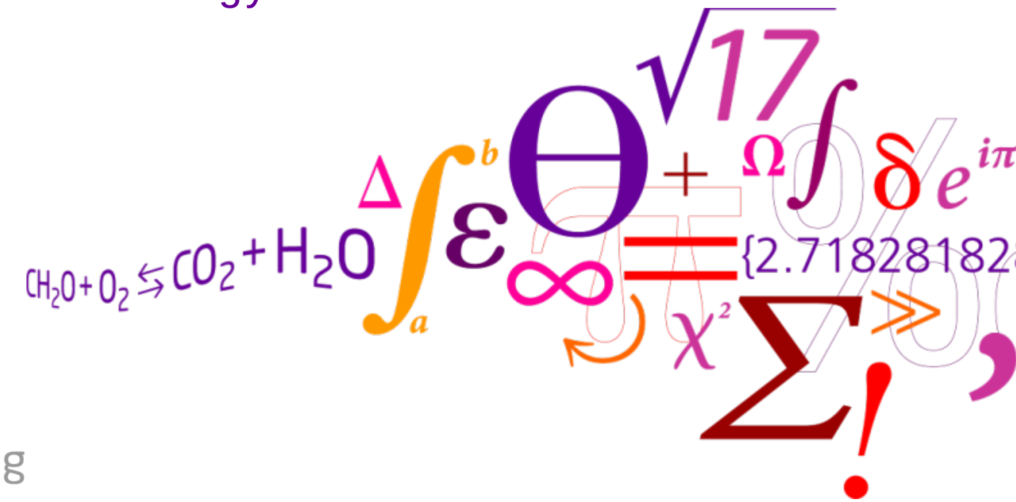
A generalized Dynamic Overflow Risk Assessment (DORA) for urban drainage RTC

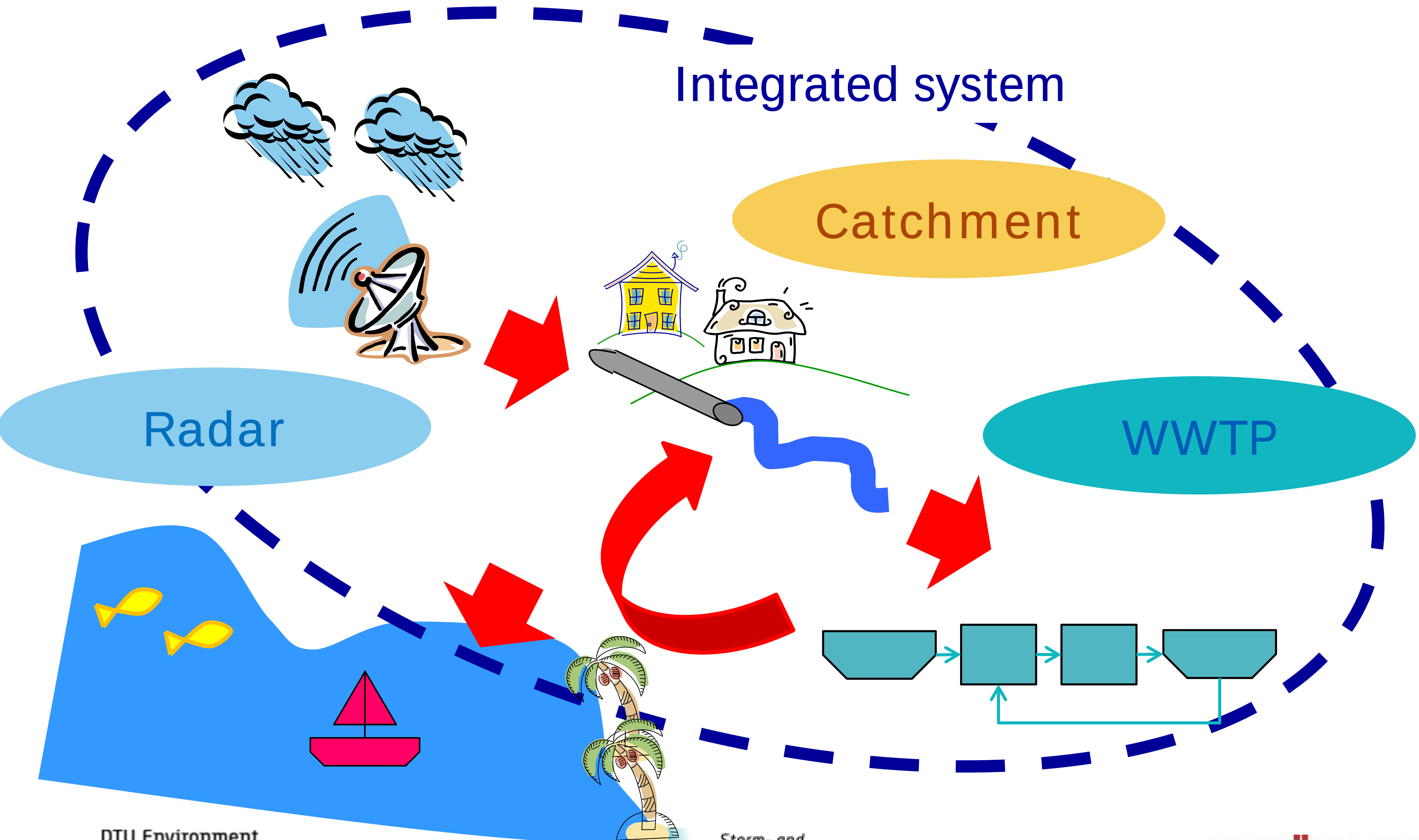
Luca Vezzaro[1,2], Morten Grum[2]

