Applications of a heat load forecast with dynamic uncertainties

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4DH Conference 27/9/2016

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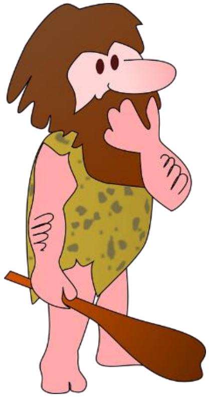
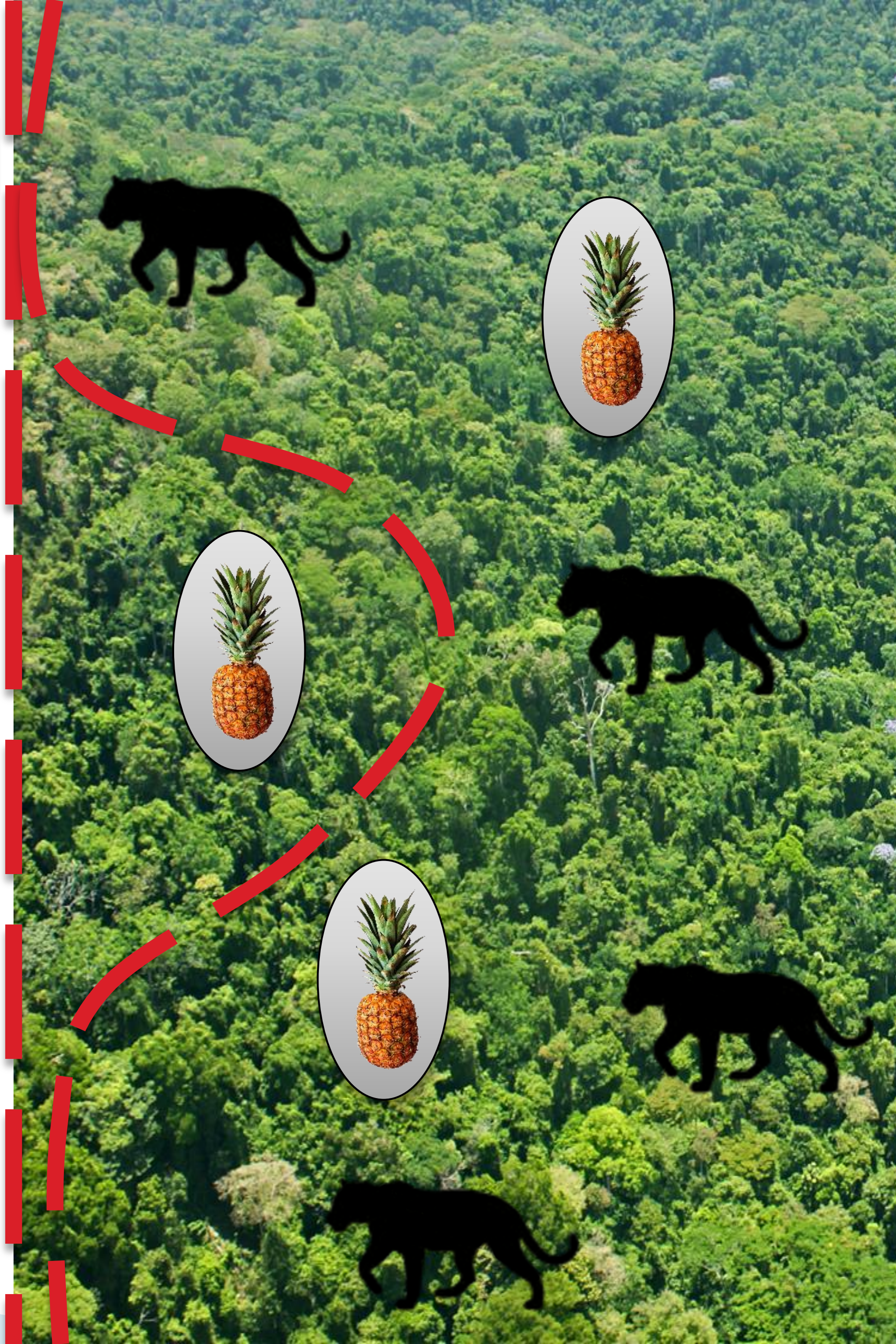
Risk and reward





