Large electric load fluctuations and how to suppress them with DSM (of heating devices)

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Hes·so // VALAIS WALLIS

DSM with heating devices

- Thermal inertia of buildings to shift load
- When is it favorable to heat …

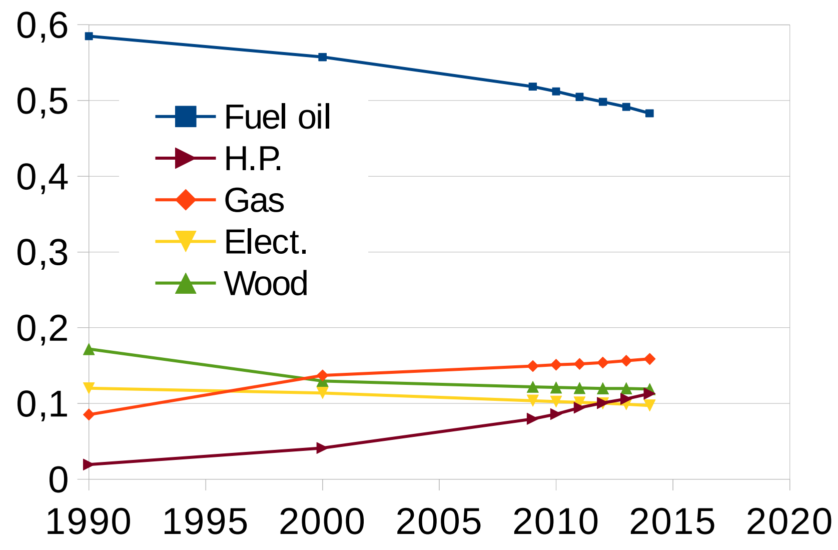
  Economically, Service to the network, Absorb own PV production, peak shaving...

- Reconcile desired consumption with constraints

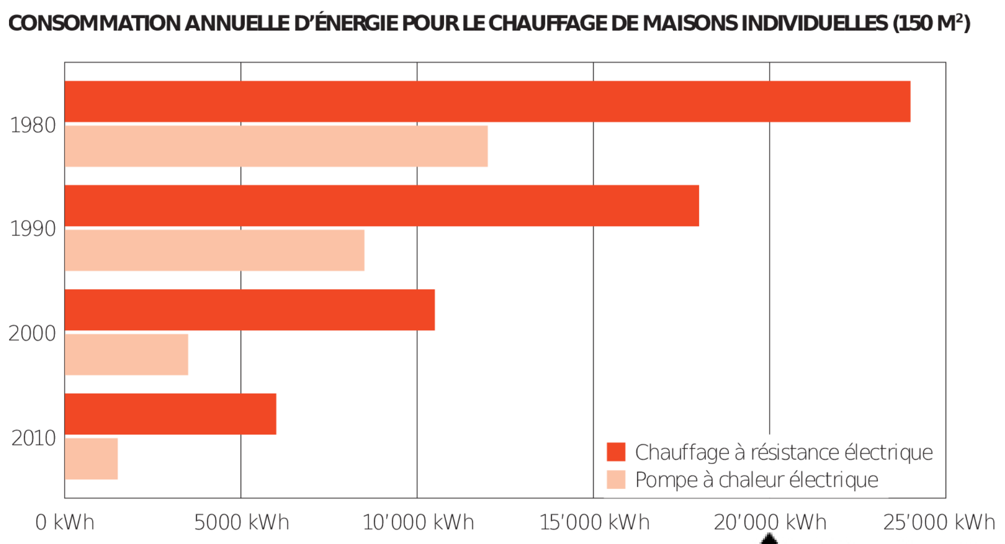
  Comfort temperatures, on/off mode of thermal devices, Number of switchings of the compressor, Total consumption does not increase...

Motivation… the Swiss context

- Electrification
  - → ~200'000 H.P.



