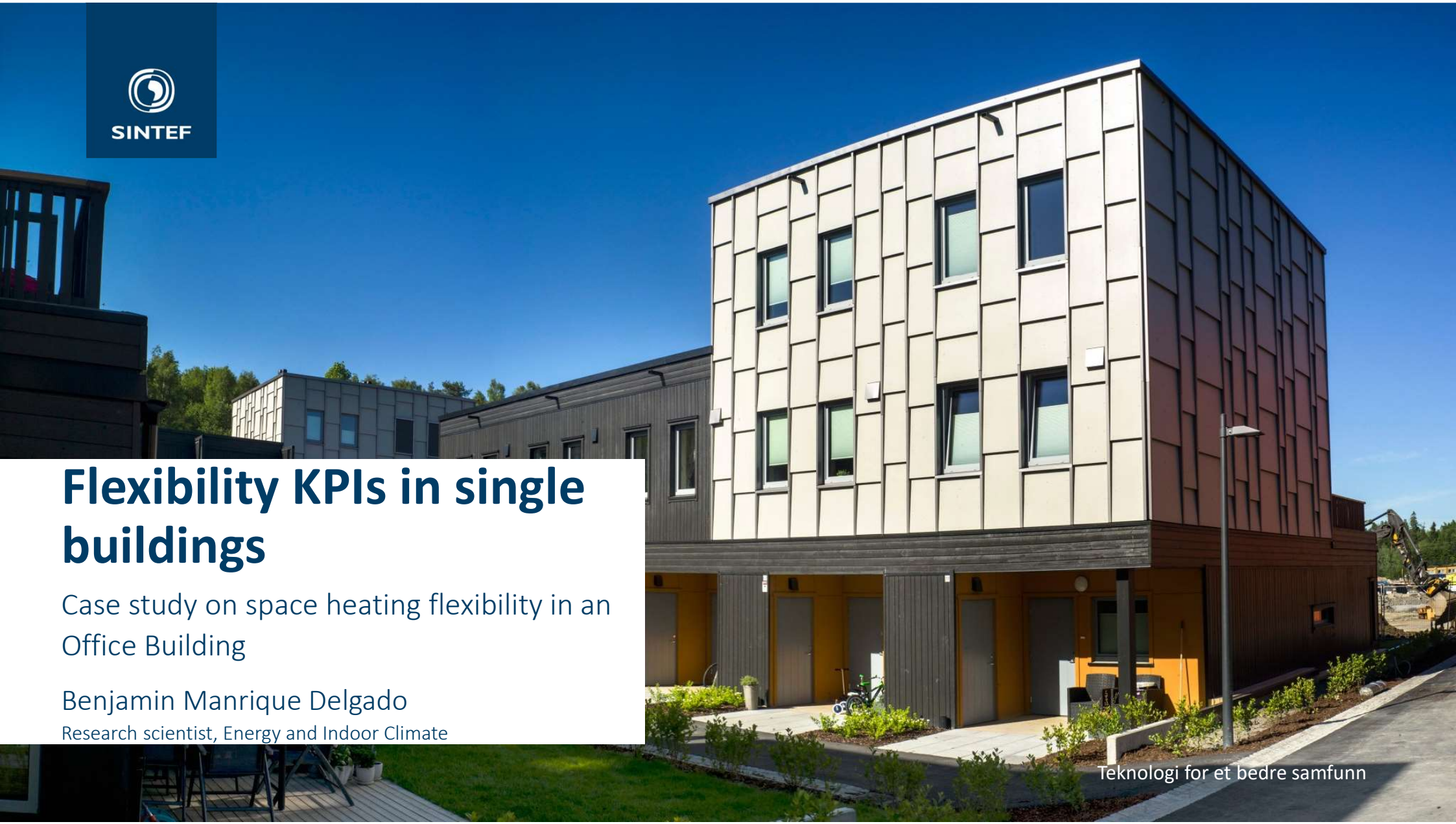

Flexibility KPIs in single buildings

Case study on space heating flexibility in an Office Building

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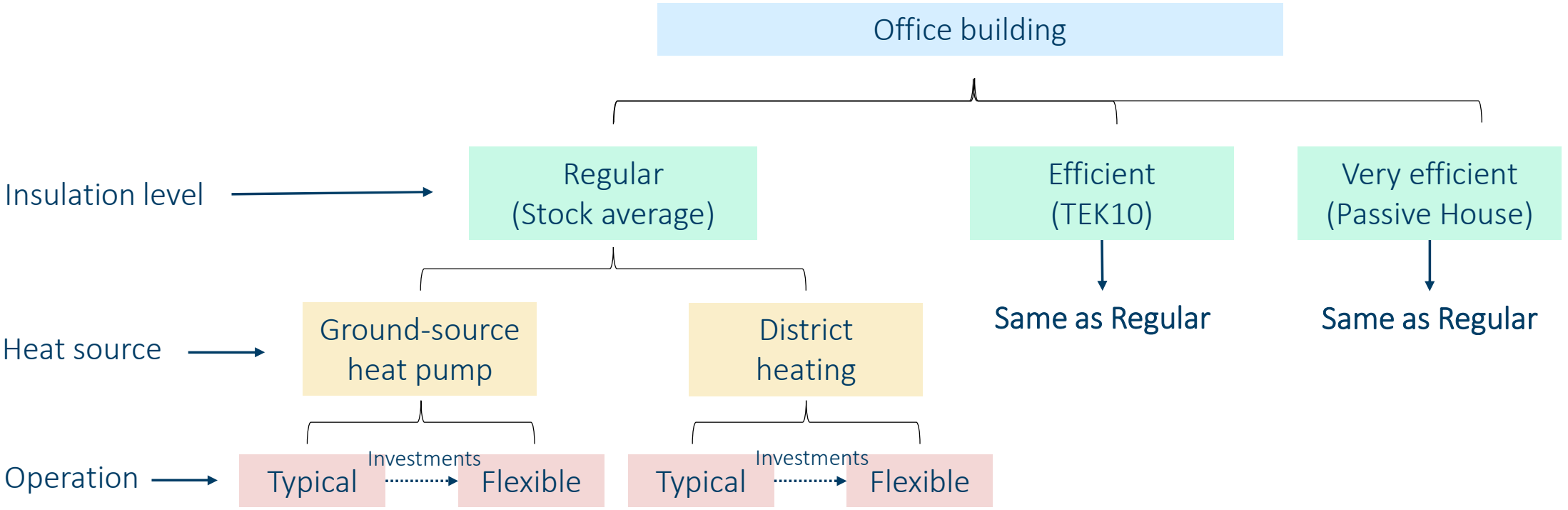
General description

- Space heating flexibility is a demand-side management strategy that involves shifting the operation of space heating to avoid high market prices while keeping comfortable conditions for the users.
- The main objectives of the investigation are to:
  - Calculate lifetime costs, including operations and investments.
  - Quantify the savings in operation costs that can be achieved through space heating flexibility in office buildings.
  - Quantify the peak load reduction and of energy savings during stress hours (when high prices typically occur).
  - Show an example calculation of Key Perfomance Indicators for a single building:
    - Δ Energy
    - Δ Cost
    - Δ Energy during stress hours
    - Δ Peak load

Case description: prices and tariffs

- For a typical commercial consumer, energy flexibility can provide savings by
  - reducing consumption during hours with high prices if **hourly prices** are available (Spotpris), and
  - reducing their **peak load** (peak import) if peak power tariffs are applied (Effektledd).
- Energy and Peak power tariffs can be applied for electricity and district heating.
- Pricing scenario:
  - Electricity spot prices of 2012,
  - with technology prices of today (2020).
- The costs are calculated for a period of 60 years, at an interest rate of 4%.

