floors above ground and 3 underground floors. The U-value of all constructions was equal to required values (as defined in [2]) in the original design and double glazing with internal blinds and a natural gas condenser boiler as a main heat source were proposed. The aim of the optimization was to reduce energy consumption, CO_2 production and minimise discomfort hours. All these parameters were calculated using dynamic simulation modelling software DesignBuilder [3].

2 Building envelope parameters and heating plant type

Glazed area of about 83 % in the original design is not an optimal choice for the office building due to high solar gains in summer and significant heat losses in winter. We were not allowed to change window / wall ratio because of the ongoing administration process. As a result of the late introduction of energy optimization in the design process, the opportunity of energy consumption reduction reached by decreasing the glazed area was lost: each 10 % of extra glazing raises the energy consumption of this particular building by 6 %. As the glazed area was fixed, we focused on building envelope parameters,

especially on glazing (double counter triple) and the standard of thermal insulation (U-values). The evaluated options are listed in **Tab. 1**.

Tab. 1 *Evaluated possibilities*

Heating plant	Thermal insulation (U-values)	Glazing	Window shading position
Low-temp. boiler (CoP = 0.92)	Required values [2]	Double U = 1.40 W/(m^2.K) g = 0.38	Inside
Condenser boiler (CoP = 0.98)	Recommended values [2]		Outside
Heat pump (CoP = 2.70)	Recommended values for passive houses [2]	Triple U = 0.8 W/(m^2.K) g = 0.35	Mid-pane
			None

For each of total 63 combinations energy consumption, CO_2 production, discomfort parameters, initial and operational costs were calculated. Results are arranged in a chart representing economic parameters combined with CO_2 production (**Fig. 1**). The CO_2 production is represented by size of the circle mark. The x-axis represents total operational savings (or deficits) in 20 years introduced by extra initial costs on the y-axis.

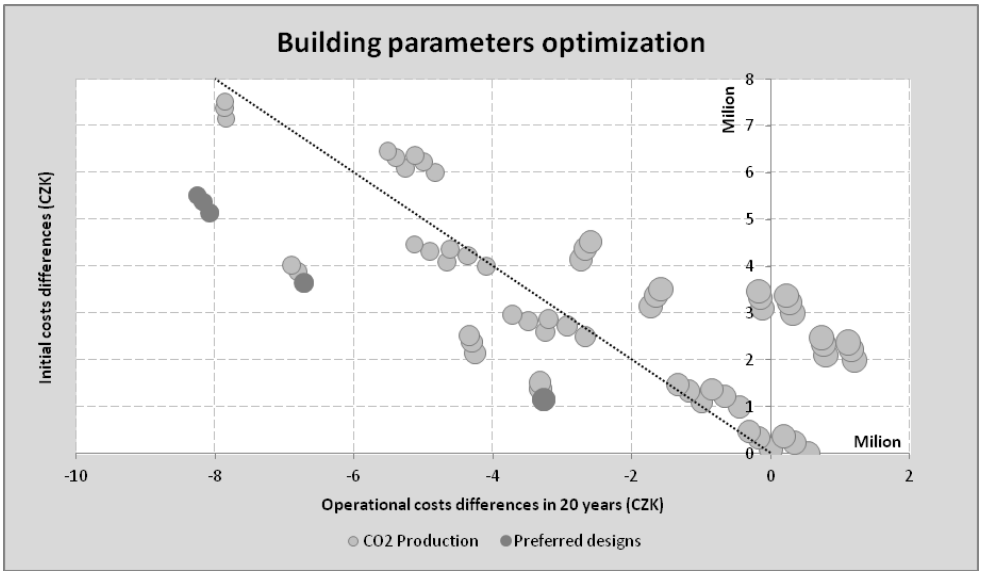

Fig. 1 *Dependence of economic parameters on CO_2 production*

Preferred designs had to maximize the economic benefits and minimize the CO_2 production. Designs that meet the requirements are highlighted in dark gray (**Fig. 1**) and stated in **Tab. 2**, where the recommended design is highlighted in bold.

Tab. 2 *Preferred designs*

	Heating plant	Thermal insulation (U-values)	Glazing	Window shading position
1	Heat pump	Recommended values for passive houses	Double	External
2	**Heat pump**	**Recommended values**	**Double**	**External**
3	Heat pump	Required values	Double	External
4	Heat pump	Required values	Double	Mid-pane
5	Heat pump	Required values	Double	None

To evaluate the number of discomfort hours, all design variants were divided according to the used glazing. The triple glazing designs resulted into around 40 discomfort hours, and the double glazing designs into around 270 discomfort hours. The difference is caused by lower surface temperatures of the double glazed façade in winter. All variants were evaluated with identical HVAC systems schedules and temperatures (heating set-point: 21 °C, cooling set-point: 26 °C). After discussion we decided to lower the number of discomfort hours by optimizing the HVAC schedules, instead of using triple glazing, which is economically disadvantageous.