- Improved efficiency



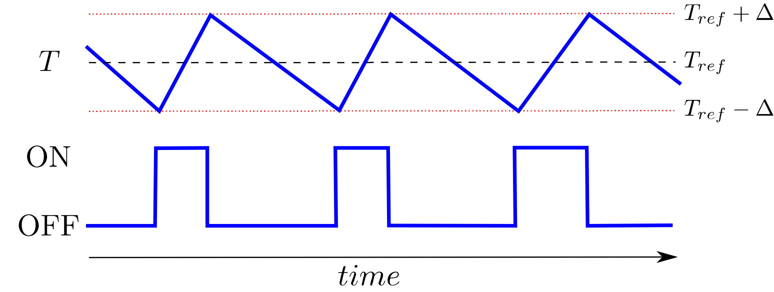
Energy balance for a building

- Single temperature point

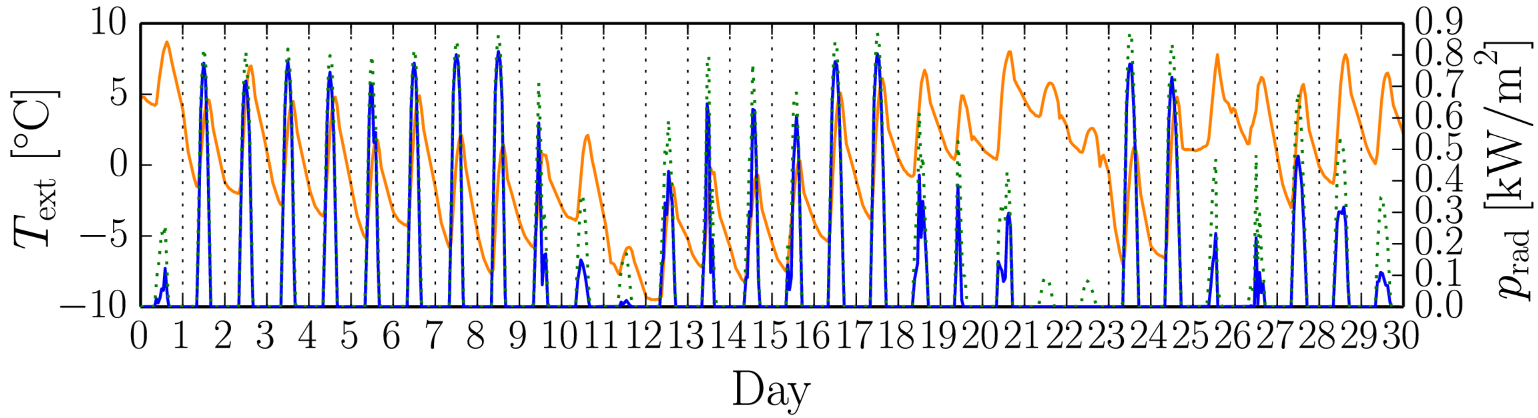
$$C\frac{dT}{dt} = \kappa(T_e(t) - T) + P_{rad}(t) + P_h(t)$$

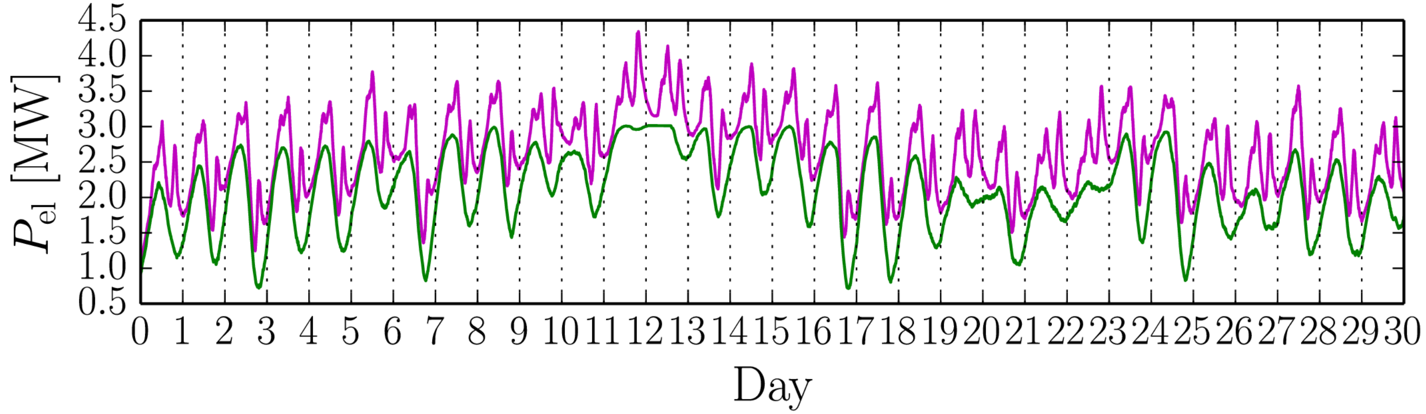
- Thermal capacity C
- Thermal conductance κ
- Radiation power $P_{rad}(t) = p_{rad}(t) \cdot S \cdot g$
- Heating power $P_h(t) = P_h \cdot s(t)$

