
DTU

QUANTIFICATION OF HEAT DEMAND FORECAST ACCURACY IMPROVEMENTS BY LOCALIZED WEATHER FORECAST

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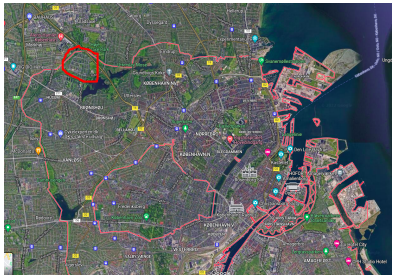
Research Question

What is the gain of localizing weather forecast for heat demand forecast?

Inspiration

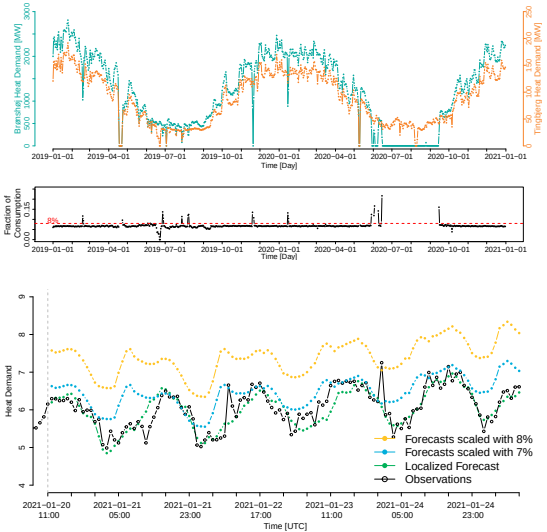
1. The IDASC project was to investigate how to operate the network of Tingbjerg more efficiently. Can Smart Meters help?.
2. Investigate Heat Demand Forecasts.
3. Perform temperature optimization of the Heat Exchanger.



[1] See findings in the *IDASC project*

Inspiration

1. Operation of DH area which consists of smaller areas inside where heat exchangers operate the smaller areas



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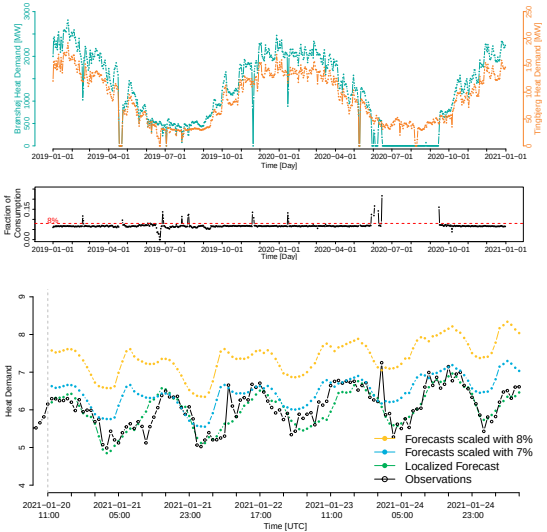
2. The load Forecast for total area scaled with fixed (old) fraction to operate the smaller areas



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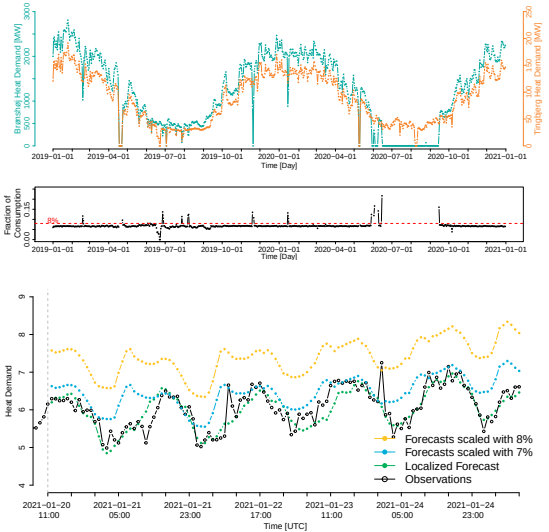