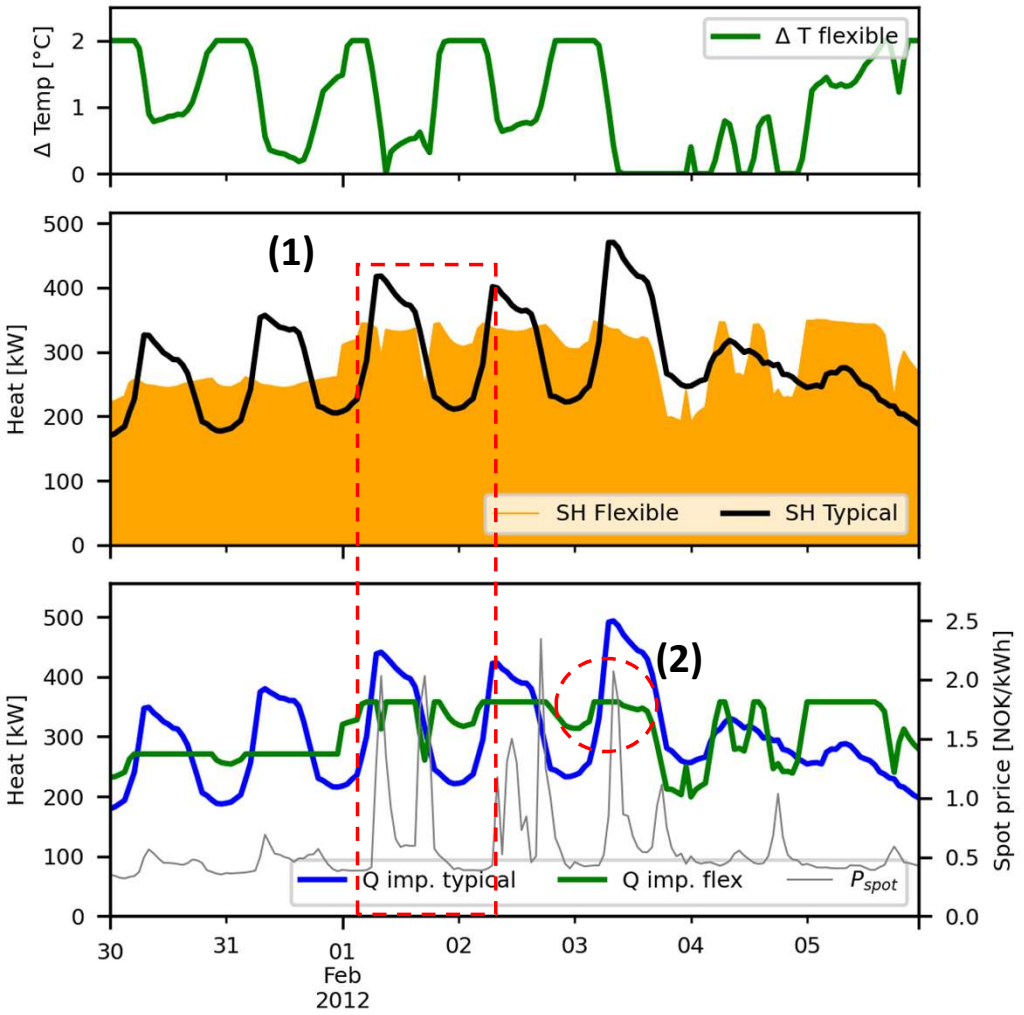
Case description: system configuration



Results: Dynamics

- Space heating flexibility
  - Flexibility can be achieved by storing heat in the building mass.
- Flexibility bounds
  - In these cases, we set an operation window of 2 °C above the dynamic reference temperature, so the building is allowed to be warmer than in typical operation.
- Results
  - Import from the grid is lower when prices are high and vice-versa (1), and
  - Lower peak loads reduces the *effektledd* costs (2).

