WaterLoss2022

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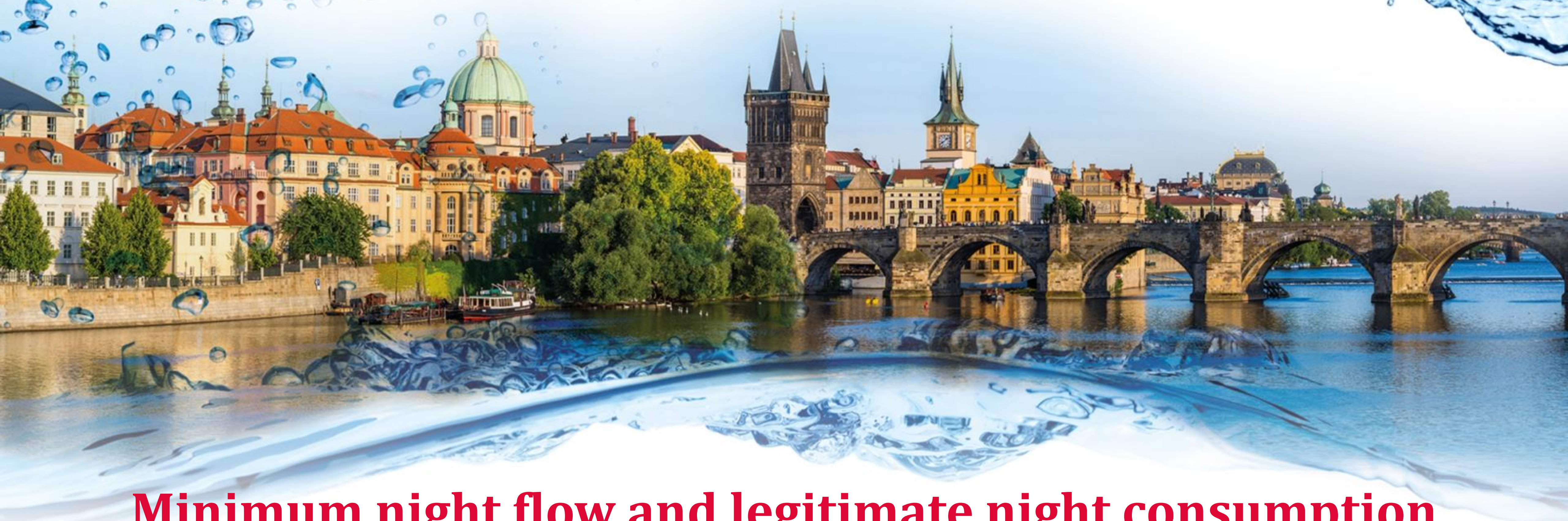
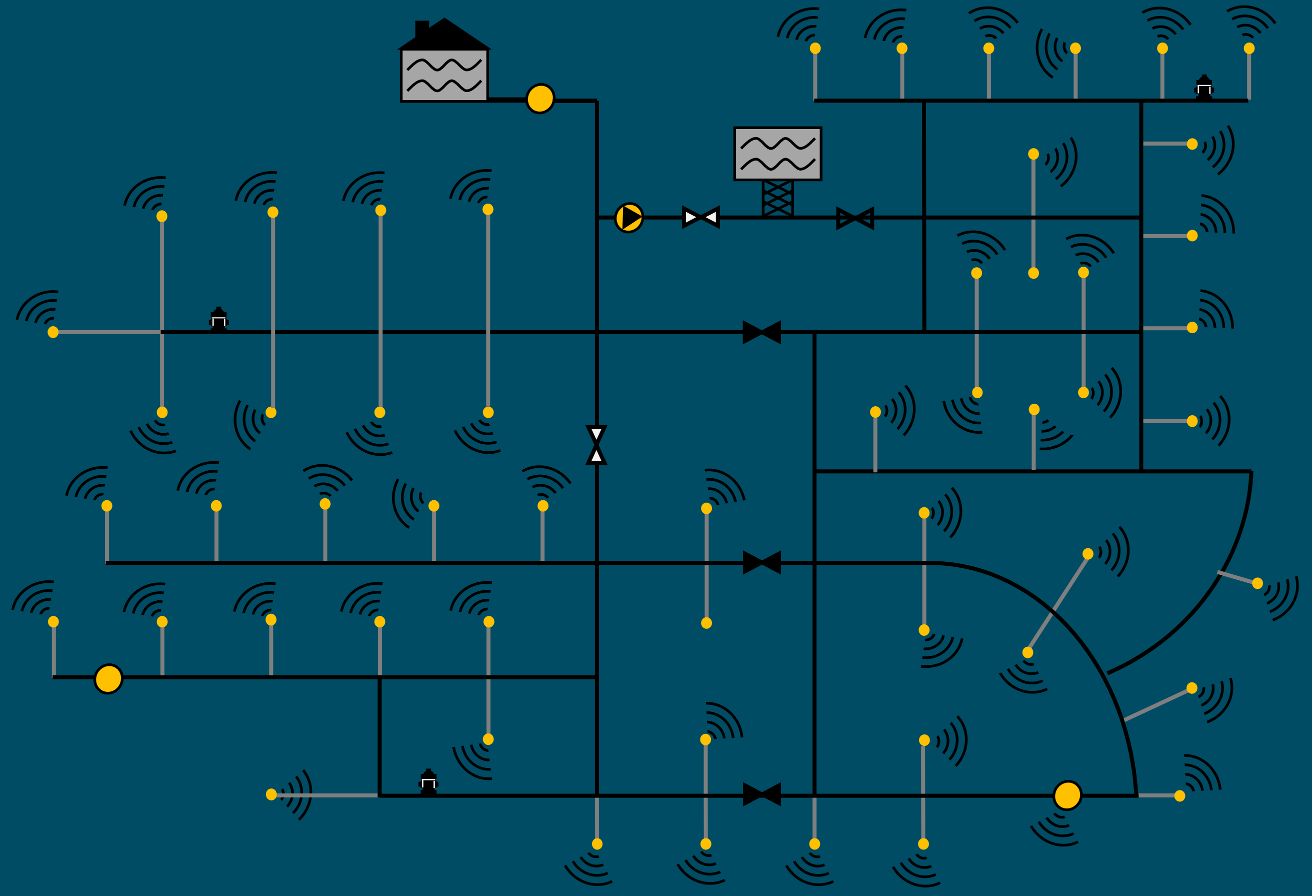