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Risks and rewards in DH

- Inability to meet demand
- Economic risk
- System failure
- Investment risk

- Reduce heat losses
- Reduce CO_2–emission
- Produce cheaper heat
- Facilitate RES integration

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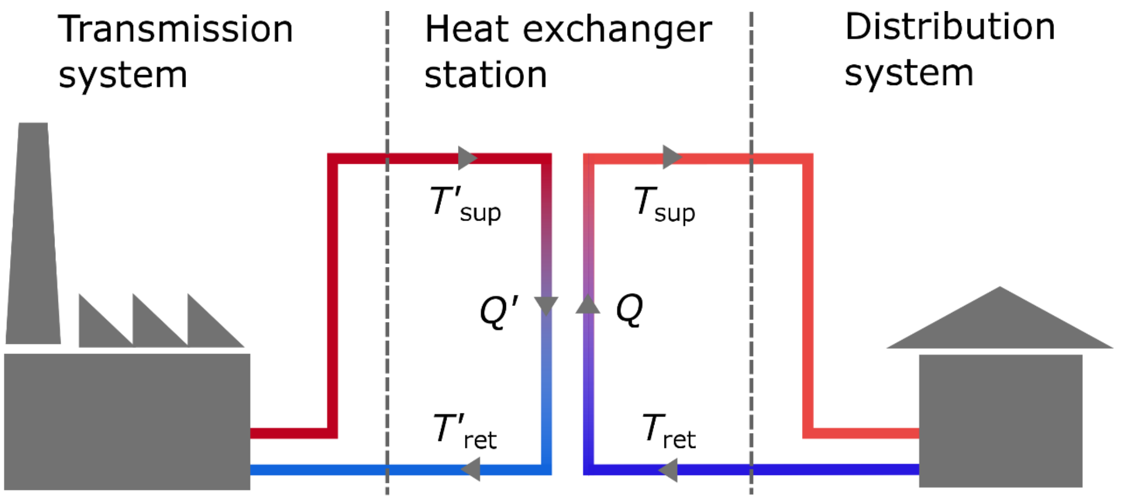
Application: Operation of area substations



$$P = c\rho Q \left[T_{\text{sup}} - T_{\text{ret}}\right]$$

Reward: Lower supply temperature
→ reduced heat loss

Risk: Inability to cover heat demand

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Case from Aarhus – Denmark

- Area substations:
  - Holme
  - Hørning
  - Rundhøj

- Scenarios
  - Scenario 1: Current operation
  - Scenario 2: Optimized temperature control
  - Scenario 3: Optimized temperature control
    + dynamic uncertainties

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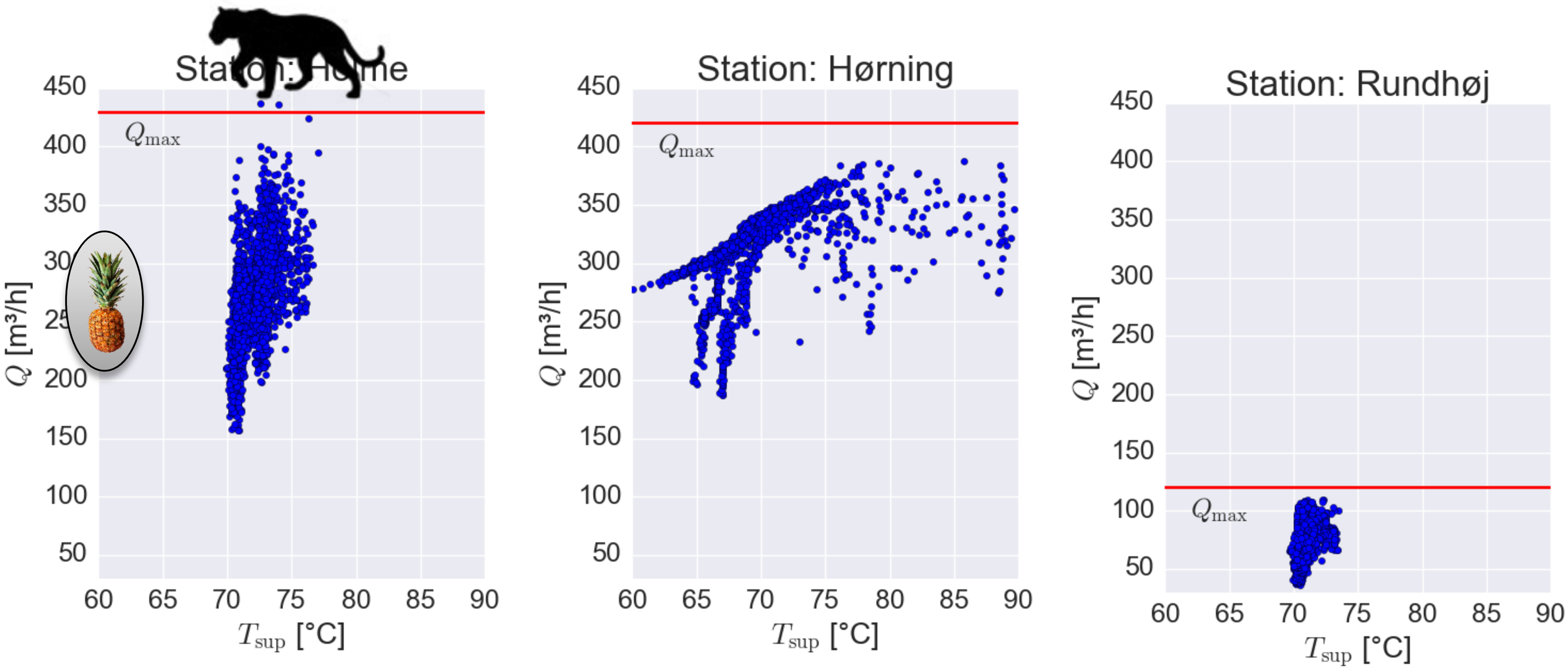
Scenario 1: Current operation