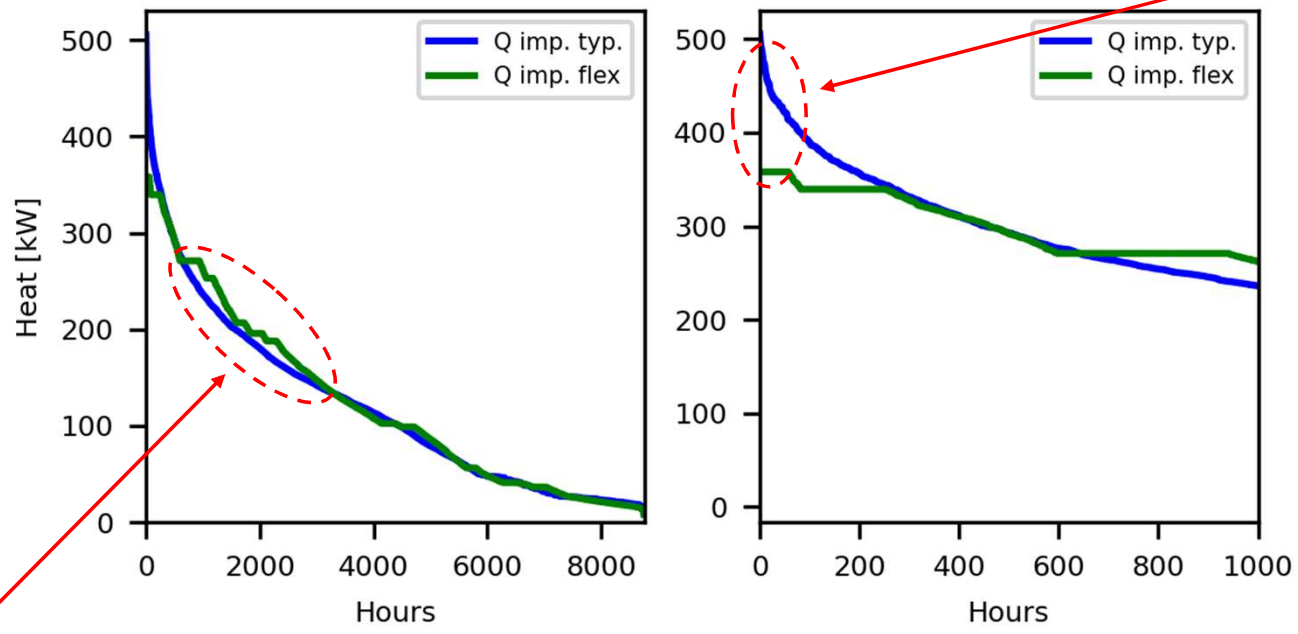
Office, Regular, District Heating



Results:
Duration curves of heat import

Office, Regular, District Heating

29% reduction



Increased import at lower power

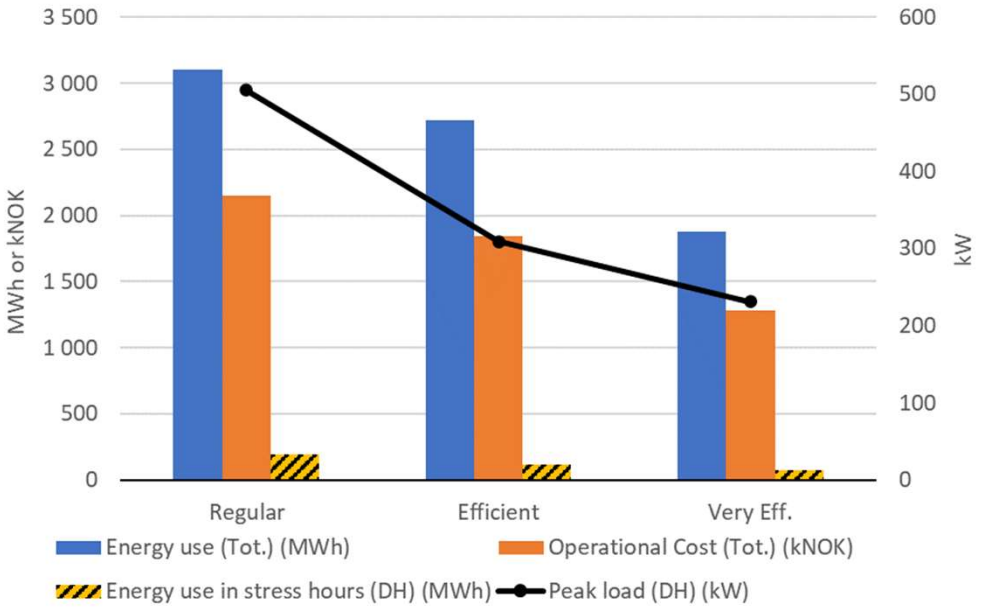
Office building, District Heating
Investment and operation costs

