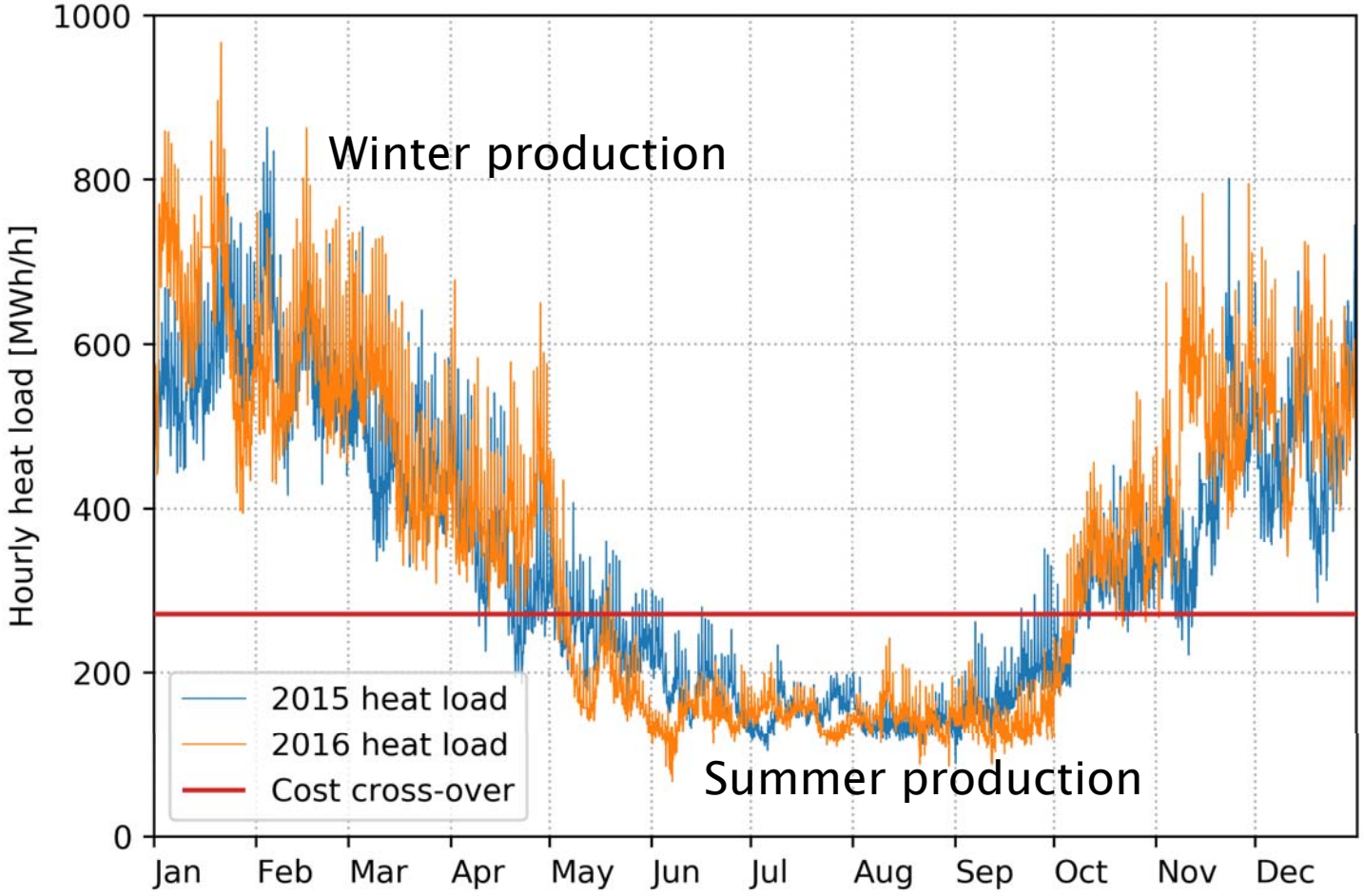
Long-term production planning in large district heating systems

Magnus Dahl
magnus.dahl@eng.au.dk
4DH Conference 13/9/2017

The challenge



READY

AARHUS UNIVERSITY

CITY OF AARHUS

Economic potential

- Potential annual savings: 4.5 – 7.6 million €
- 5% of annual operational production costs
- Average year: 6.3 million €