3 HVAC schedules

The goal of the HVAC schedules optimization was to reduce the CO_2 production (corresponding to energy consumption) and the number of discomfort hours. The limit of discomfort hours was set onto 90 hours (this is approximately equal to 5 % of working hours). In these hours a human body thermal adaptation is assumed for reaching a thermal neutral state. Changeable parameters were heating set-point temperature, heating set-back temperature, boiler preheat hours and cooling set-point temperature. Optimization tools integrated in DesignBuilder software were used for evaluation. The results are plotted on an x-y graph (**Fig. 2**). The preferred variants are listed in **Tab. 3**. The recommended variant is highlighted in bold.

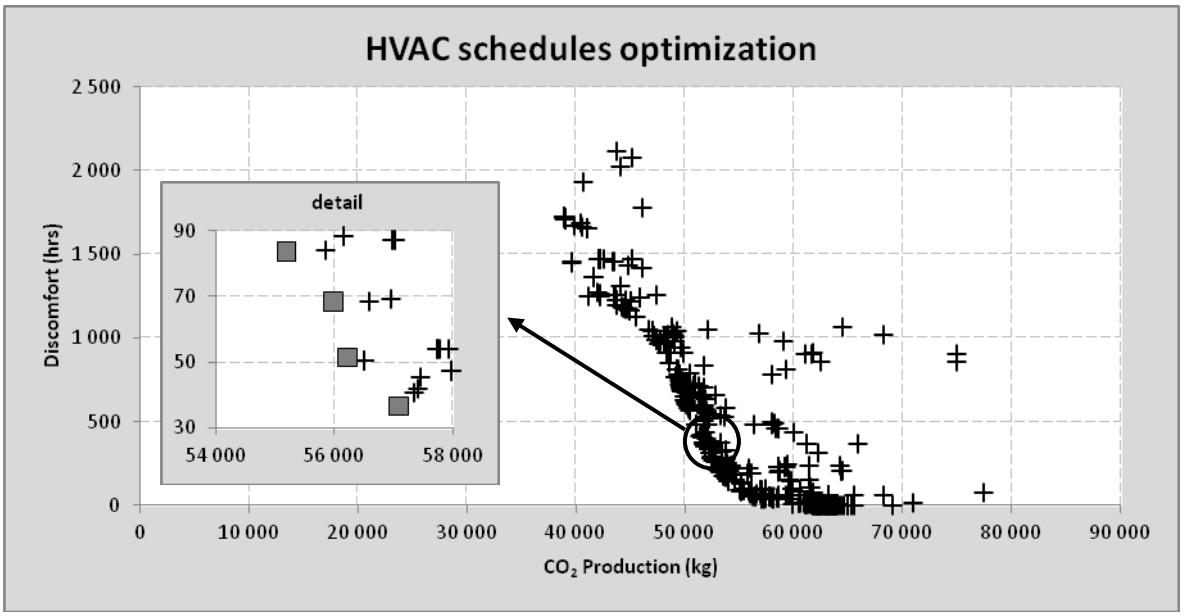

Fig. 2 *HVAC schedules optimization*

Tab. 3 *Preferred variants*

	Heating set-point (°C)	Heating set-back (°C)	Boiler preheat (hrs)	Cooling set-point (°C)	CO_2 Production (kg)	Discomfort (hrs)
1	23.0	14.0	5.00	25.5	55 197	84
2	**22.5**	**17.0**	**1.75**	**25.5**	**55 986**	**68**
3	23.5	10.0	1.75	26.0	56 512	50
4	24.0	13.5	2.50	25.5	57 086	37

4 Lighting

So far the calculations were focused on heating and cooling. However the significant part of office building energy consumption comes from lighting requirements. We compared four variants of light sources and of lighting control shown in **Tab. 4**. The recommended variant is highlighted in bold.

Tab. 4 *Lighting possibilities*

	Light source	Lighting control	Energy consumption (kWh)	
			Lighting energy	Total energy
1	Fluorescent tube	On/Off	210 504	318 984
2	Fluorescent tube	Stepped (3 steps)	133 231	224 361
3	Light-Emitting Diode (LED)	On/Off	140 336	243 516
4	**Light-Emitting Diode (LED)**	**Continuous**	**82 026**	**175 566**

5 Conclusion

During our optimization work we found a lot of possibilities, how to make the office building more energy efficient and environmental friendly with a sufficient thermal comfort. Unfortunately some good possibilities were lost because of ongoing administration process (e.g. the reduction of glazing area of 30 % would bring energy savings of about 18 %).

Due to major price increase of natural gas in the last two years in the Czech Republic, the heat pump became energetically and economically more advantageous with similar emission production compared to natural gas boilers.

The area of opaque envelope structures of the building is small; hence the changes in thermal insulation have very limited impact on energy consumption. In highly glazed facades the triple glazing introduces a better thermal comfort for occupants and comparable energy consumption. But with optimized HVAC schedules, the double glazing is competitive moreover with the advantage of lower initial costs.

In the design of new office buildings it is highly important to pay attention not only to heating and cooling energy consumption, but also to lighting energy consumption. In projects with an optimized building envelope the total lighting energy consumption can be greater than the sum of cooling and heating energy consumption.

With the optimization we were able to reduce the energy consumption by 54 %, the CO_2 production by 48% and the number of discomfort hours by 91 % and still be economically effective.

References

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