$$P = c\rho Q \left[T_{\mathrm{sup}} - T_{\mathrm{ret}}\right]$$

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Scenario 2: Optimized temperature control

$$T_{t+1}^{\mathrm{sup}} = \max \left\{ T_{\mathrm{sup}}^{\mathrm{min}}(\hat{T}_{t+1}^{\mathrm{out}}) \,,\; \hat{T}_{t+1}^{\mathrm{ret}} + \frac{\hat{P}_{t+1}}{c\rho Q_{t+1}^{\mathrm{ref}}} \right\}$$

Consumer constraint

System constraint

$$Q_{t+1}^{\mathrm{ref}} = \underset{Q'_{\mathrm{ref}}}{\mathrm{argmin}} \left| Q_{\max} - \frac{\hat{P}_{t+1} + \delta \hat{P}}{c\rho \left[T_{t+1}^{\mathrm{sup}}(Q'_{\mathrm{ref}}) - T_t^{\mathrm{ret}} \right]} \right|$$

Inspired by PRESS by Enfor:

Madsen, Henrik, et al. "On flow and supply temperature control in district heating systems."
Heat Recovery Systems and CHP 14.6 (1994): 613-620.

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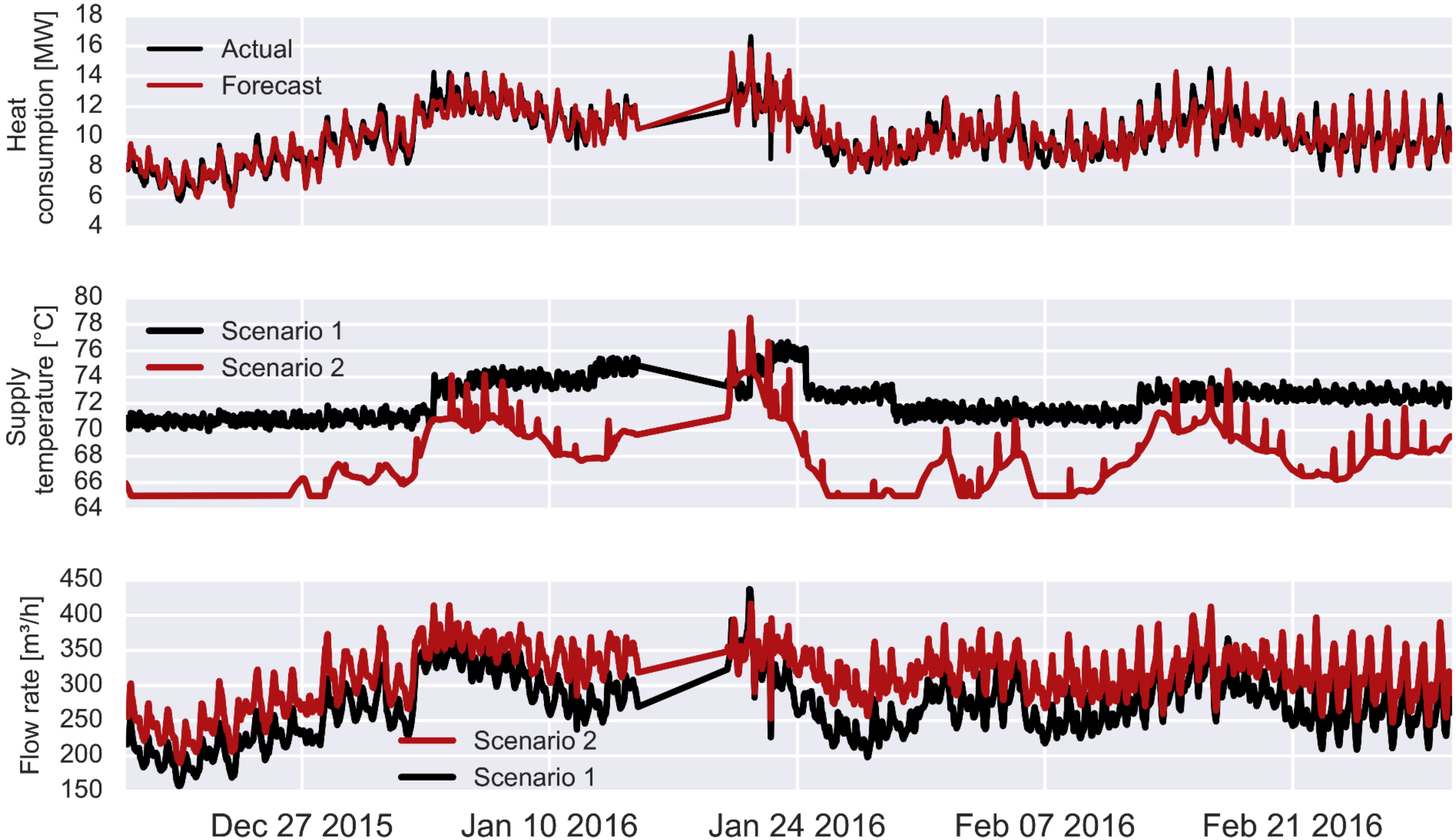
Scenario 1 and 2 – Holme



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Scenario 3: Optimized temperature control

$$T_{t+1}^{\text{sup}} = \max\left\{ T_{\text{sup}}^{\text{min}}(\hat{T}_{t+1}^{\text{out}}) \, , \, \hat{T}_{t+1}^{\text{ret}} + \frac{\hat{P}_{t+1}}{c\rho Q_{t+1}^{\text{ref}}} \right\}$$

Consumer constraint

System constraint

$$Q_{t+1}^{\text{ref}} = \underset{Q'_{\text{ref}}}{\text{argmin}} \left| Q_{\max} - \frac{\hat{P}_{t+1} + \delta\hat{P}}{c\rho\left[T_{t+1}^{\text{sup}}(Q'_{\text{ref}}) - T_{t}^{\text{ret}}\right]} \right|$$

