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Renovation strategies of typical Danish single-family house for optimization of energy efficiency and flexibility

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INTRODUCTION:

1. The **ability to be flexible** in the way energy is used will be just as **important as** implementing **energy efficiency and generating energy from renewable sources**, if planned CO₂ emissions are to be achieved.
2. The **heating need** still represents **25% of the final energy consumption** in Denmark despite the tightening of the building regulation and in **64% of Danish households** the heat demand is satisfied by **district heating**.
3. **Thermal grids struggle with** delivering the hot water to their customers during the **morning peaks**.
4. The **renovation initiatives** are focused **on minimizing the overall energy consumption** of the buildings and **not on improving the control of heat demand**.

RESEARCH QUESTIONS:

How typical cost-effective renovation packages contribute to energy consumption reduction as well as influence the energy flexibility, and if simple rule-based controller (RBC) can contribute in reducing morning consumption peaks.

CASE STUDY



RENOVATION PACKAGES

- P1: renovation of 54 % of envelope including the roof and the crawl floor
- P2: renovation of 75 % of envelope except the windows and ground floor
- P3: renovation of 80 % of envelope except the ground floor
- P4: renovation of 100 % of envelope & light finish
- **P5 renovation of 100 % of envelope & new brick finish**

CONTROL STRATEGIES

- Cut-off – the heating power is turned off at 7:00 a.m. until a) 2:00 p.m. (7h); b) 3:00 p.m. (8h) and c) 4:00 p.m. (9h).
- Pre-heating before cut-off – T_{set} is increased by 2K for 1h-2h before the heating power is turned off at 7:00 a.m. for the same duration as in the cut-off modulation: 7h, 8h or 9h.

RESULTS

Renovation package	Heat consumption (kWh/m ²)	Energy efficiency improvement (%)	Autonomy time (min)
Before renovation	192.8	-	13.6 - 26.1
P1	126.9	34.2	23.0 - 41.0
P2	92.9	51.8	44.4 - 79.2
P3	71.9	62.7	69.2 - 111.7
P4	69.5	64.0	71.5 - 126.0
P5	70.8	63.3	70.7 - 115.0

Thermal comfort for P5 and cut-off control strategy

Control strategy	Number of hours < 20°C	$T_{operative,min}$ (°C)
Cut-off 7:00-14:00	143	18.3
Cut-off 7:00-15:00	231	18.0
Cut-off 7:00-16:00	333	17.6

CONCLUSIONS

- Different renovation packages can reduce the space heating by 34 - 64% and increase the flexibility time by 200 – 500%.
- The building envelope thermal resistance has a great importance for both energy efficiency and flexibility, since it conserves the heat indoors.
- The simple RBC of turning off the heating power can further reduce the heating consumption and contribute in reducing the morning load peak with small compromise on the thermal comfort level. However, special attention should be given to the period of afternoon activation of the heating system (end of the cut-off period) in order not to create the new peaks close to the already known afternoon peak