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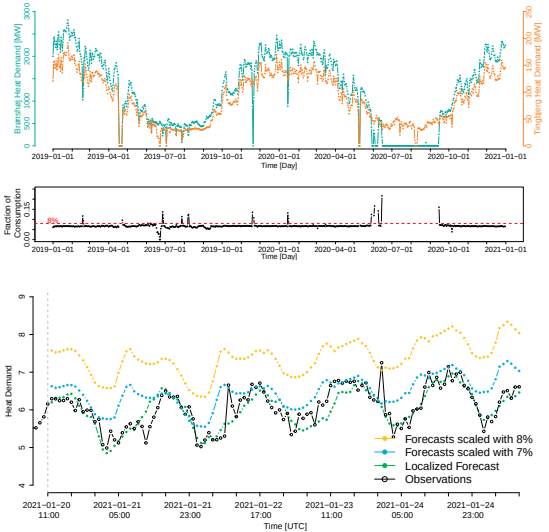

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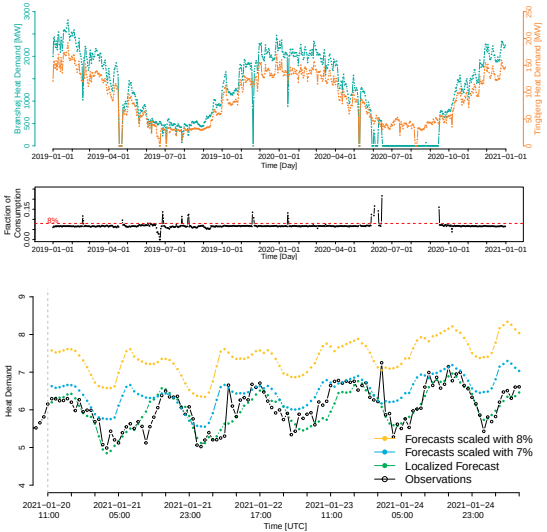
5. **Localized Heat Demand Forecast!** [1]



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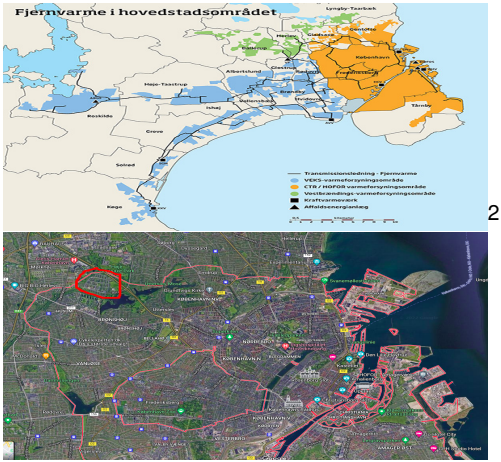
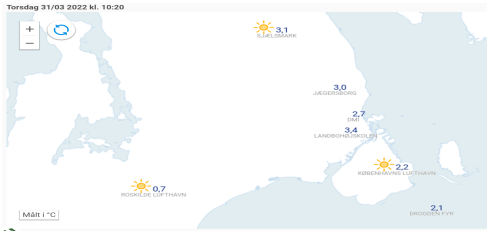
Inspiration: Localized Weather Forecast



[2]



[3]

[2] Figure from *Varmelast*

[3] Snapshots from *DMI weather stations*

Localize Weather Forecast in Cities

Why localize weather forecast?

- DH is applied in areas with urban areas while NWPs are usually tuned for rural areas.
- Climate in urban areas is different to rural areas.
- Systematic bias between NWP and local weather stations is often observed.[4]
- Thus, localizing the NWP by adjusting them using local climate stations represents the city climate better.
- So, does this increase the accuracy of a forecasting model?