[1] DTU Environment (luve@env.dtu.dk)

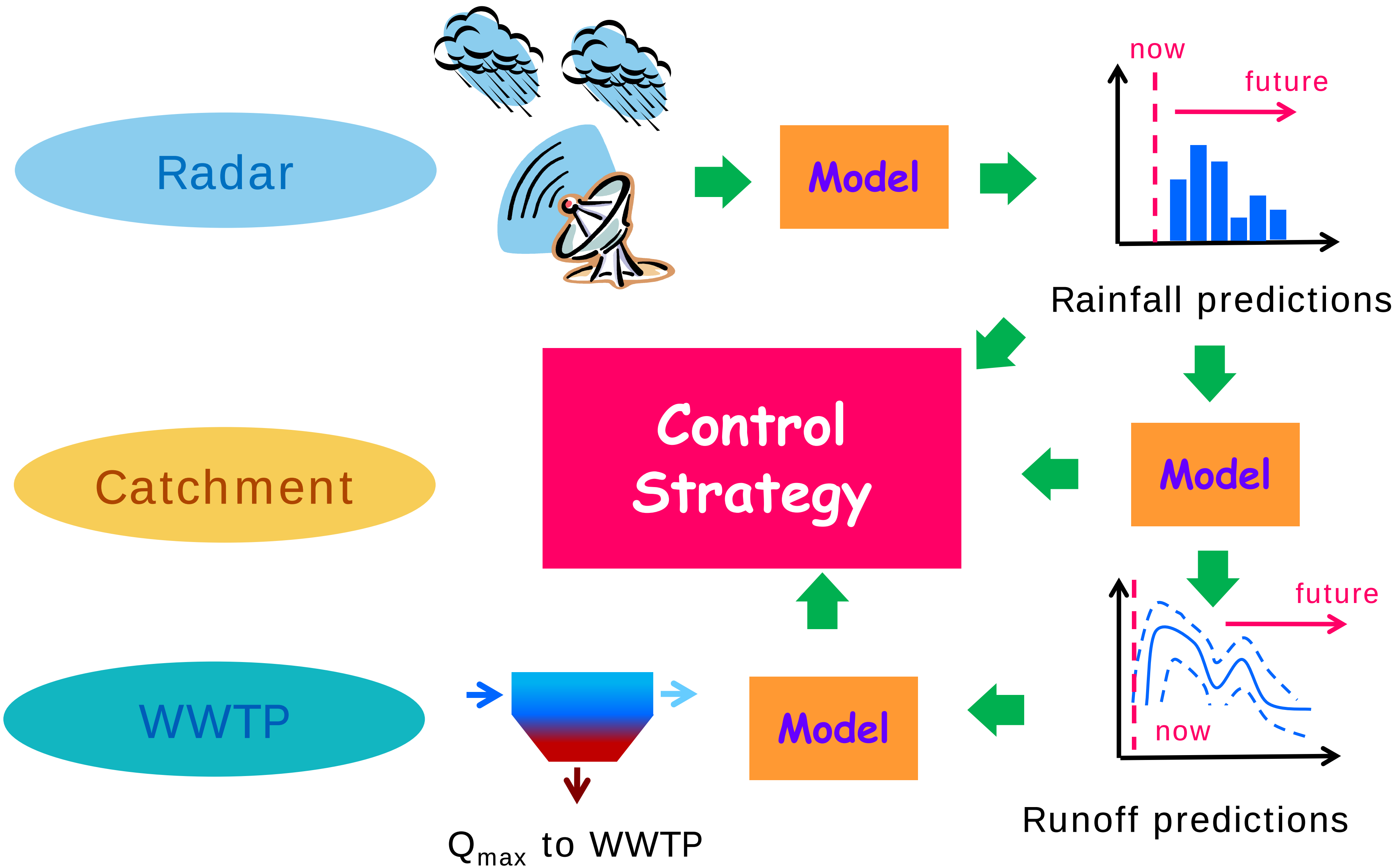
[2] Krüger A/S, Veolia Water Solutions & Technology