Forecast uncertainty: $\delta\hat{P}$

- Scenario 2: constant
- Scenario 3: time-dependent, ensemble-based

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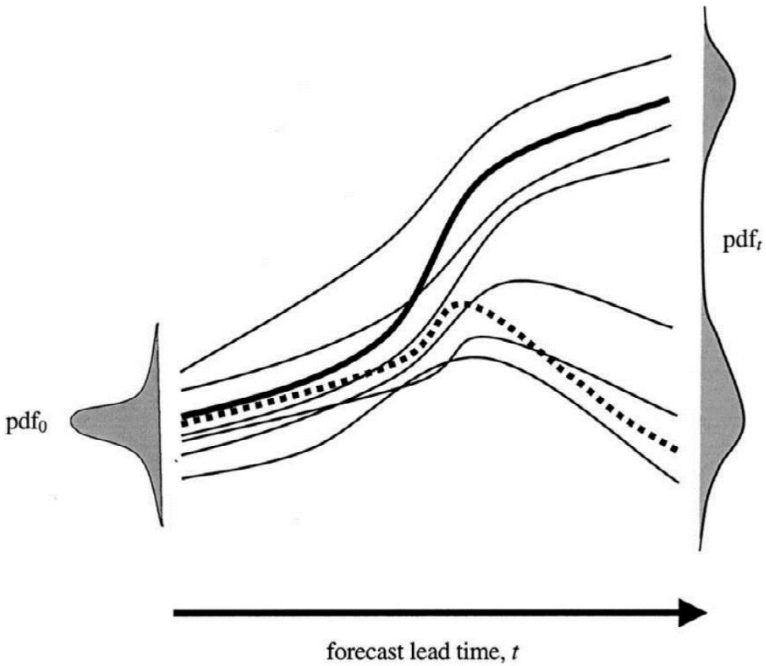
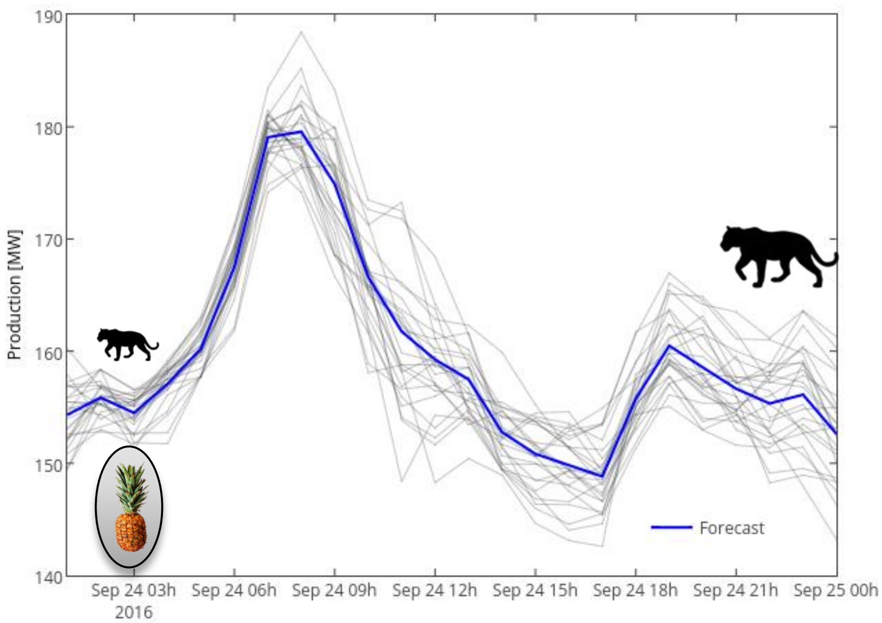
Ensemble forecasting



From: Taylor, James W., and Roberto Buizza. "Using weather ensemble predictions in electricity demand forecasting." *International Journal of Forecasting* 19.1 (2003): 57-70.

