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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 – Tset 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/m²) | 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        |

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.