Results with Space Heating Flexibility

	Office		
	District Heating		
	Regular	**Efficient**	**Very Eff.**
DH [kW]	505	309	231
Investment costs [kNOK]	2 714	1 680	1 268
Annual Operation Cost [kNOK/a]	2 075	1 797	1 249
Lifetime Operation Cost [kNOK]	46 951	40 654	28 250
Total Lifetime Costs [kNOK]	49 665	42 334	29 518
Reduction (compared to typical)	3%	2%	3%

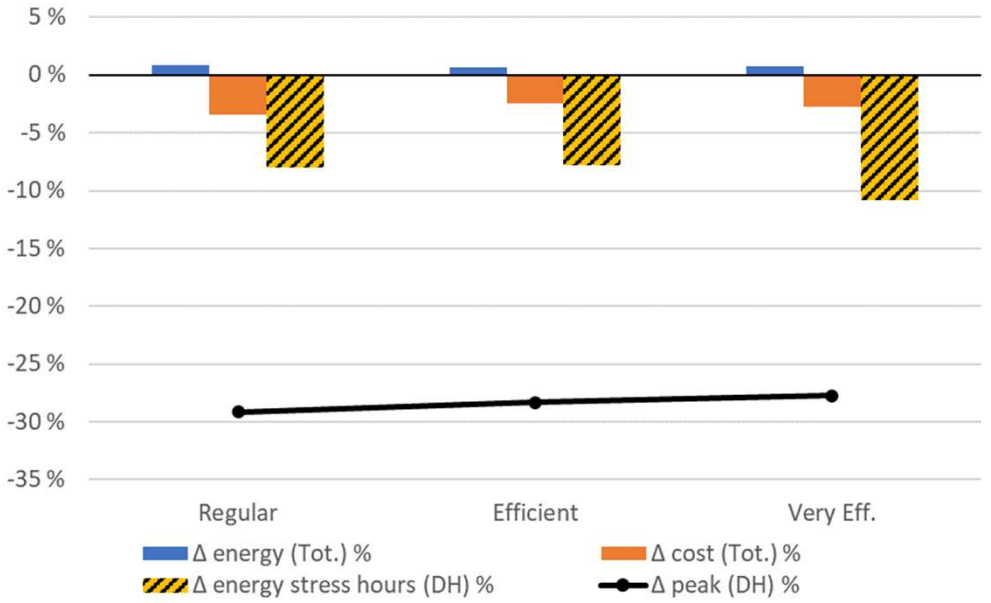
Office building
KPIs: District Heating

Typical operation



Vs.

Flexible operation



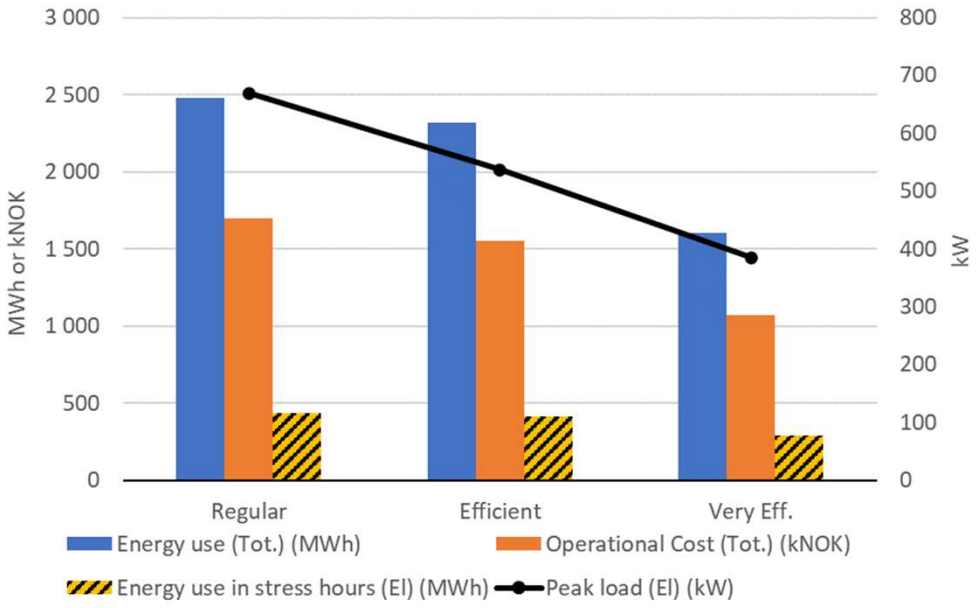
Office building, Ground-source Heat Pump Investment and operation costs