Minimum night flow and legitimate night consumption statistics using smart meter data

Jonas Kirstein & Klavs Høgh

Agenda

1. Motivation
2. Case study
3. Data Processing
4. Methodology
5. Results
6. Conclusions



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Motivation

- In Denmark, the number of smart meters is rising but a lot of data is not used fully (mostly for billing purposes only)
- Detailed customer night consumption statistics not available in Denmark (to our knowledge). Statistics open up for benchmarking possibilities.
- Retrieve better leakage-estimates in monitored areas without smart meters.
- New open data-sets available, that can increase the value of smart meter data.

Case Study

Utility	Information	Meters
A – Brønderslev	Sparsely populated rural area	1,096
B – HOFOR (Copenhagen)	Moderately populated urban area	2,304
C – Novafos	Moderately populated affluent urban area	2,727

- Period: 01/2018 – 04/2022
- Mostly smart meters of types: flowIQ 2200 (Kamstrup) , Hydrus (Diehl) and Multical 21 (Kamstrup)
- Raw sampling resolution between 15 seconds and more than several days (good and poor signal coverage, respectively), totaling 182 million telegrams.

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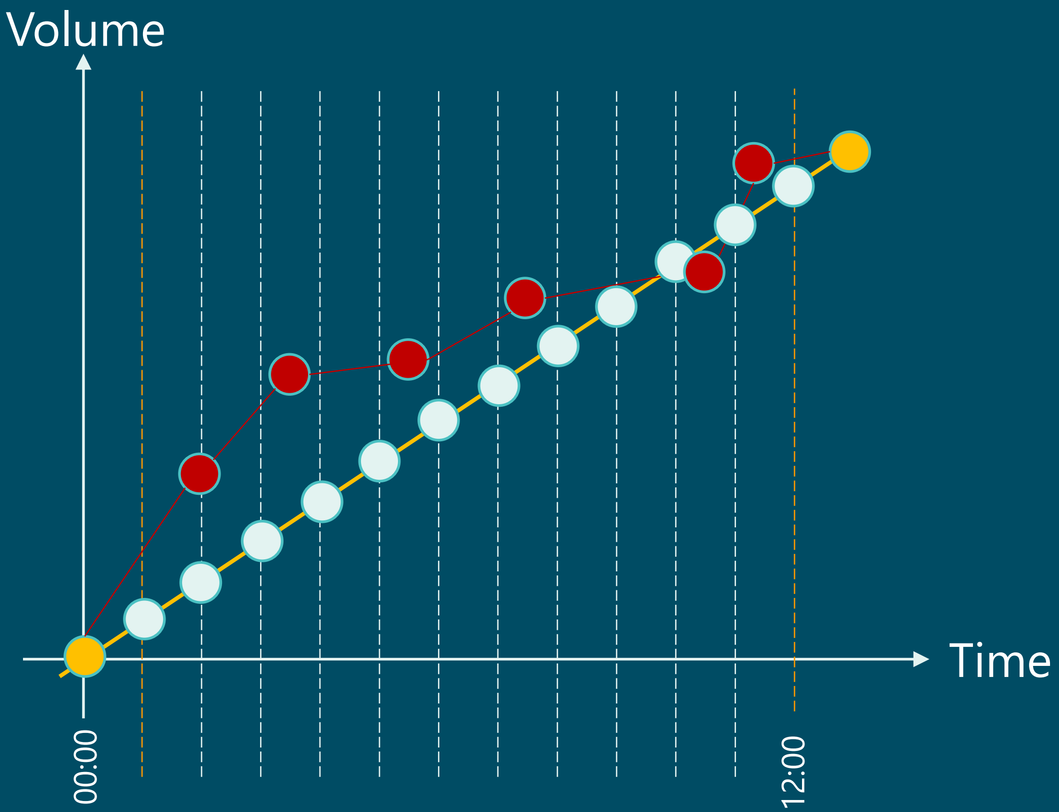
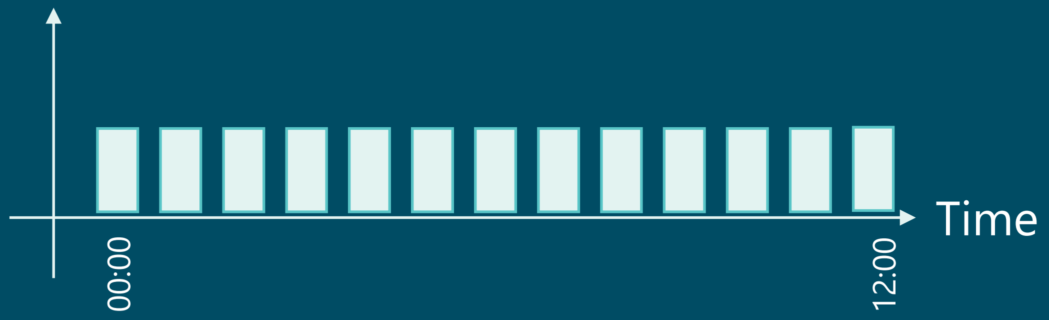
Data processing

Actual meter readings
Interpolated values
Missing readings

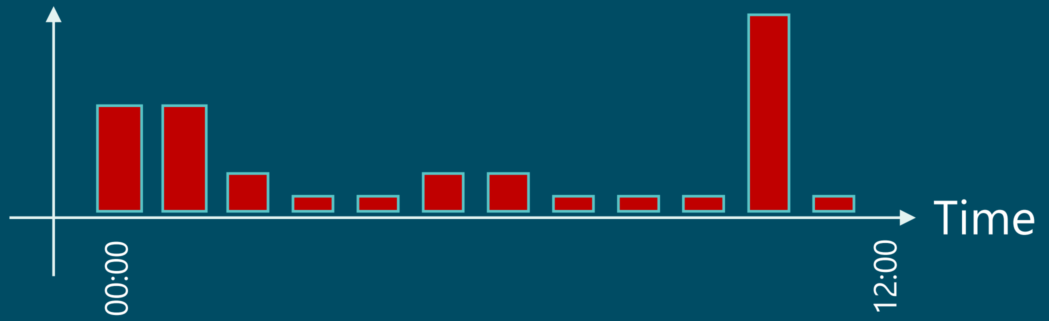
- Raw smart meter data is sampled at unsynchronized timestamps.
- Volume readings were linear interpolated to hourly-aligned data sets.[2]



Hourly flow (poor coverage)



Hourly flow (improved coverage)



- The longer distance between readings, the less we know when the actual consumption occurred.

Data processing

1. The raw 182 million telegrams were aligned to 325 million hourly samples.
2. Filtration rules: Hourly data, based on telegrams older than 1.5 hour, and samples resulting in negative flows were removed from the analysis. This reduced the data set to 100 million hourly samples.

Additional data and information available from the utilities:

- Partially: Meter size (Q_3 and/or DN-size).
- Inconsistent: Housing/Demand categories defined by utilities.
- GPS coordinates!