READY
AARHUS UNIVERSITY
CITY OF AARHUS

Two stages

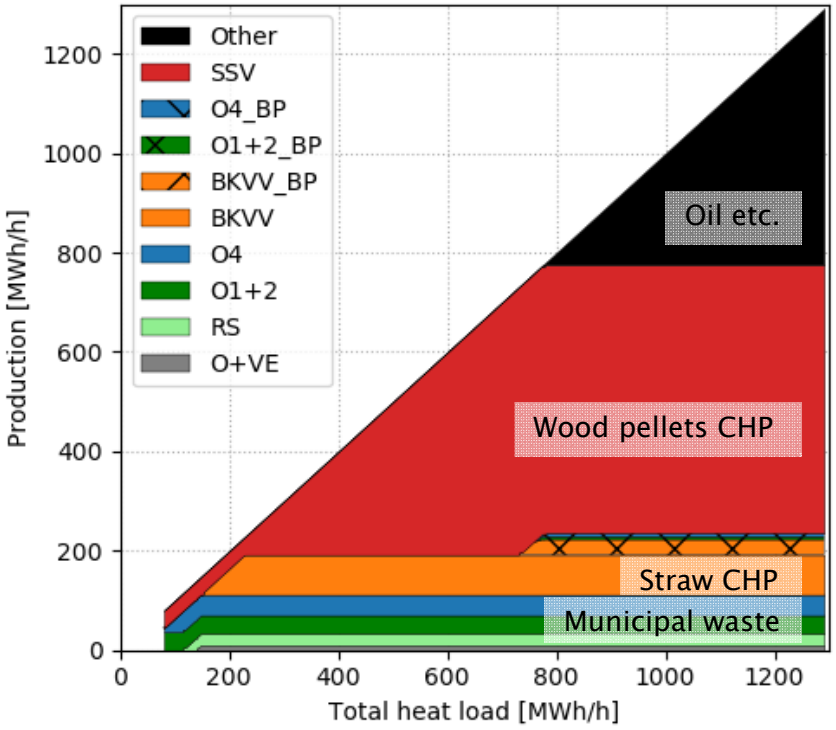
1) Perfect knowledge analysis

2) Practical decision rules

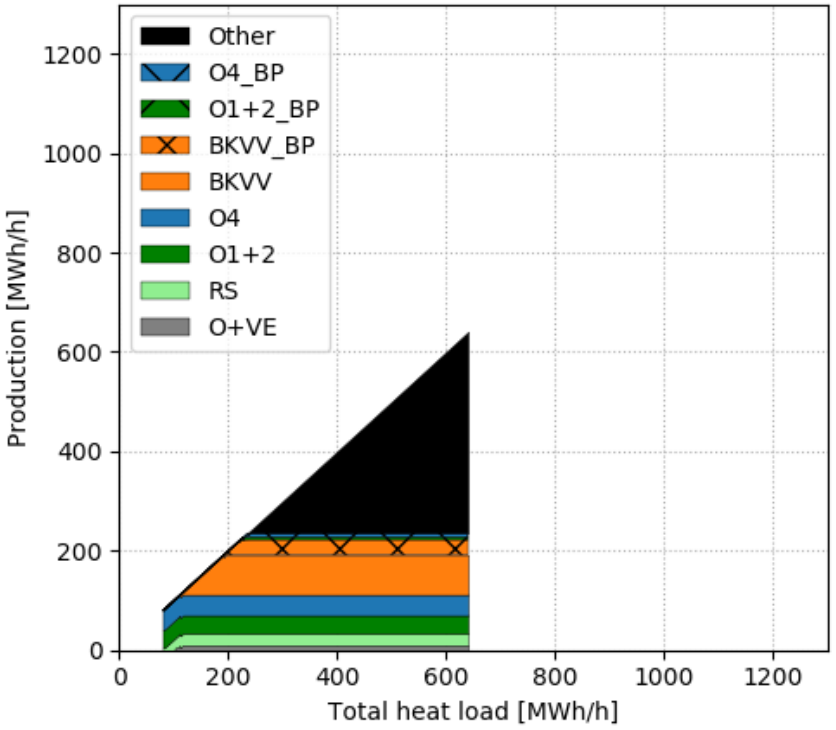
Merit order of production units