The urban drainage system in Storm- and Wastewater Informatics (SWI)



The bricks of integrated control
The SWI approach

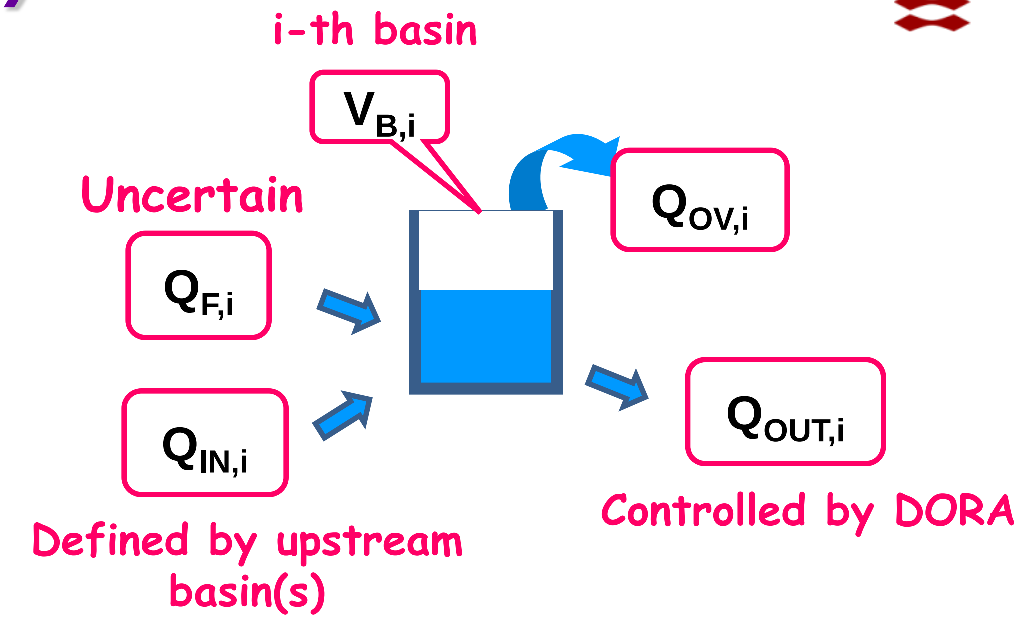


The Dynamic Overflow Risk Assessment (DORA) control strategy

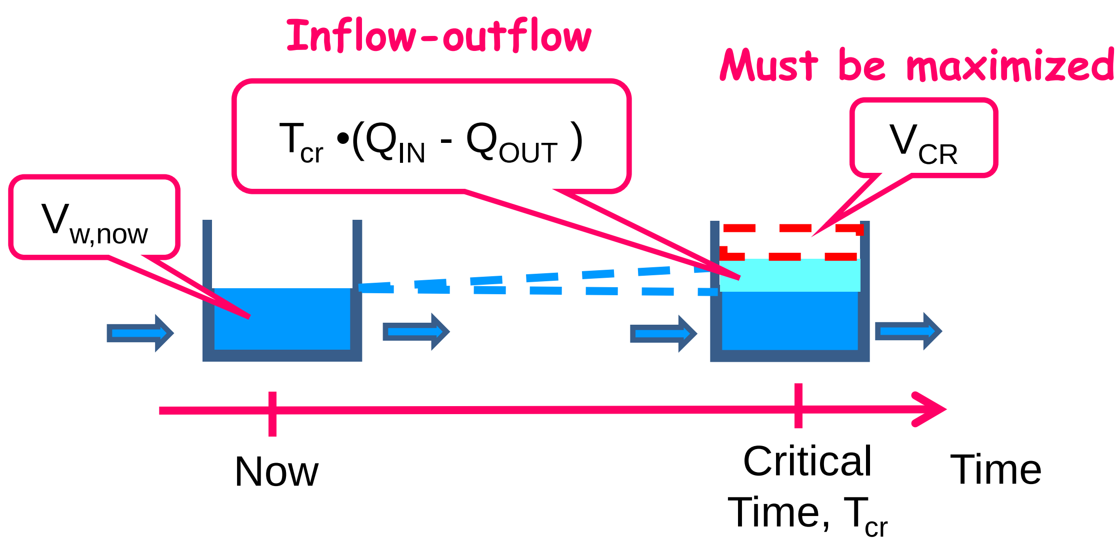
- Control strategy developed to benefit from outcomes of SWI project
  - Considers uncertainty in rainfall and runoff predictions
  - Consider spatial heterogeneity of rainfall
- Optimizes the system by minimizing a global cost function
  - Possible to prioritize areas of the catchment
  - Possible to add additional objectives (flooding risk, energy consumption, etc.)