My online heat demand forecast



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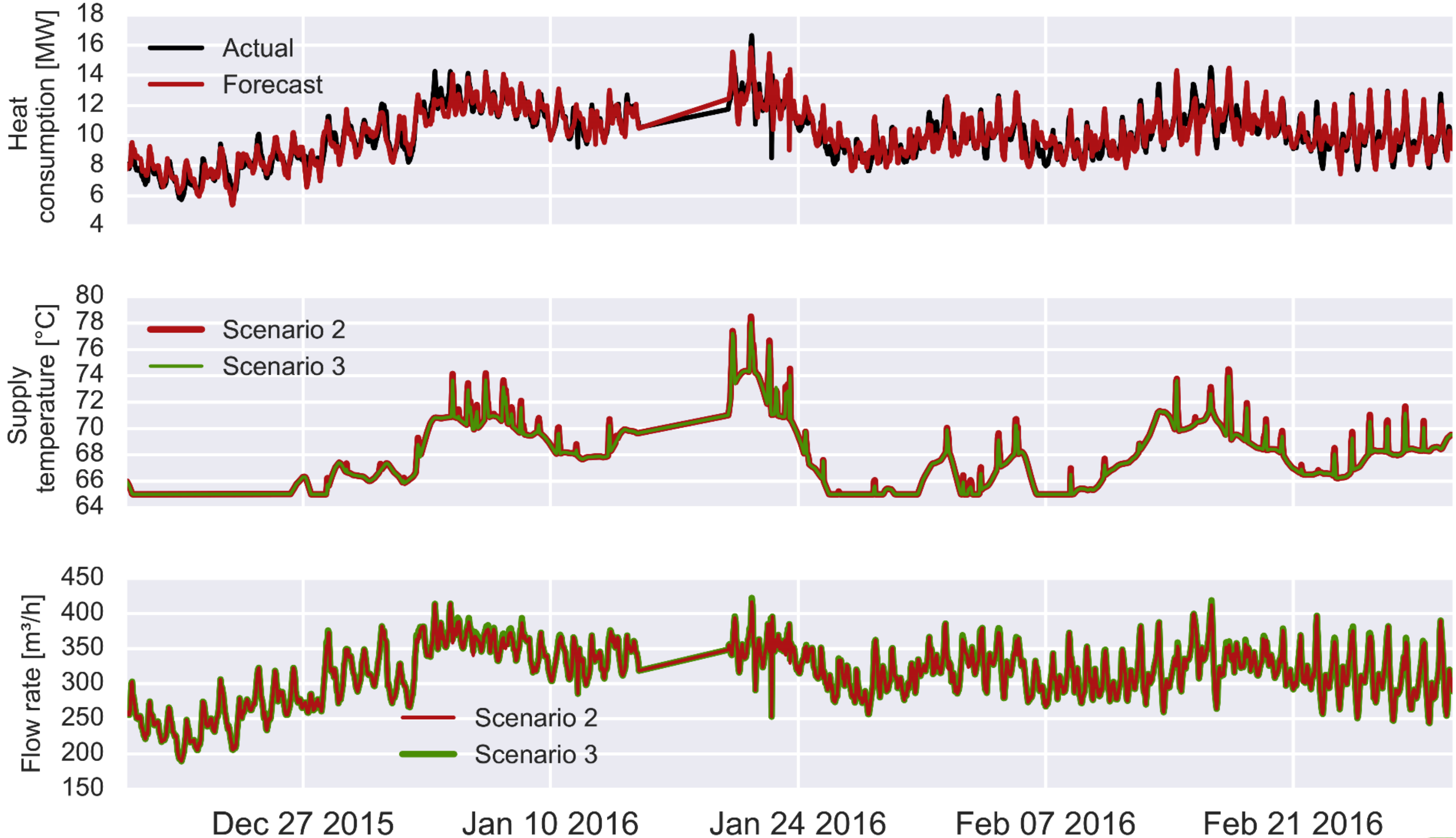
Scenario 2 and 3 – Holme