Thermostatic control



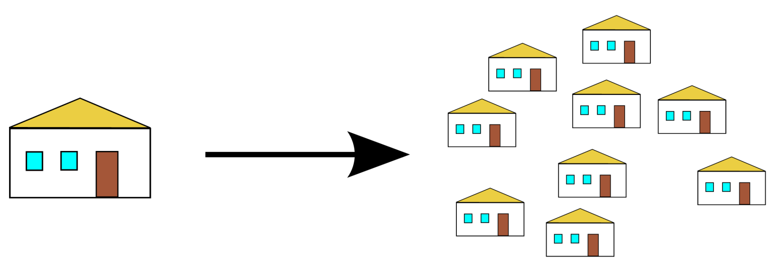
- Large fluctuations





“Smart” control: residual load & aggregation

- Household consumption
  - → Flexible: Heat Pumps
  - → Non Flexible: Domestic appliances
- Production
  - → PV (non flexible)
- Residual load $P_i^{\mathrm{net}} = P_i^{\mathrm{flex}} + \sum P_i^{\mathrm{non-flex}}$ R_i
- Aggregation

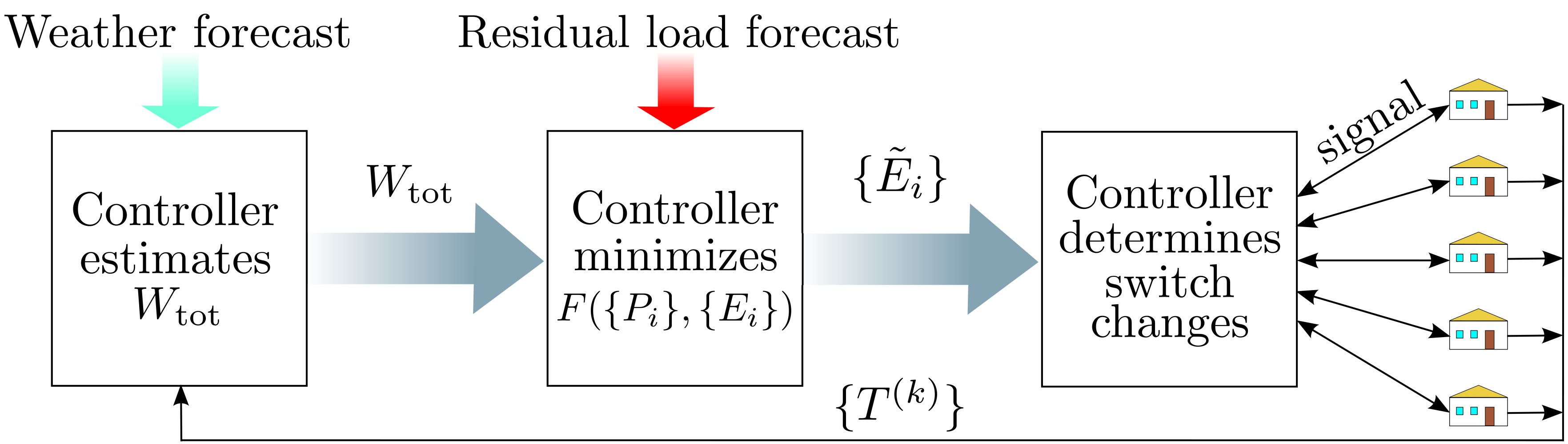


“Smart” control : Load smoothening

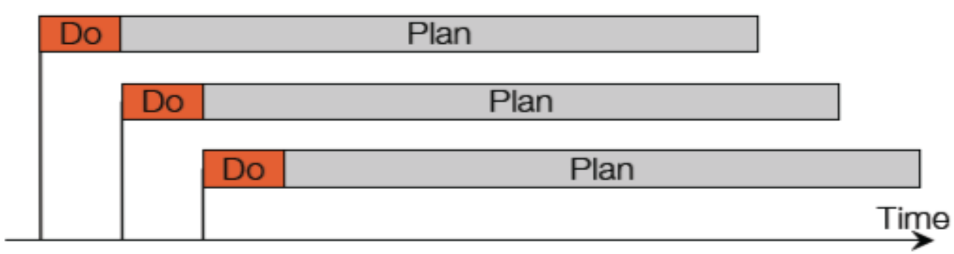
- H: Neighborhood's electric consumption for heating is ideally flexible
- Flexibility managed by a central controller
- Objective function $F\left(\{E_i\}\right) = \sum_{i=0}^{24h} (E_i - P_i)^2$
- Desired profile $P_i = \frac{W_{tot}}{\epsilon_{COP} N \Delta t} - R_i$
- Constraint $W_{tot} = \sum_{i=0}^{24h} \left(\epsilon_{COP} E_i\right) \Delta t$

→ Thermal requirements estimated based on weather forecast and buildings' temperatures