DORA – definitions (1)

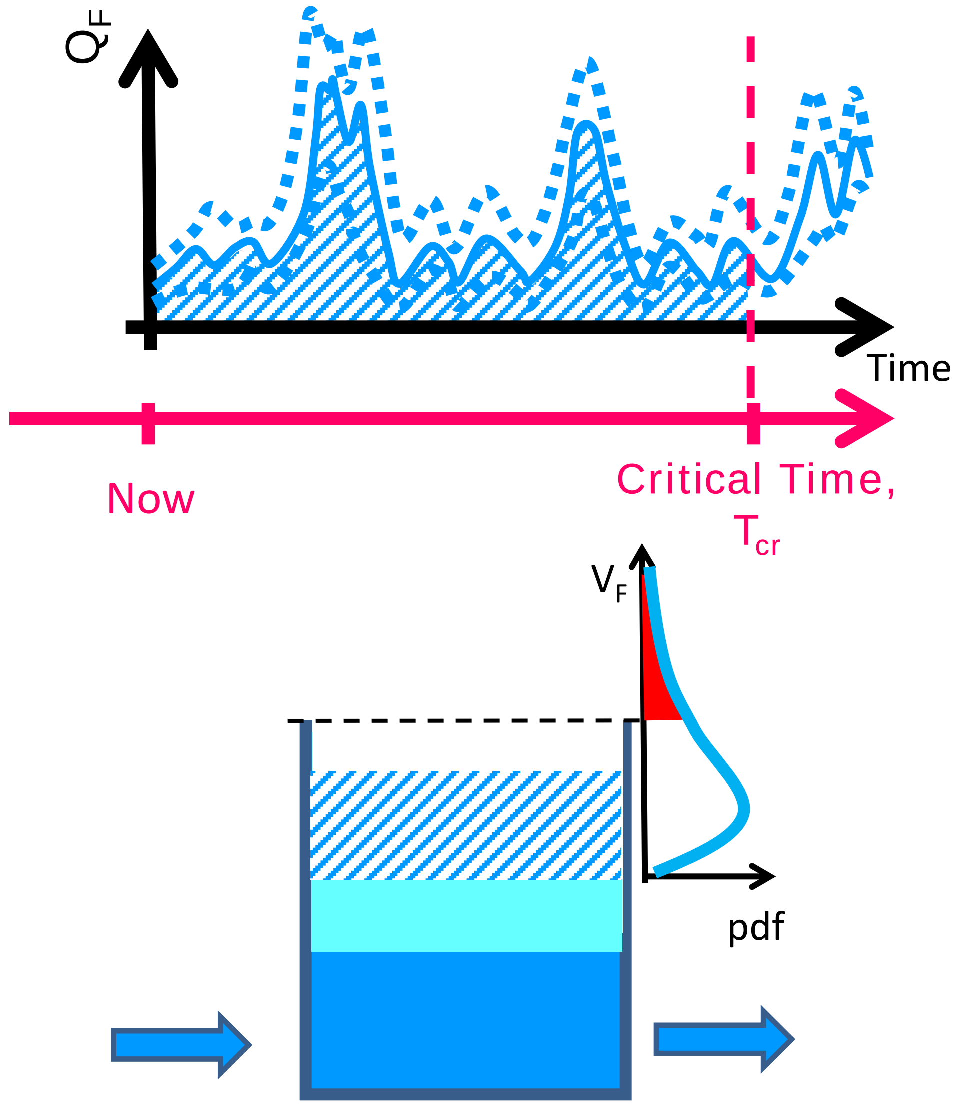
- Detention basins
  - Inflow from upstream (Q_F)
  - Outflow (Q_{OUT})
  - Inflow from catchment (Q_{IN})