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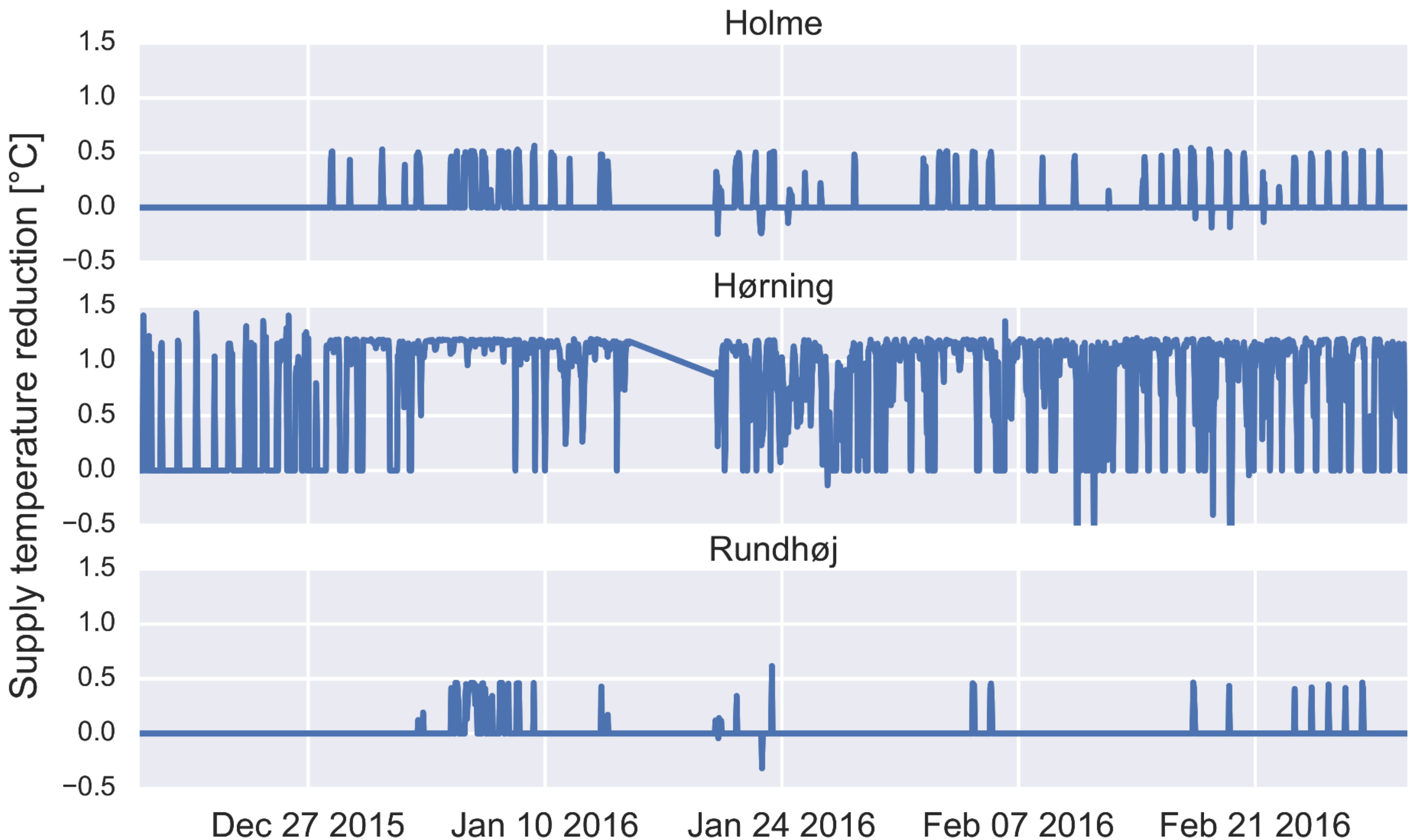
Supply temperature reduction