Results with Space Heating Flexibility

	Office		
	Ground-source Heat Pump		
	Regular	**Efficient**	**Very Eff.**
GSHP [kW]	202	124	82
EB [kW]	245	141	118
Space heating tank [kWh] / [liters]	197 / 5 500	154 / 4 300	84 / 2 350
DHW tank [kWh] / [liters]	65 / 1 850	66 / 1 850	72 / 2 000
Investment costs [kNOK]	6 443	4 047	2 757
Annual Operation Cost [kNOK/a]	1 643	1 519	1 045
Lifetime Operation Cost [kNOK]	37 161	34 358	23 635
Total Lifetime Costs [kNOK]	43 604	38 405	26 392
Reduction (compared to typical)	3%	2%	2%

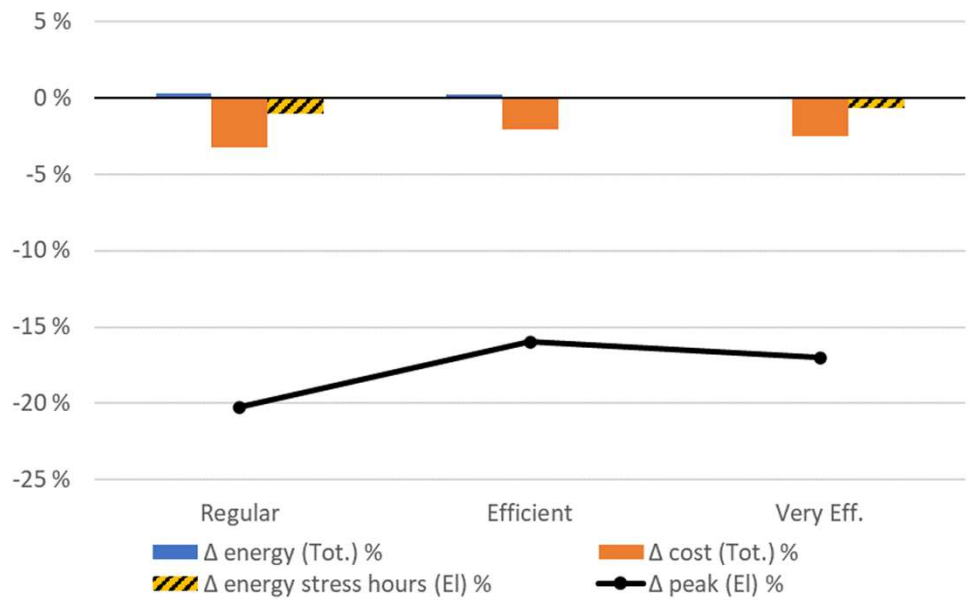
Office building KPIs: GSHP

Typical operation



Vs.

Flexible operation



Main outcomes

- Space heating flexibility can achieve
  - Reduced operational costs
    - between -2% and -3%, and
  - Reduced peak load
    - around -28% with district heating, and
    - between -16% and -20% with ground-source heat pumps
  - Increased energy consumption
    - around +1%
- The majority of the savings in operational costs are provided by the peak load reductions (savings in Effektledd tariff).
- Even though the total heating demand increases when space heating flexibility is activated, the cost of this additional energy is offset by the savings.

SINTEF

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