- Critical volume
  - Available volume for storage

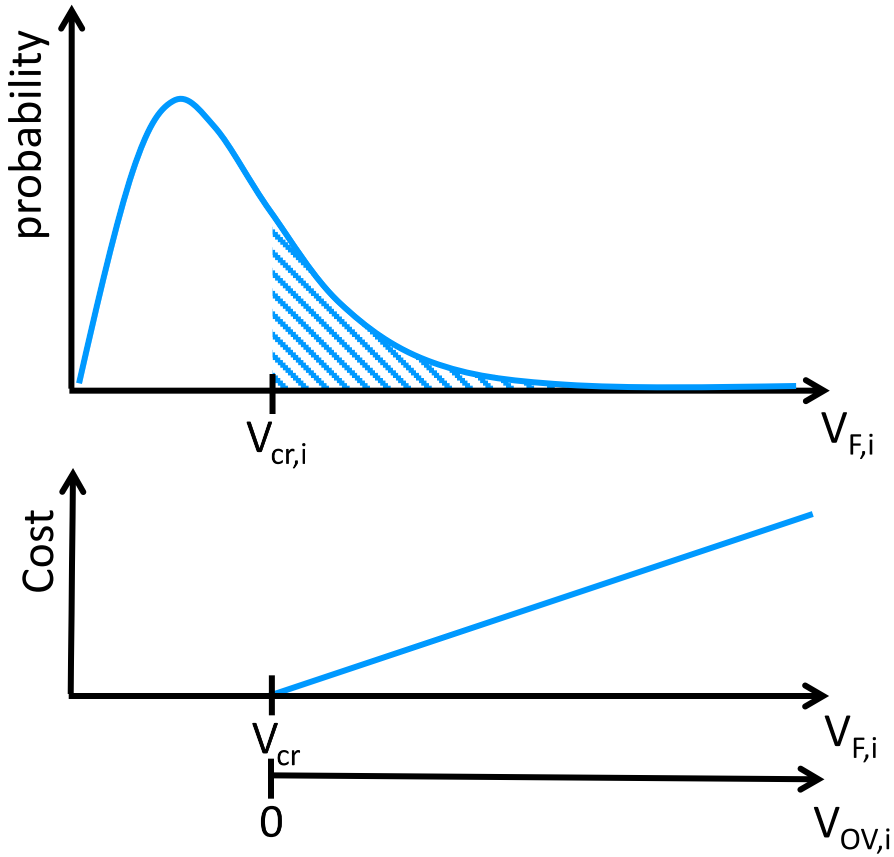


DORA – definitions (2)



- Runoff volume
- Uncertainty on volume prediction
- Overflow probability

DORA – Overflow cost



- Probability of overflow volume is calculated
- Risk is calculated by using a linear overflow-cost function

$$C_{F,i} = \int_{V_{CR,i}}^{\infty} C(V_{F,i}) \cdot p(V_{F,i})\, dV_{F,i}$$

DORA – Global overflow risk

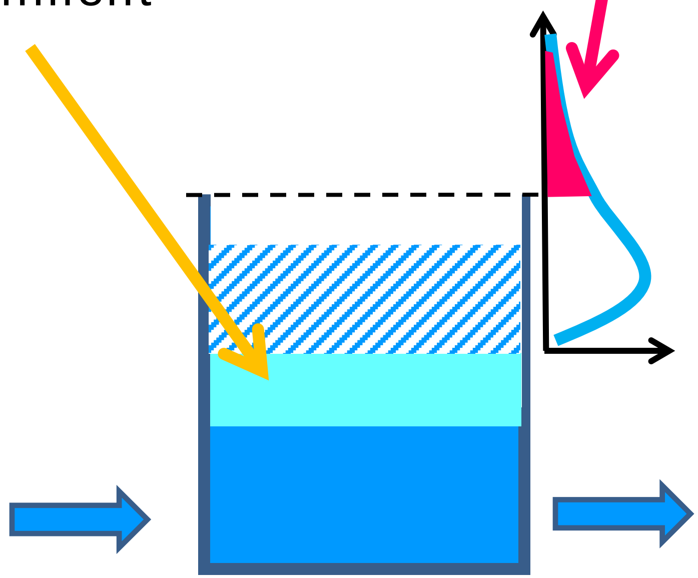
$$Cost = \sum_{i=1}^{N_{basins}} \left(C_{cr,i} + C_{F,i} - C_{hor,i} \right)$$

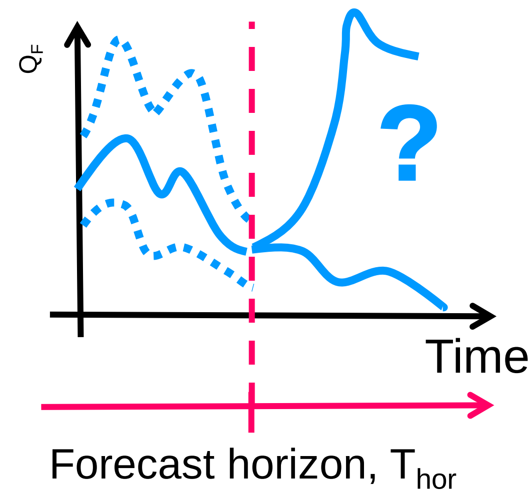
Cost due to water already fallen in the catchment