- The Aarhus production system

Winter production

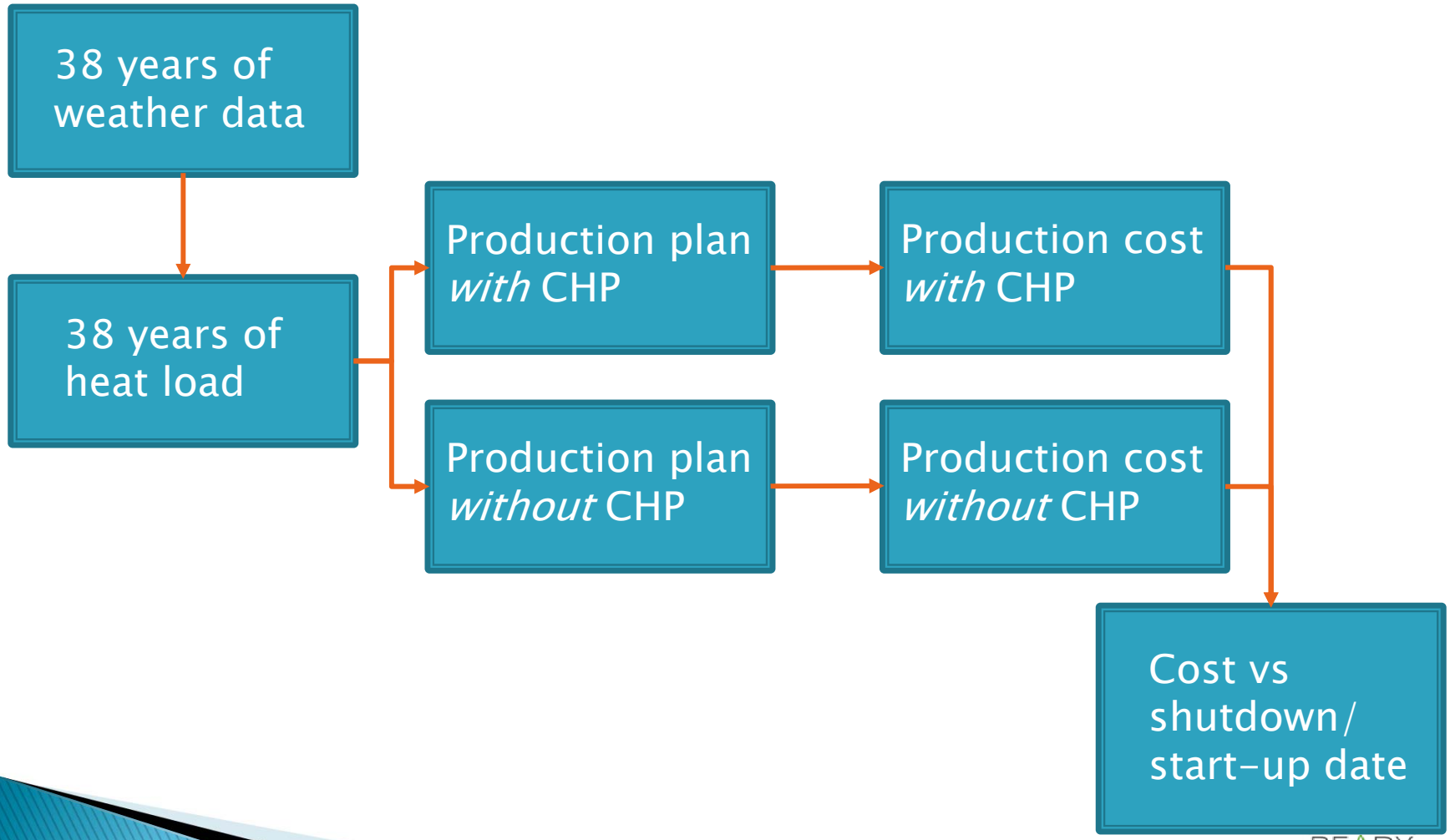


Summer production



READY
AARHUS UNIVERSITY
CITY OF AARHUS

Weather-based modeling

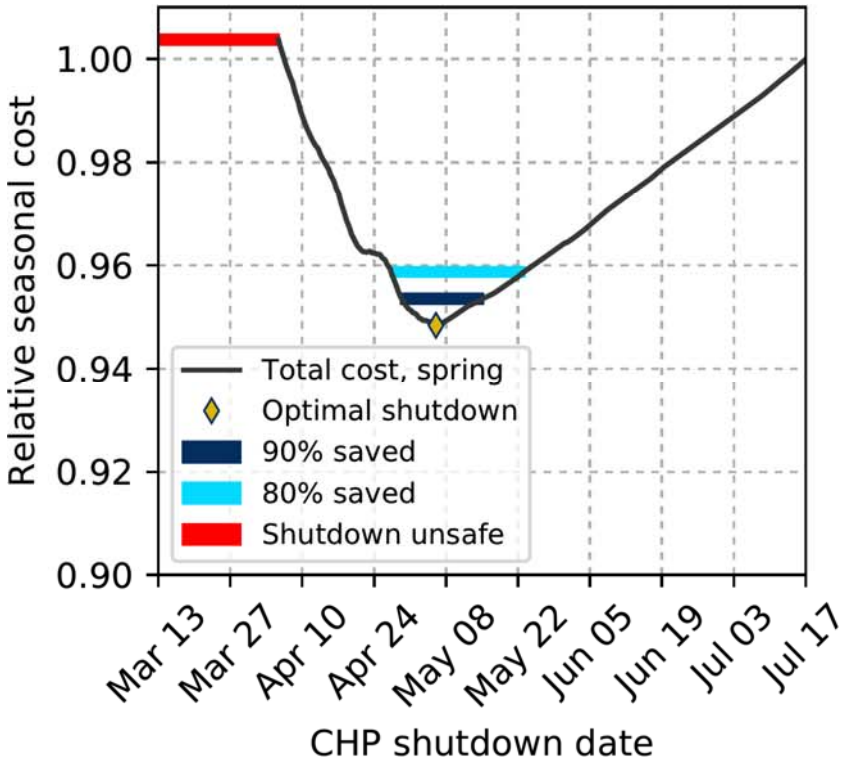