[2] Crochet, P., 2004

How to localize Weather Forecast

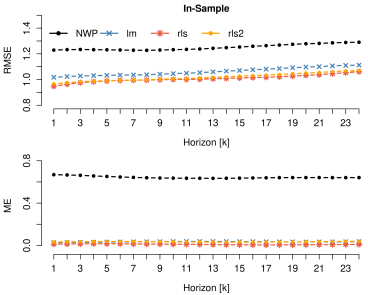
- The NWP are adjusted using the Model Output Statistics methods [5],

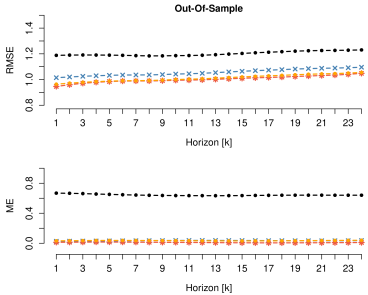
$$y_{\mathrm{T^{obs}}} = \beta_0 + \beta_1 T_a^{\mathrm{nwp}} + \epsilon$$

- Three different models are created
  1. Least Squares (lm) - constant parameters
  2. Recursive Least Squares - time varying parameters with $\lambda = 0.994$
  3. Recursive Least Squares - time varying parameters with $\lambda = 0.998$.
- Thus, four different weather forecast realizations of ambient air temperature are used in this study,
  1. T_a^{nwp} - raw NWP.
  2. $T_{a,lm}^{\mathrm{nwp}}$ - Adjusted NWP with constant parameters.
  3. $T_{a,rls}^{\mathrm{nwp}}$ - Adjusted NWP with time-varying parameters.
  4. $T_{a,rls2}^{\mathrm{nwp}}$ - Adjusted NWP with time-varying parameters.

[5] *Glahn & Lowry, 1972*

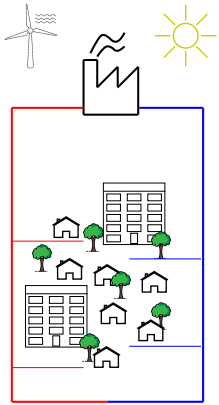
Localized Weather Forecast





District Heating

- DH system consist of production, network of pipes (forward and return water) and the end-users.
- Heat demand consists mainly of *Space Heating (Radiators)* and *Domestic Hot Water (Tap Hot Water)*
- Space heating is driven by the climate and social components.



Heat Demand Forecast Model

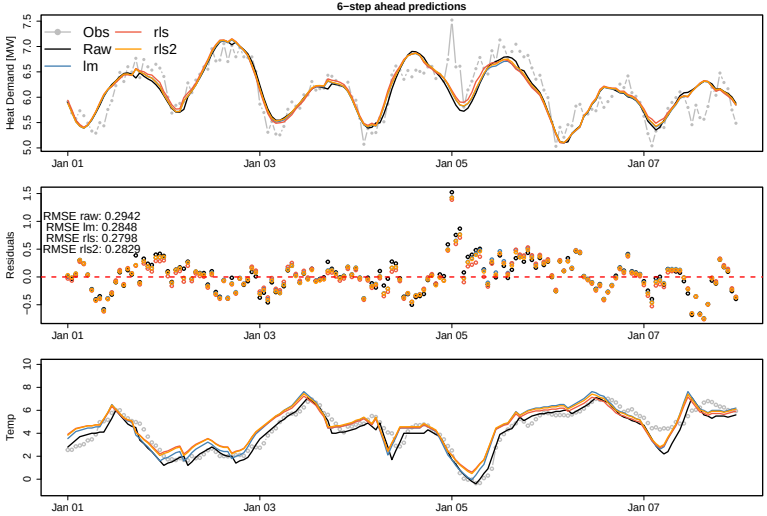
For simplification, a simple model will be used to illustrate the forecasting model[6],

$$Y_{\text{HeatDemand}} = \beta_0 + \beta_1 X + \epsilon$$

where X will be replaced with one of the four ambient air temperature forecast. Hence, creating four different forecast of the heat demand using different inputs to quantify the improvements.

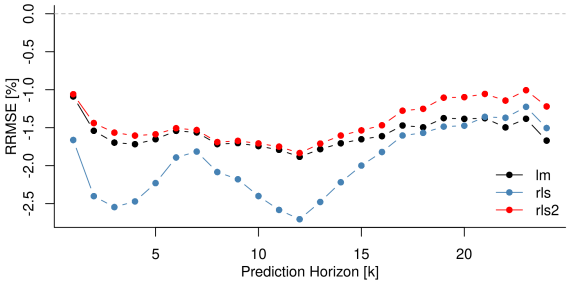
[6] See the conference paper or the last two additional slides for information on the model used.