Cost due to forecasted runoff

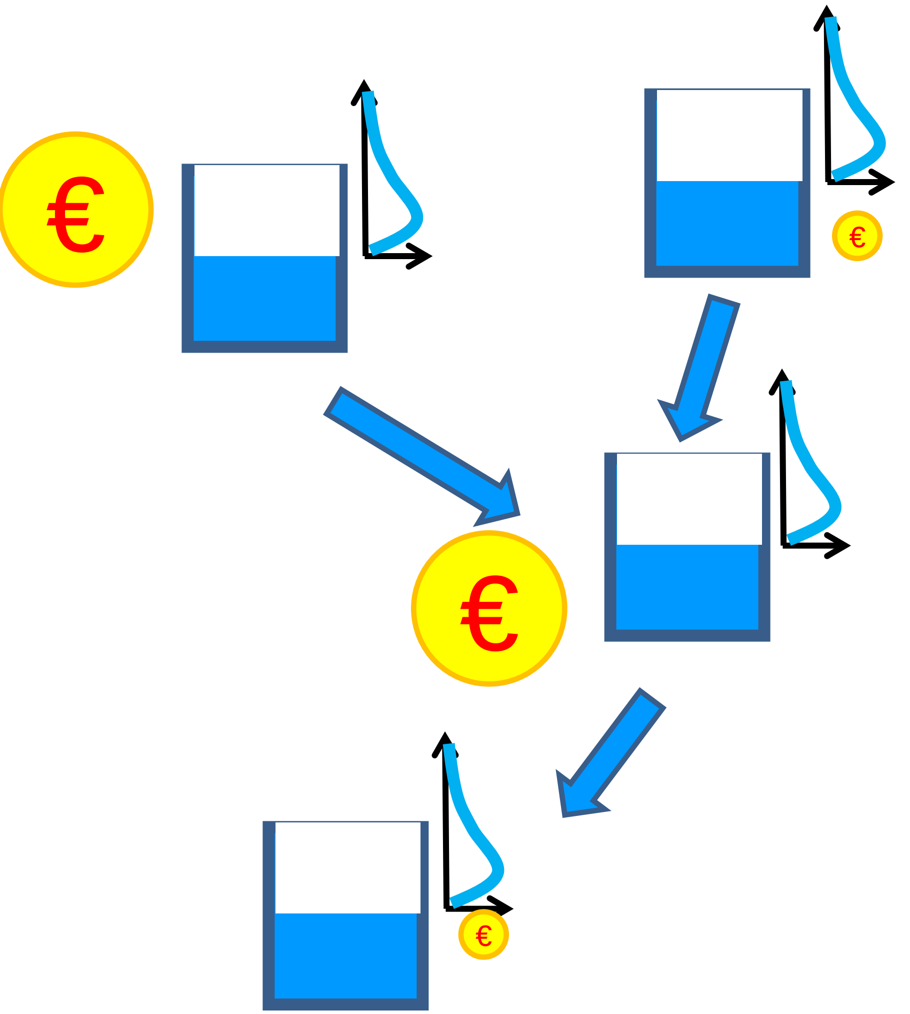
Discount accounting for qualitative uncertainty

(we don't know everything about the future)