Danish Central Register of Buildings and Dwellings (BBR)

- Since 1976, the BBR is a baseline register about building and housing conditions that includes, among other things, each individual building's identification, location, purpose, year of construction, technical conditions, layout and electric installations and tenancy[1].
- GPS coordinates from meters are used to acquire detailed housing information.

Selected attributes of housing unit (example):

- Total unit area (incl. e.g. garden) (84 m^2)
- Area for living (84 m^2)
- Number of rooms (3)
- No. of toilets (1) & no. of bath (1)
- Kitchen with drainage available? (1)
- Type of housing/business (apartment in multi-family building)

ONLY the type of housing used in this study

Location used.

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Simplification of data set

- BBR-type of housing/business reduced from 110 to 14 categories (5 shown):

Multi-family and apartment houses
Single-family houses
Building related to agricultural production
Hotels, restaurants and other service industries
Office, trade and warehouse buildings

(Currently limited by the number of types available from the DMAs)

Demand category	Total no. of smart meters
Multi-family houses	289
Single-family houses	4,370
Other & Unknown	1,468

Meter size (Q_3 [m^3/h])	Total no. of smart meters
2.5 – 4	5,628
6.3 – 10	250
Other & Unknown	249

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Method

The minimum night flow (MNF) analysis is often carried out to assess the level of leakage in a district metering area (DMA). At the time of the MNF, the fraction of leakage (Q_L) of the total flow is expected to be at its highest:

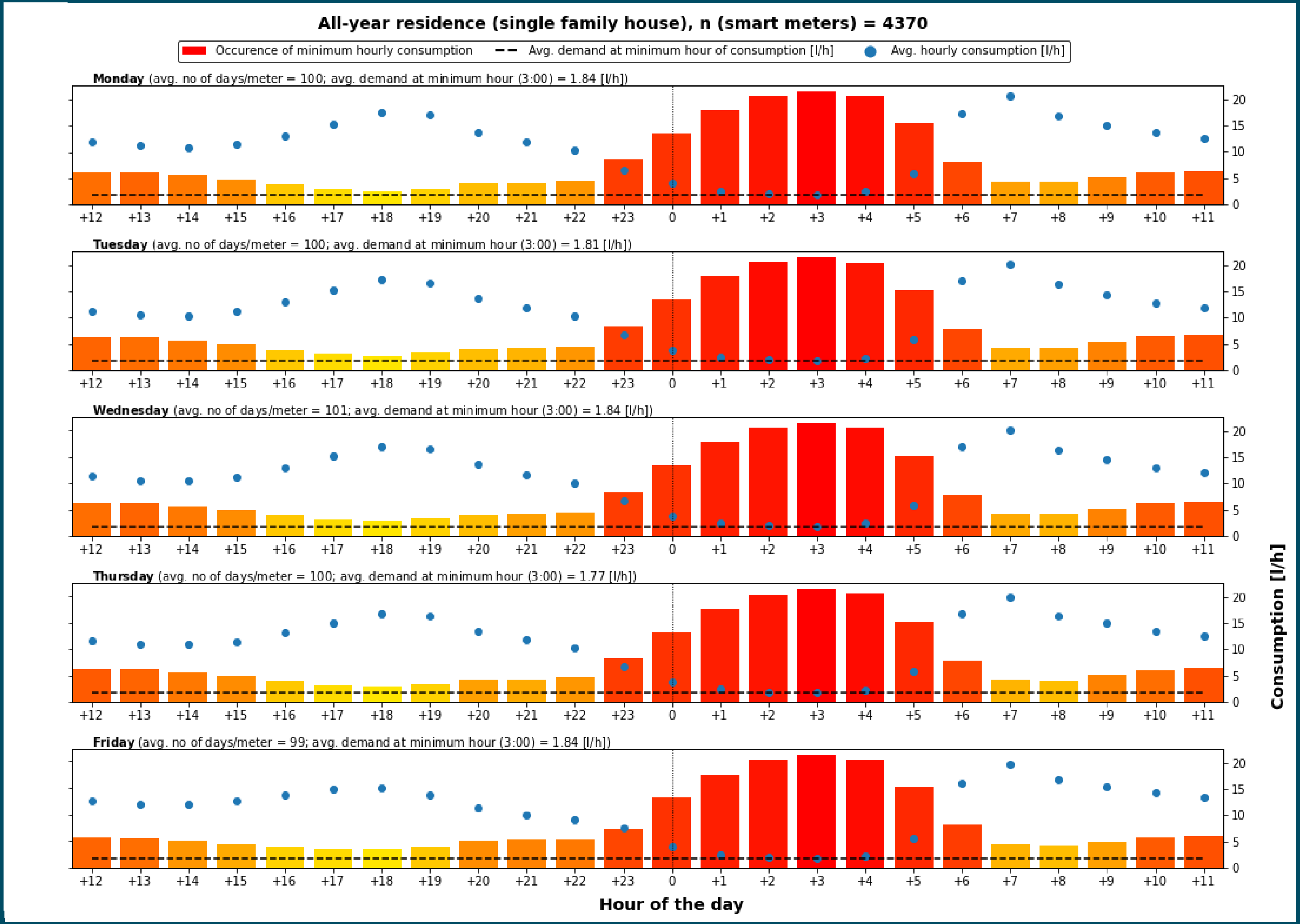
$$MNF(t_d, P_z) = LNC(t_d) + Q_L\ (P_z)$$