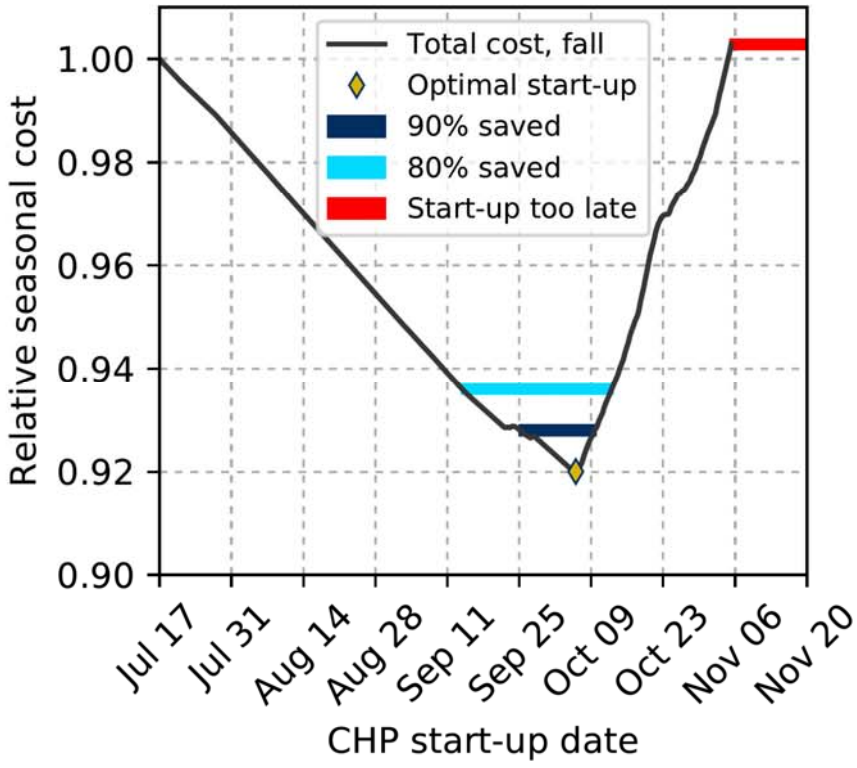
READY

AARHUS UNIVERSITY

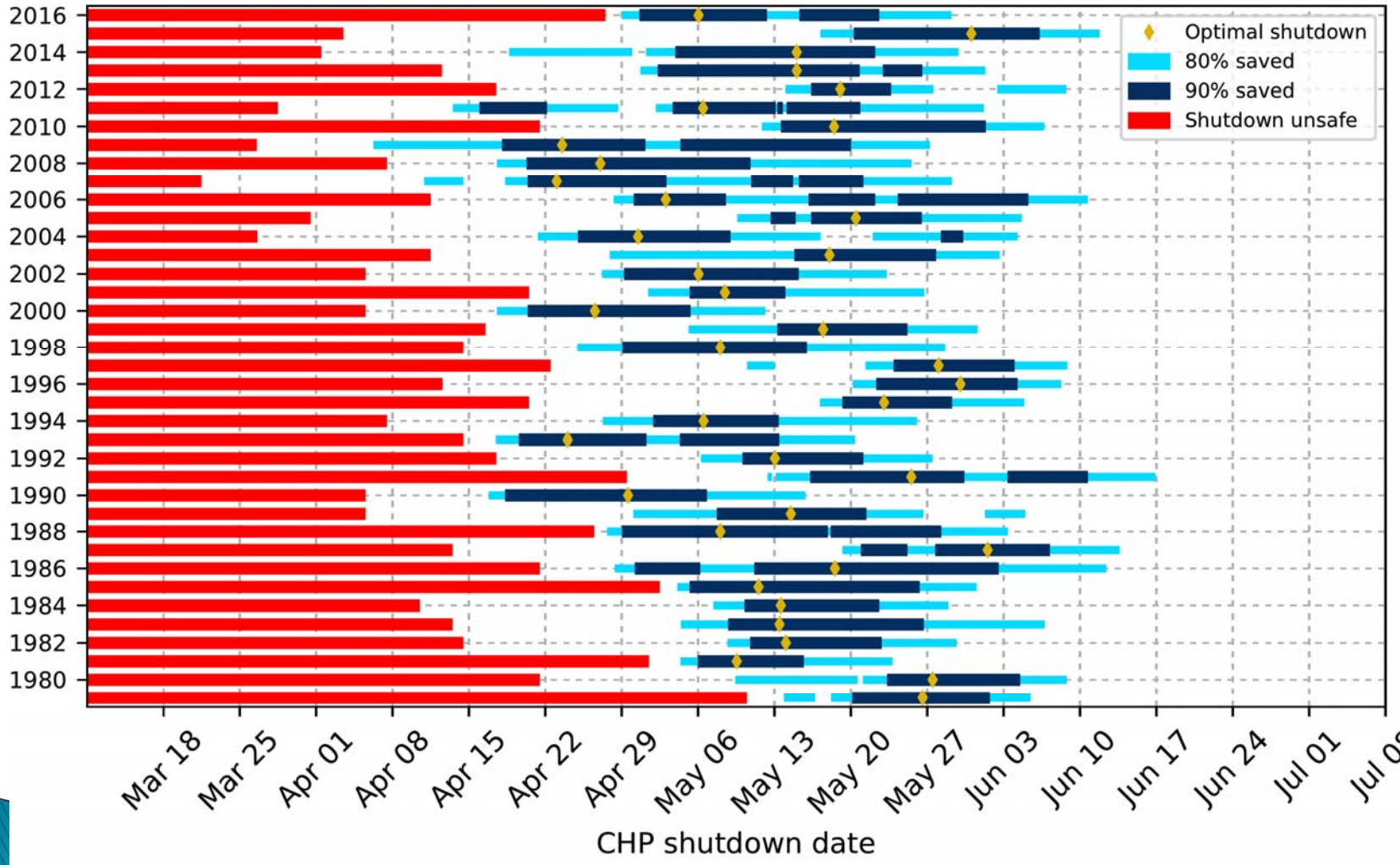
CITY OF AARHUS

Cost vs shutdown date



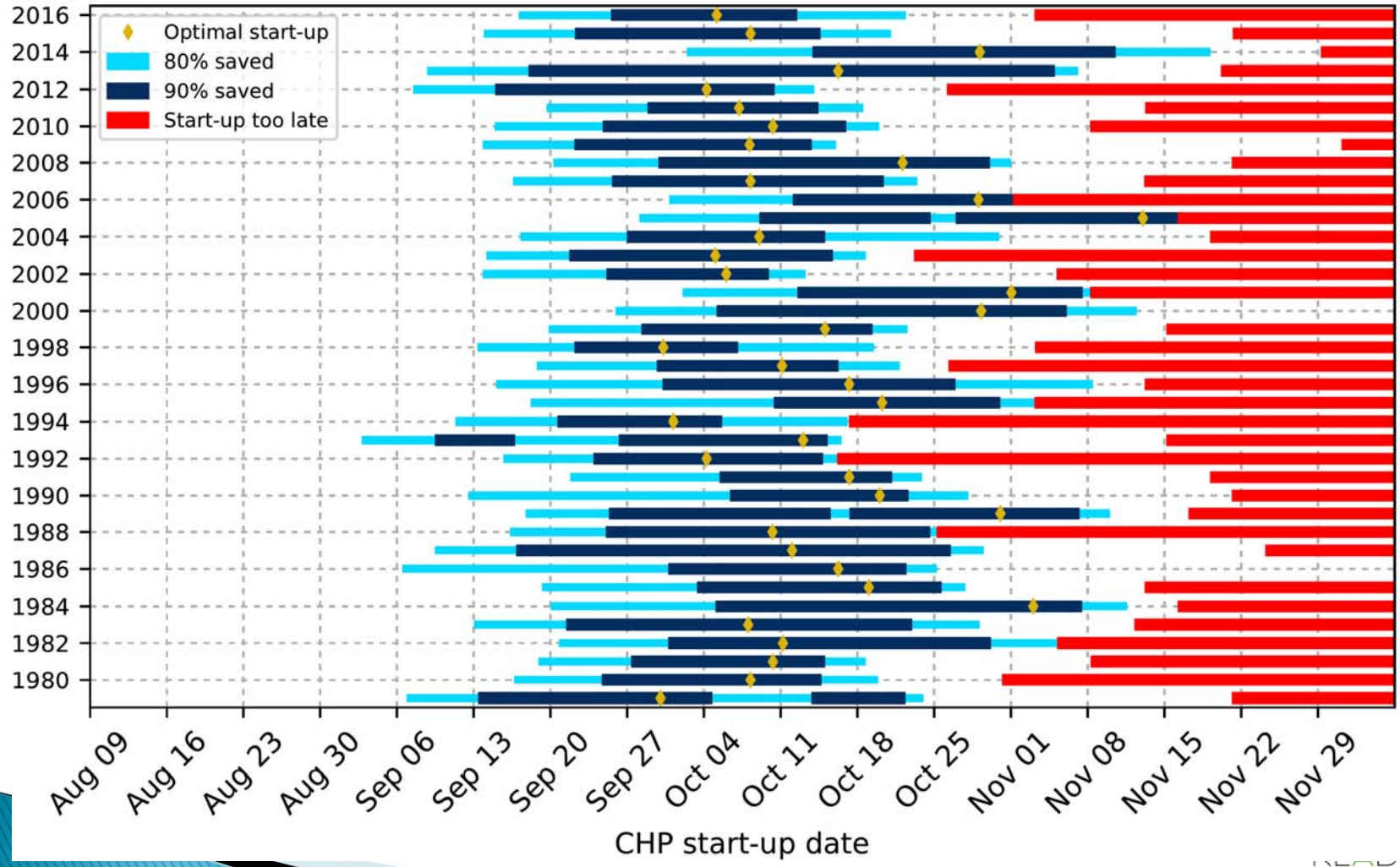


Optimal spring shutdown