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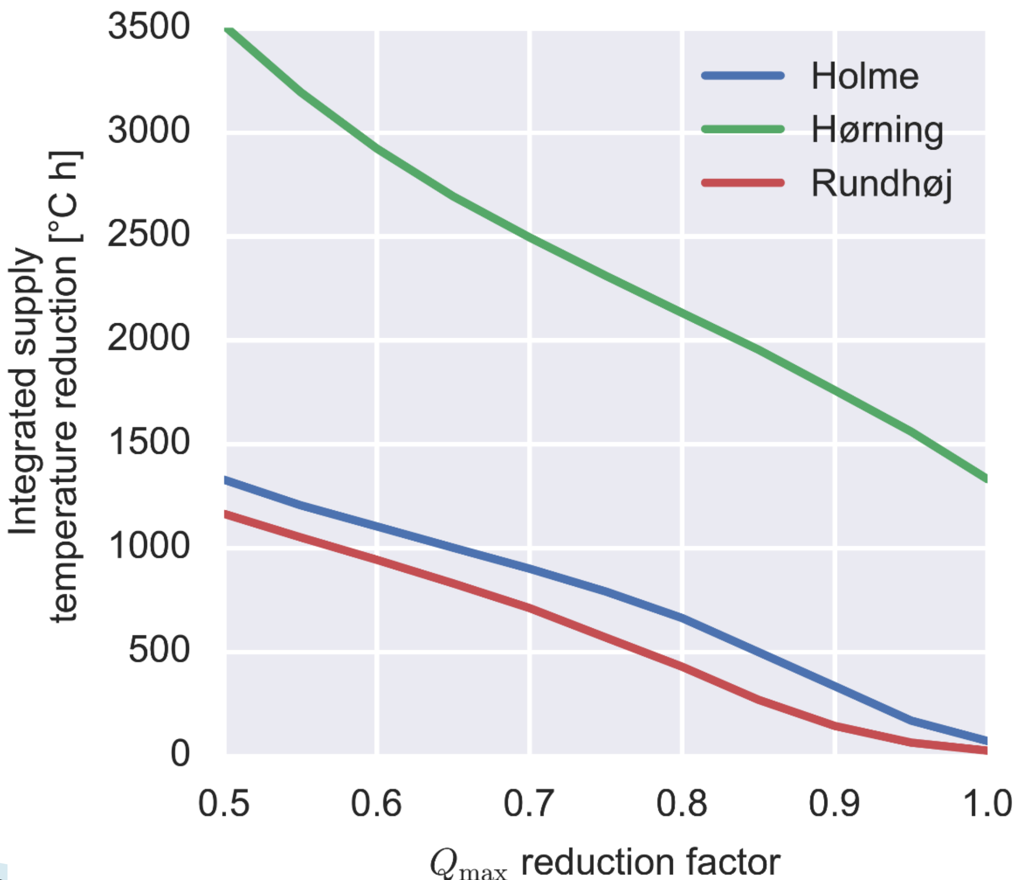
Size matters