The legitimate night consumption (LNC), e.g. into a DMA, may vary from day to day and depends on the number of customer types *N* in the DMA:

$$LNC(t_d) = \sum_{\mathrm{i}} N_i \cdot CNC_i(t_d)$$

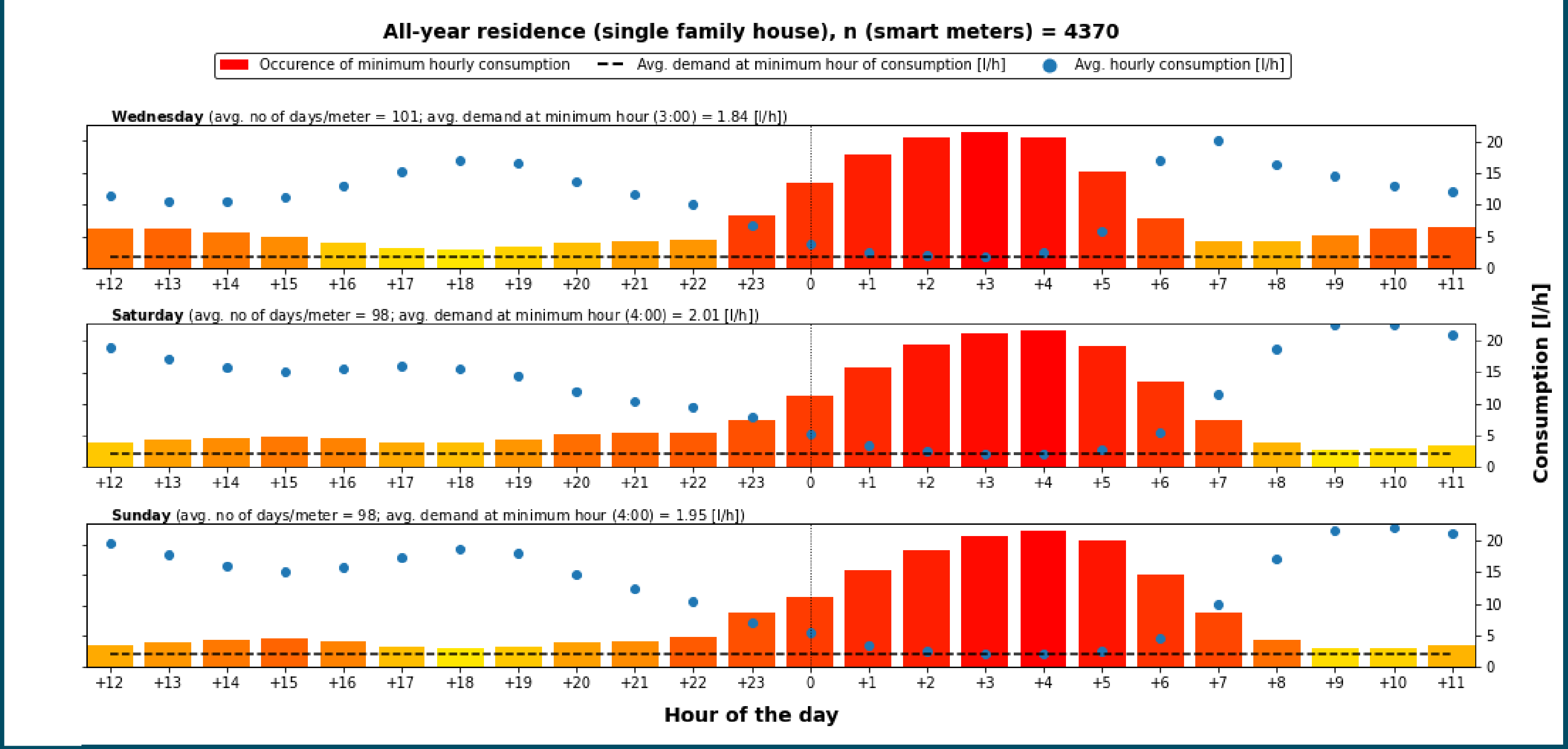
Next step: Compute the customer night consumption (CNC) for different customer groups at different times.