Overflow cost function

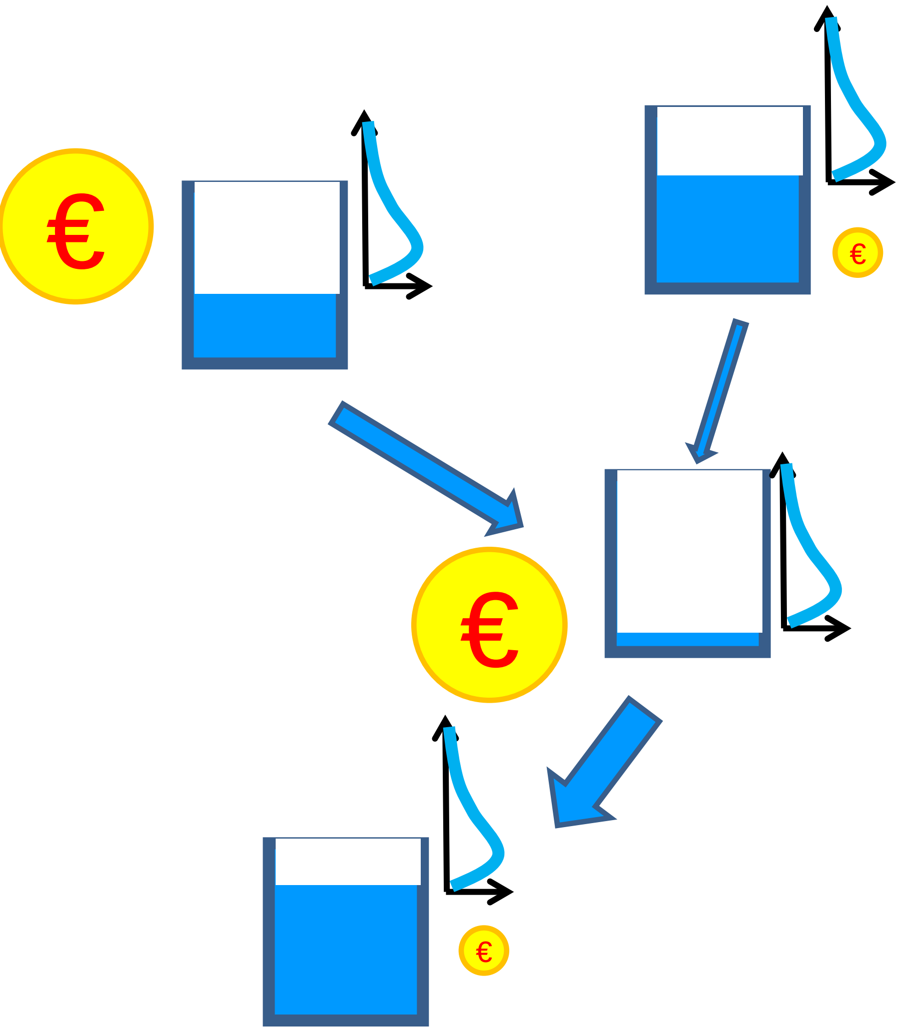


- Overflow cost is defined according to the sensitivity of receiving waters

€ Bathing area

€ Not sensitive

Overflow cost function



- Overflow cost is defined according to the sensitivity of receiving waters