AARHUS UNIVERSITY CITY OF AARHUS

Optimal fall start-up



Decision rules for shutdown/start-up

- Fixed date rule
- Load based rule
- Load based rule with 15 day forecast

Trade-off

Planning horizon vs performance

READY

AARHUS UNIVERSITY

CITY OF AARHUS

Load based decision rule

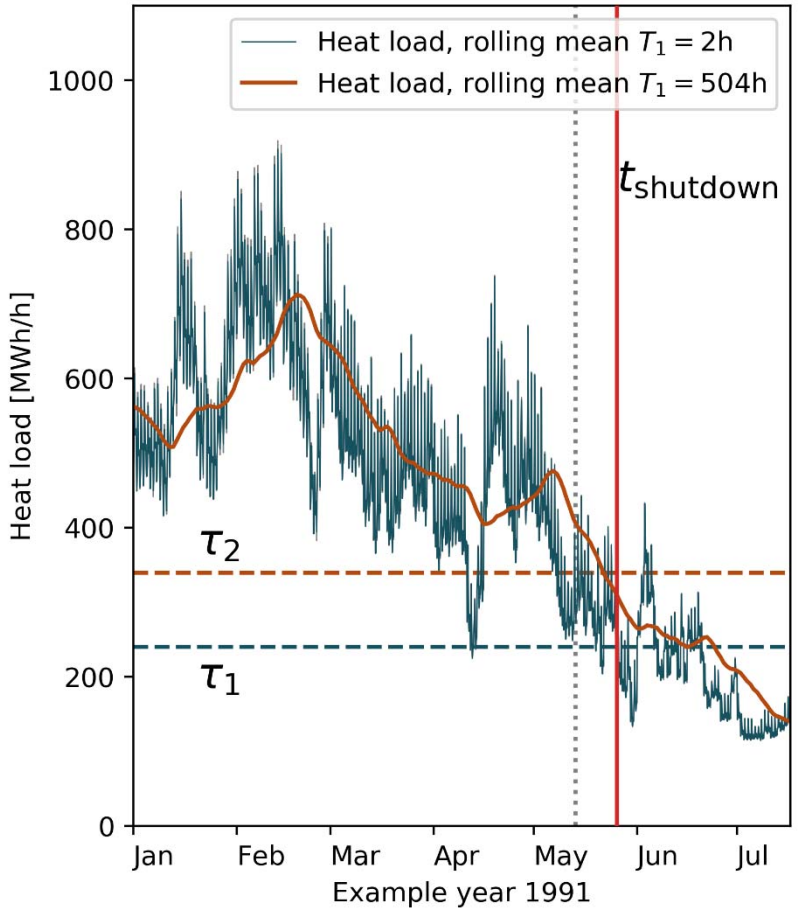
- Shut down the plant in the first time step t in which:

$$\frac{1}{T_1}\sum_{t'=t-T_1}^{t} P_{t'} \leq \tau_1$$

$$\frac{1}{T_2}\sum_{t'=t-T_2}^{t} P_{t'} \leq \tau_2$$

$$t \geq t_{\text{fixed}} - T_{\text{anchor}}$$

$P_{t'}$	Heat load in hour t'
τ_1, τ_2	Thresholds
T_1, T_2	Smoothing time scales
T_{anchor}	Anchoring time scale
t_{fixed}	Fixed date rule shutdown