Single-family houses (Monday to Friday)



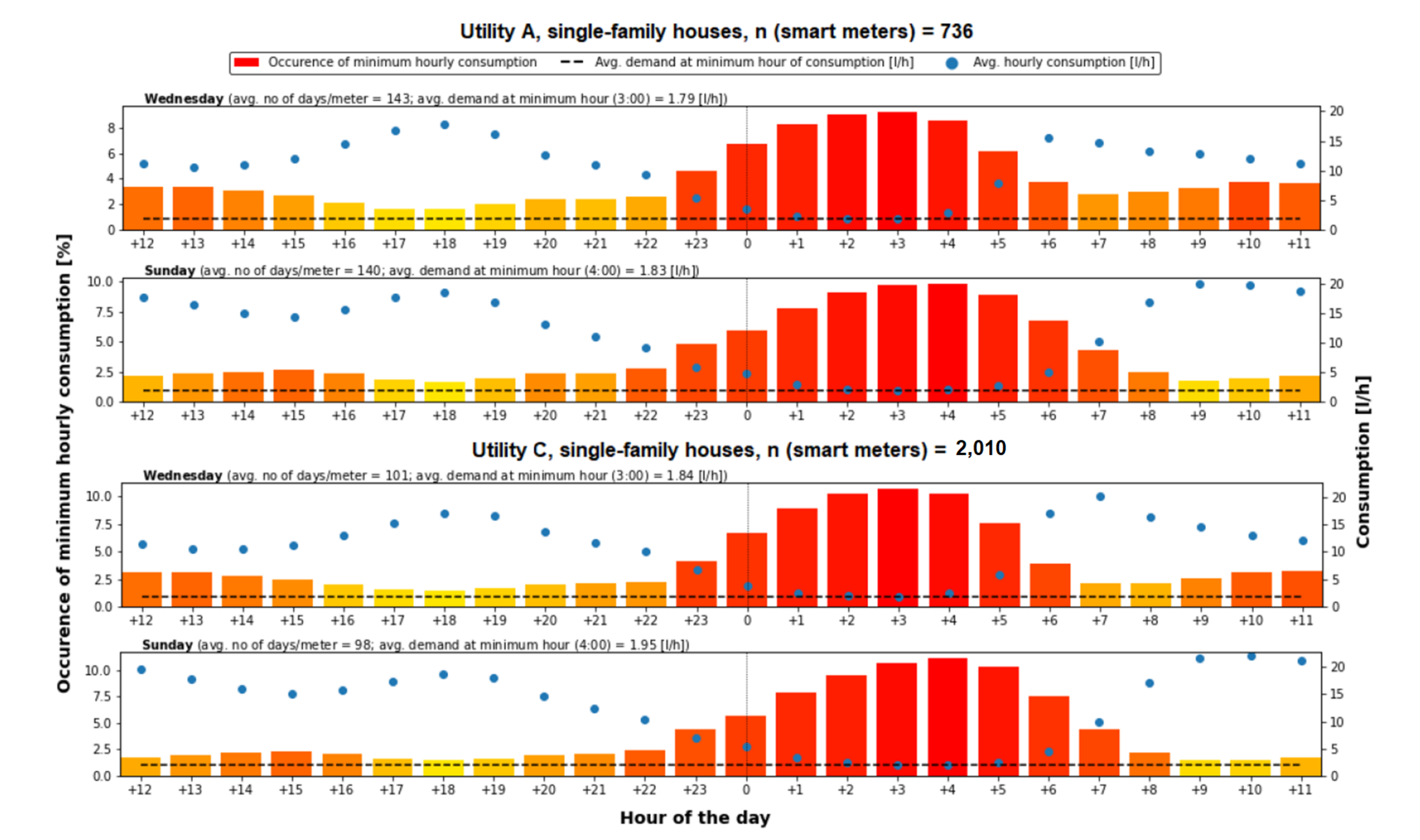
- Almost no difference in demand between Monday - Friday
- Minimum consumption hour typically in period 03:00–04:00
- Typical weekday: 2.02 l/s (between 02:00–05:00)
- 50% of minimum flow between 00:00–06:00