Modelling and Forecasting in DH: Showcase



Improvements by localizing

- Base model uses raw NWP and is used to compare the improvements of adjusting NWP.
- All three adjusted NWP models improve the heat demand forecast.
- Allowing the coefficients to vary more freely has the largest improvements, especially in the first 12 k-step horizons.



$$\mathrm{RRMSE} = \frac{\mathrm{RMSE}}{\mathrm{RMSE}_{\mathrm{BASE}}} - 1$$

Conclusion

- Adjusting NWP to local climate stations gives a better representation of the local climate.
- The heat demand forecast accuracy is improved by adjusting the NWP to the local climate.
- Higher accuracy of forecast leads to better operation of a DH system, especially temperature optimization.

Future Work

- Is there a difference in accuracy depending on what hour of the day the forecast is made? (NWP used here is updated twice daily, at noon and midnight)?
- Can the forecasting model be improved?
- Where do the improvements come from?
- How much impact does the low-passing the temperature using either combination of observations and NWP or only the NWP?
- Optimal number and grid of local climate stations is needed?

Thanks!

Any Questions?

Feel free to contact me if you want to discuss this more!

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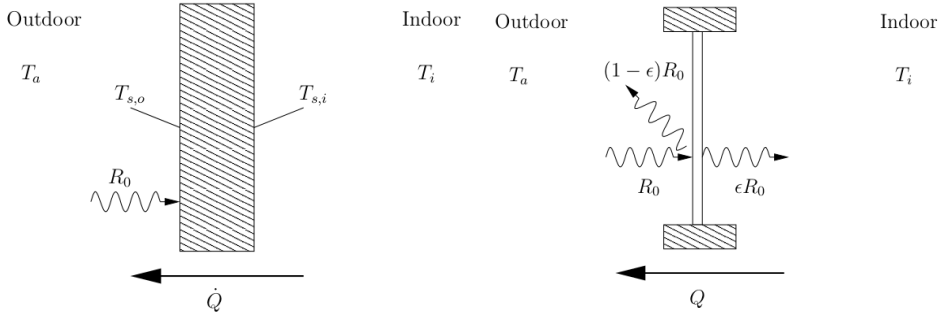
Heat Demand in DH



(a) Heat transfer through a wall.

(b) Solar Radiation through a window.

Figure: The figures demonstrate the stationary heat transfer through wall and window of a building. Missing is the effect of the ventilation. The source of these figures are found in Nilsen & Madsen, 2000

Modelling and Forecasting in DH

$$\hat{y}_{t+k|t} = \beta_{0,k} + \beta_{1,k} y_t + \beta_{3,k} H(q) T^{\text{obs,nwp}}_{a,t+k|t} + \beta_{4,k} H(q) W^{\text{nwp}}_{s,t+k|t} + \beta_{5,k} H(q) G^{\text{nwp}}_{t+k|t} + \mu_k(t, n_{\text{har}}, \alpha_{\text{diu}})$$

$$H(q) = \frac{1-a}{1-aq^{-1}}.$$

- $\hat{y}_{t+k|t}$ are the k-step ahead head demand forecast [7]
- β and α are the model coefficients that are time-varying.
- $T^{\text{obs,nwp}}_{a,t+k|t} = \{\ldots, T^{\text{obs}}_{a,t-1}, T^{\text{obs}}_{a,t-1}, T^{\text{nwp}}_{a,t+1}, \ldots, T^{\text{nwp}}_{a,t+k}\}$ - Combine series of local observations of the ambient air temperature and NWP.
- $W^{\text{nwp}}_{s,t+k|t}$ is NWP of the wind speed.
- $G^{\text{nwp}}_{t+k|t}$ is NWP of the global radiation.

[7] Heat Demand forecast are created by the `R` package, *onlineforecast*