$$\hat{P} + \delta\hat{P} > \rho c Q_{\max}\left[T_{\text{sup}}^{\min}(\hat{T}^{\text{out}}) - \hat{T}_{\text{ret}}\right]$$



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Conclusions

- Implementing optimized control:
  - Significant supply temperature reductions

- Improving optimized control w. dynamic uncertainties:
  - Smaller additional supply temperature reductions

- Substations with limited capacity can benefit most

Paper submitted to Applied Energy:
Dahl, M., Brun, A. and Andresen, G.B.
"Using ensemble weather predictions in district heating operation and load forecasting"

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Outlook – other applications

- Operation of heat storage to cover economic risk
  - What is the price of always keeping your promises?
- Qualify risk estimates for unit commitment decisions
  - Should we start up a more expensive production unit?

How much are we willing to gamble?

vs

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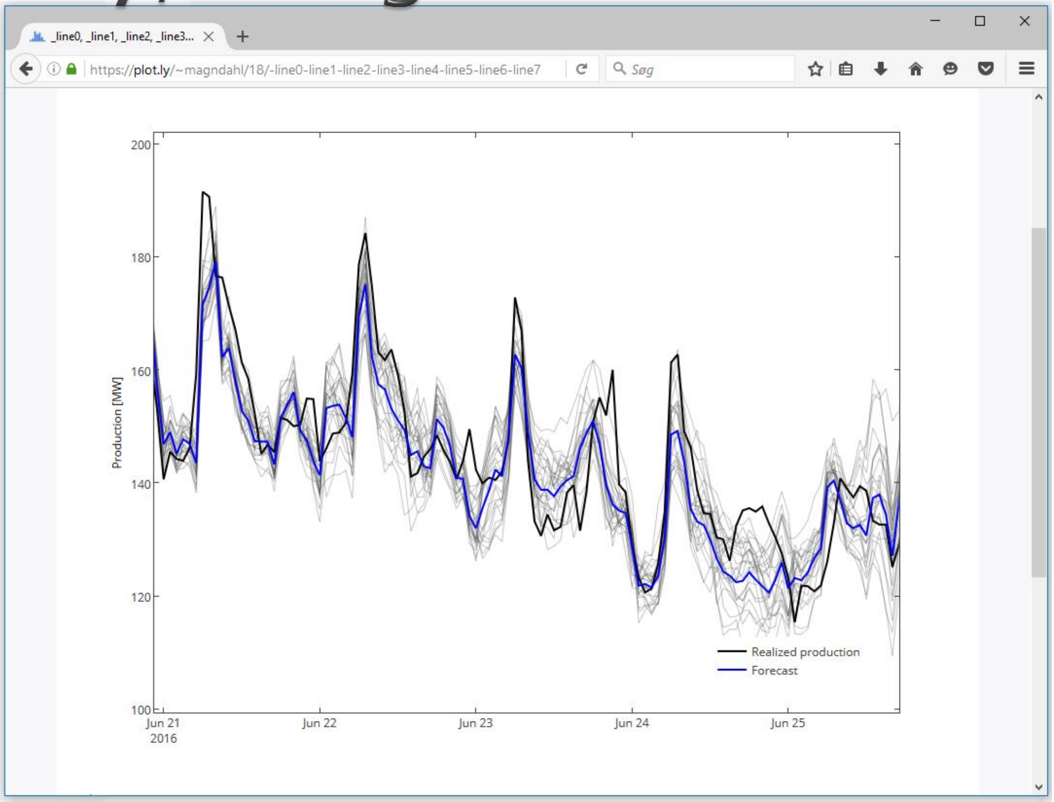
Thank you for listening! Questions?

Visit plot.ly/~magndahl



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