Single-family houses (Weekends)



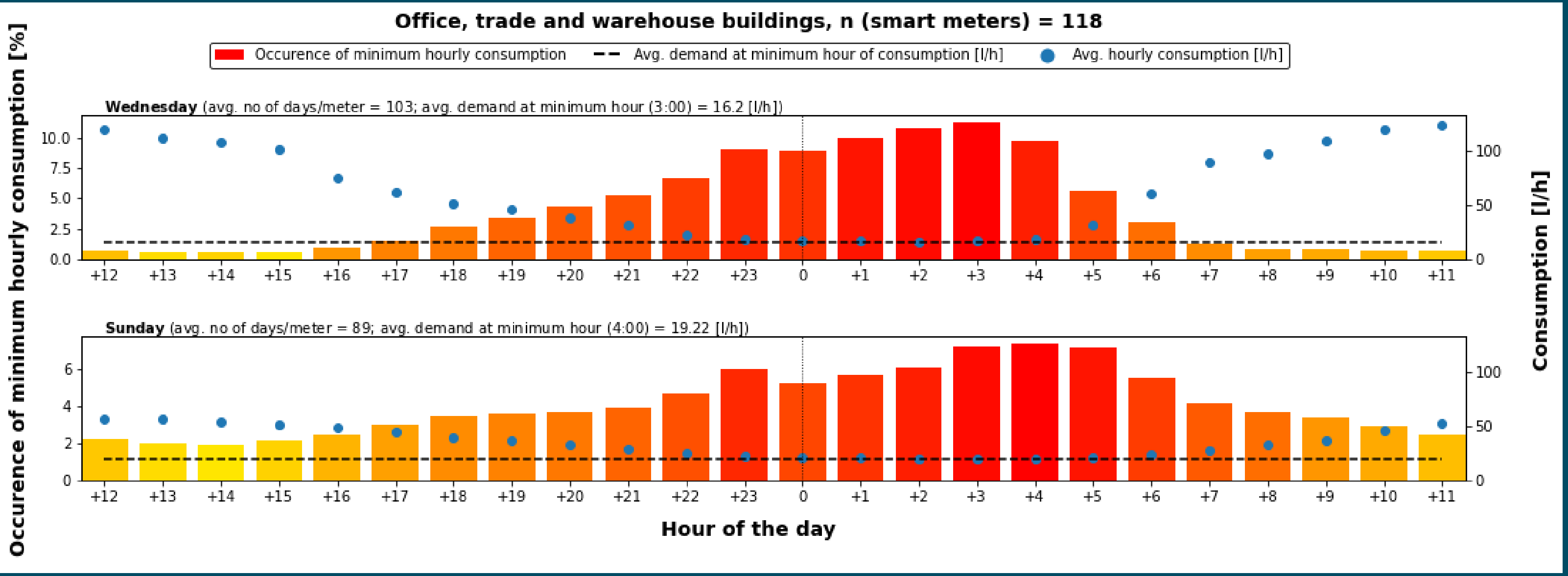
- As expected, weekend consumption very different
- Minimum consumption hour shifted one hour to 04:00–05:00
- Typical weekend: 2.14 l/s (between 02:00–05:00)
- **Most demand groups show that weekdays and weekends show similar results, respectively.**
- ~10% increase in CNC during weekends.

Single-family houses - Regional differences?



- Very similar patterns, but morning peak in Utility A indicates that people tend to get up an hour earlier than in Utility C
- Demand in Utility C at minimum night hour slightly higher during weekdays and weekend.

Example of other demand groups



- More flattened distribution of minimum flow hour
- On weekends, higher percentage of minimum flow hour occurs also during the day

Summary of CNC and Q_{Min}

Demand group / housing unit	Q_{min}-Hour	CNC [l/h] At Q_{min}-hour	CNC [l/h] (02:00-05:00 hours)	Q_{min}-Hour	CNC [l/h] At Q_{min}-hour	CNC [l/h] (02:00-05:00 hours)
		Workday			**Weekend**	
Single-family houses	3	1.82	2.02	4	1.98	2.14
Multi-family houses	3	1.85	1.99	4	2.03	2.30
Q_3 = 2.5–4 m^3/h	3	2.03	2.25	4	2.24	2.41
Q_3 = 6.3–10 m^3/h	3	23.85	24.44	4	24.55	25.47

- In general, the minimum flow-hour shifts from 03:00 to 04:00 hours on weekdays and weekends, respectively.
- The CNC between a single-family and multi-family housing unit is very similar. The CNC between 02:00 – 05:00 is slightly higher for multi-family houses.
- Regional differences appear between demand groups of the utilities. For example, single-family houses in utility B (HOFOR) consume 0.5 l less than in utility A (not shown here).
- Literature values[3] for Germany and Austria are in the range 0.4 – 0.8 l/person/h. In Utility B, on average 2.9 persons reside in single-family houses, resulting in ~ 0.7 l/person/h.