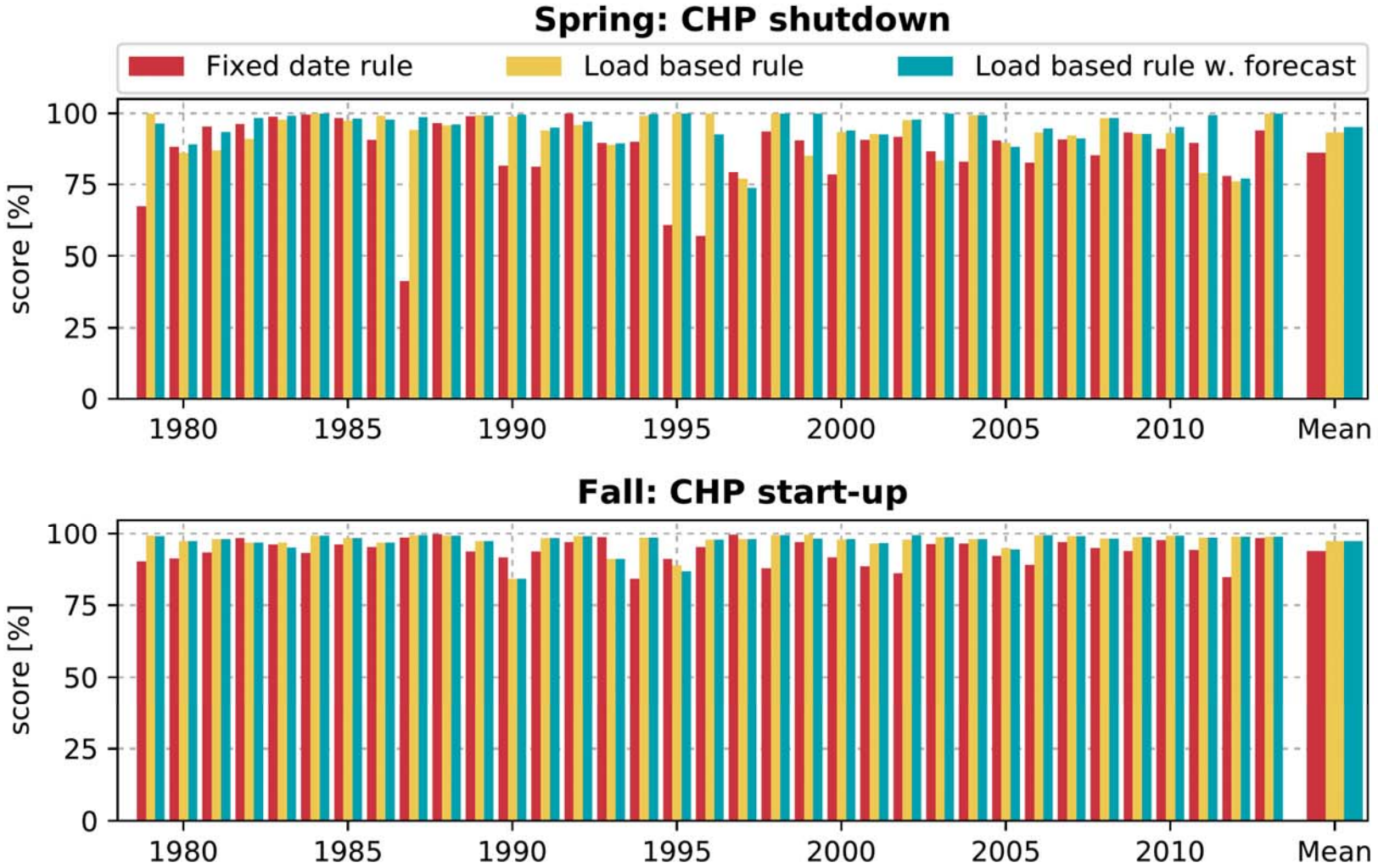
AARHUS UNIVERSITY CITY OF AARHUS

Measuring performance of the rules

- Scoring: Production cost vs reference scenario
- Model selection
  - 7-fold cross-validation on 35 years
  - Tuning of parameters e.g. T_1, T_2
  - Least squares training determines τ_1, τ_2
- Cross-validation reduces risk of overfitting

Performance of the rules

- 100% score: Full saving potential achieved



CITY OF AARHUS

Conclusions

- Large economic potential: 6.3 million € annually

- Most of the potential can be realized using:
  - Fixed date rule: 90.7%
  - Load based rule: 95.8%
  - Load based rule with forecasts: 96.5%

- Accuracy comes at the cost of shorter planning horizons

READY
AARHUS UNIVERSITY
CITY OF AARHUS

Thank you for listening!

Further reading:

Paper accepted in Applied Energy: M. Dahl, A. Brun, G. B. Andresen. Decision rules for economic summer-shutdown of production units in large district heating systems (2017)

READY

AARHUS UNIVERSITY

CITY OF AARHUS