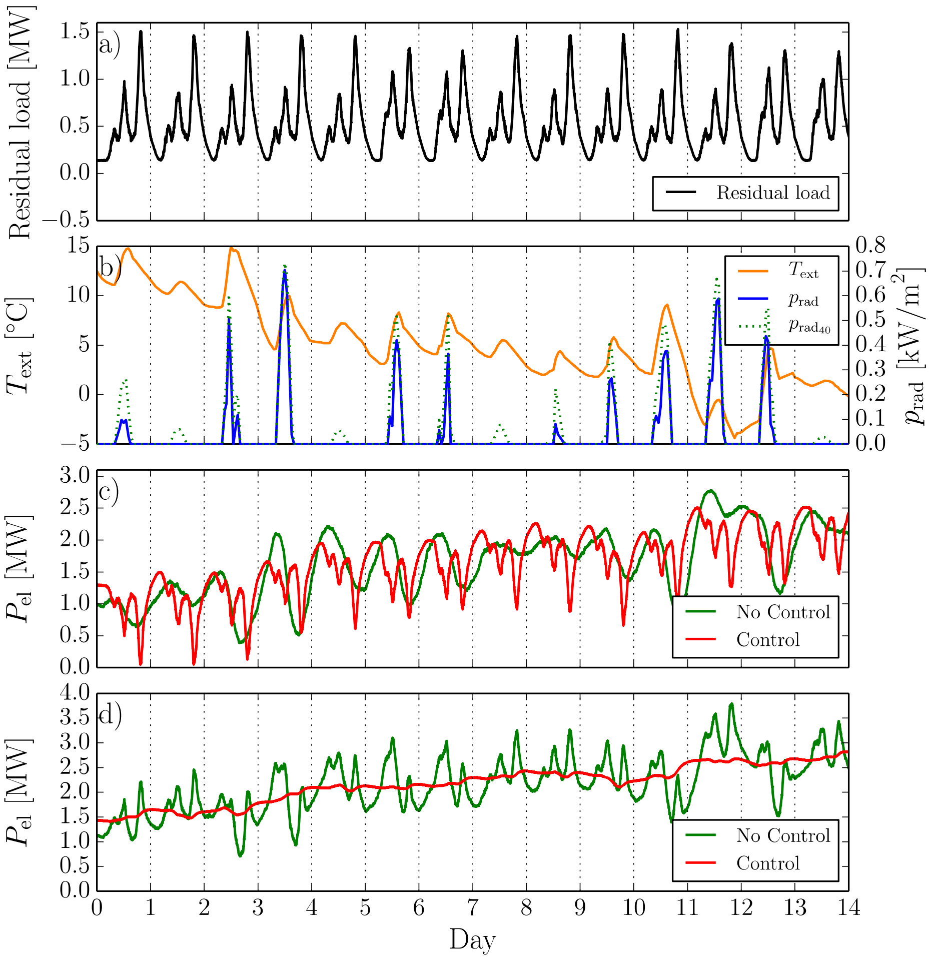
“Smart” control: Summary

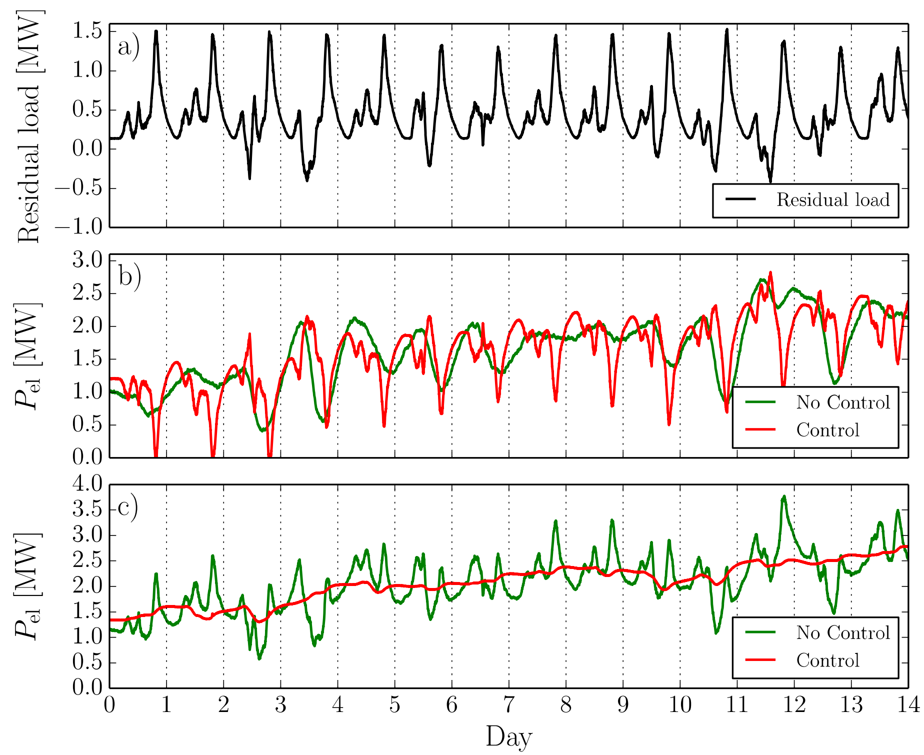


Optimal trajectory computed at each time step



“Smart” control: Results





Conclusion:

- Synchronization of heating consumption in buildings with large solar gains

  → Improved efficiency enhances this tendency

- Formulate the hypothesis that the aggregated heating consumption is ideally flexible

- Design a non-disruptive, centralized control algorithm for residual load smoothening

Building characteristics

- $C = [1.3, 2.7] \cdot 10^4 \;\; [Wh/°C] \equiv [50, 100] \;\; [MJ/°C]$
- $\kappa \in [200, 400] \;\; [W/°C]$
- $P_{hp} = \kappa \cdot 30°C \quad cop = 3 \quad P_{hp}^{el} \in [2, 4] \;\; [kW]$

  → ensures $20°C$ with $-10°C$ outside

  → on/off mode
- PV efficiency 15%
- South facing window surface $S \in [5, 15] \;\; [m^2]$

  → $g_w = 0.6 \quad g_b = 0.12$
- $T_{ref} = [21, 23]°C, \;\; \Delta = \pm 1.5$