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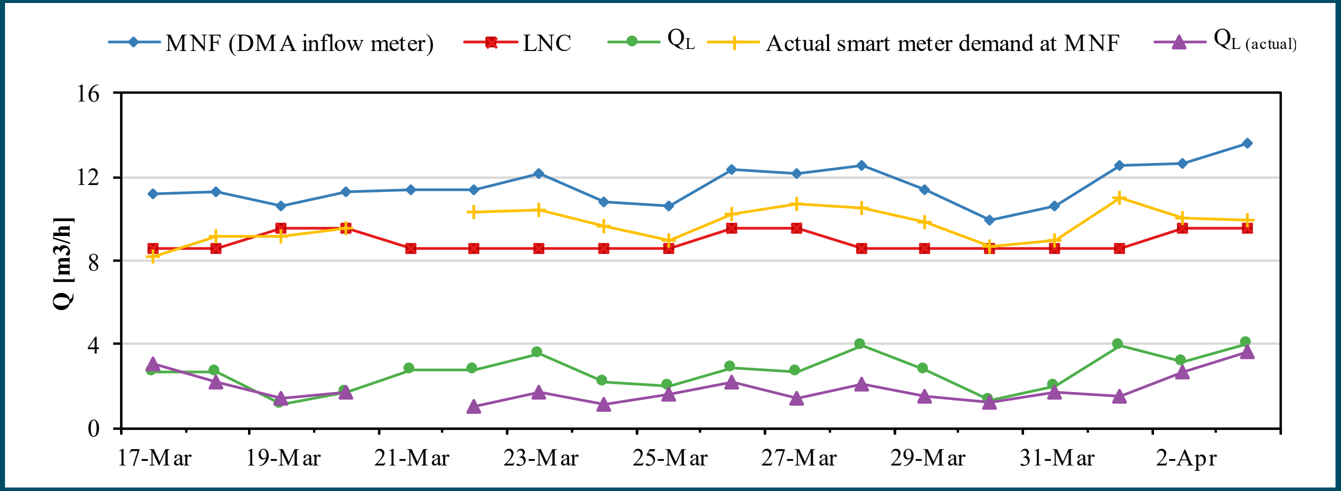
Example of leakage flow computation

The results on this slide were corrected/updated after the conference.

- Based on a DMA including 1,132 customers in Utility B.



- The LNC is based on a combination of 10 customer groups.
- Computed leakage (Q_L) estimated at 20% of the MNF.

- The estimated LNC is close to the metered night use from smart meters.

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Conclusions

Based on 6,000 smart meters the following was observed for Danish households:

- CNC is as low as 1.5–2.7 l/h (single-family houses) and 1.6–3.3 l/h for meters of size Q_3 = 2.5–4 m^3/h.
- For individual customers, the minimum consumption hour occurs only around 50 % of the time during night, between 00:00 and 06:00.
- For single-family and multi-family houses the minimum flow occurs most often at 03:00 and 04:00 during workdays and weekend days, respectively.
- Regional differences between the CNC of the utilities were observed but require further analysis.
- The results indicate that other factors, such as population density, standards of living, size and age of buildings may affect the CNC, which will need to be assessed in future studies. Results shown are just the beginning, >= 7,000 smart meters wait to be processed.

- GDPR needs to be taken care of…
- **Smart meter data are not flawless and require processing.**
- The shown results, linking smart meter and housing data, opens new angles for more research.

The End

Thank you for your attention!

Questions?

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References

[1]https://econ.au.dk/the-national-centre-for-register-based-research/danish-registers/the-central-register-of-buildings-and-dwellings-bbr

[1] Kirstein, J. K., Høgh, K., Rygaard, M. and Borup, M. (2021). A case study on the effect of smart meter sampling intervals and gap-filling approaches on water distribution network simulations. Journal of Hydroinformatics; 23 (1): 66–75.

[3]Amoatey, P. K., Minke, R. and Steinmetz, H. (2014). Leakage estimation in water networks based on two categories of night-time users: a case study of a developing country network. Water Supply 1 April 2014; 14 (2): 329–336.