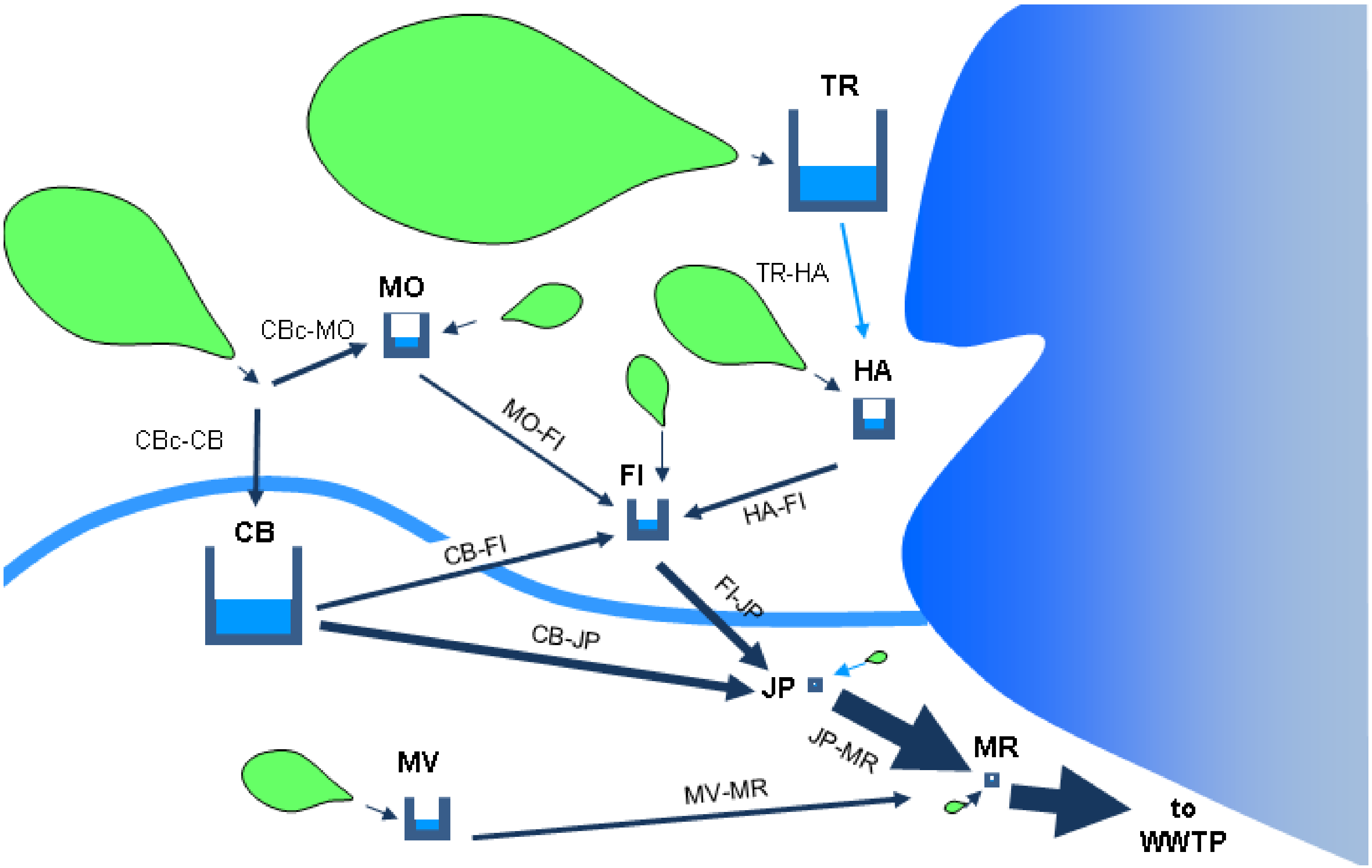
Bathing area

Not sensitive

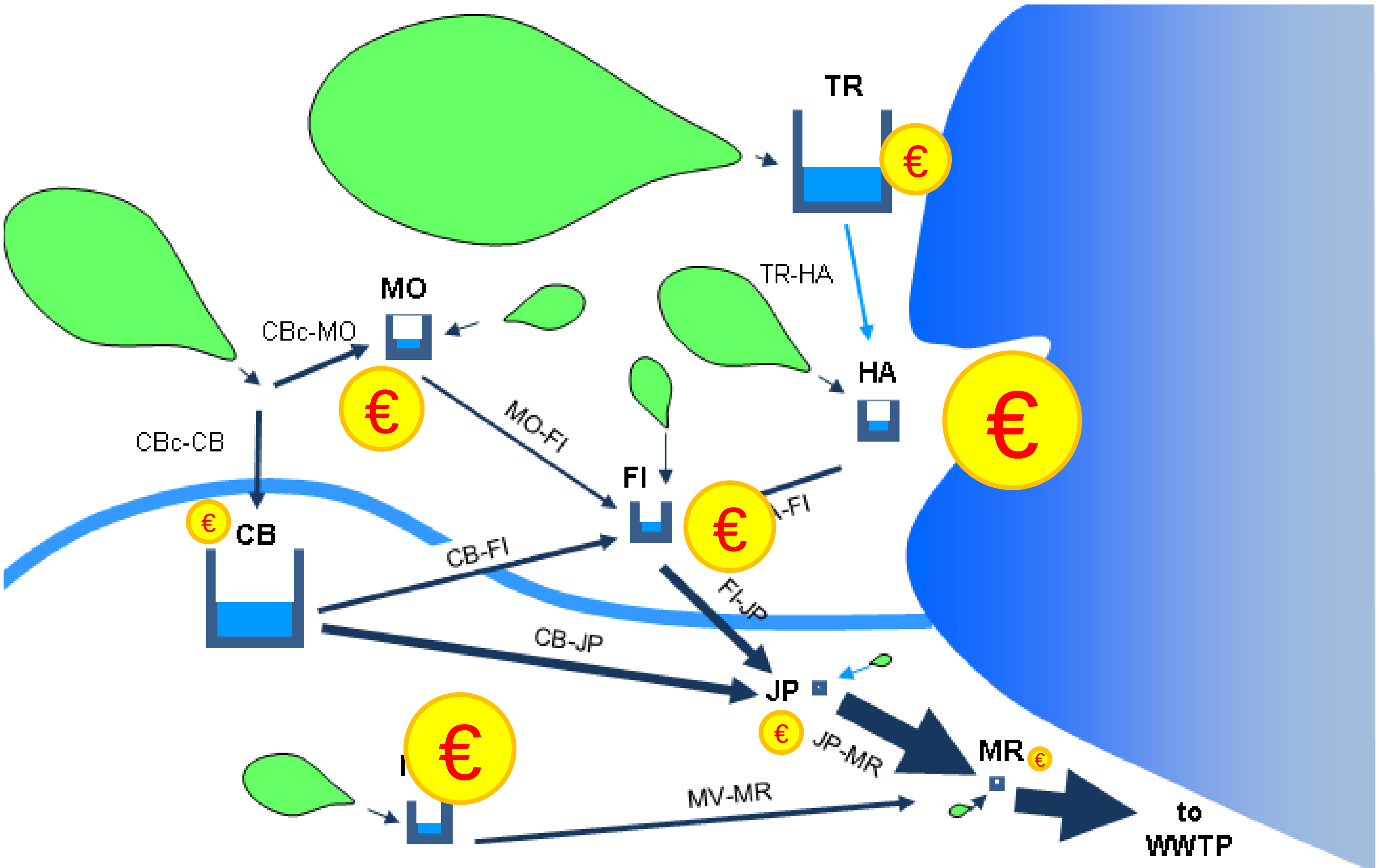
- A genetic algorithm finds flows that minimize overflow risk

A theoretical example

Inspired by Aarhus - Marselisborg catchment



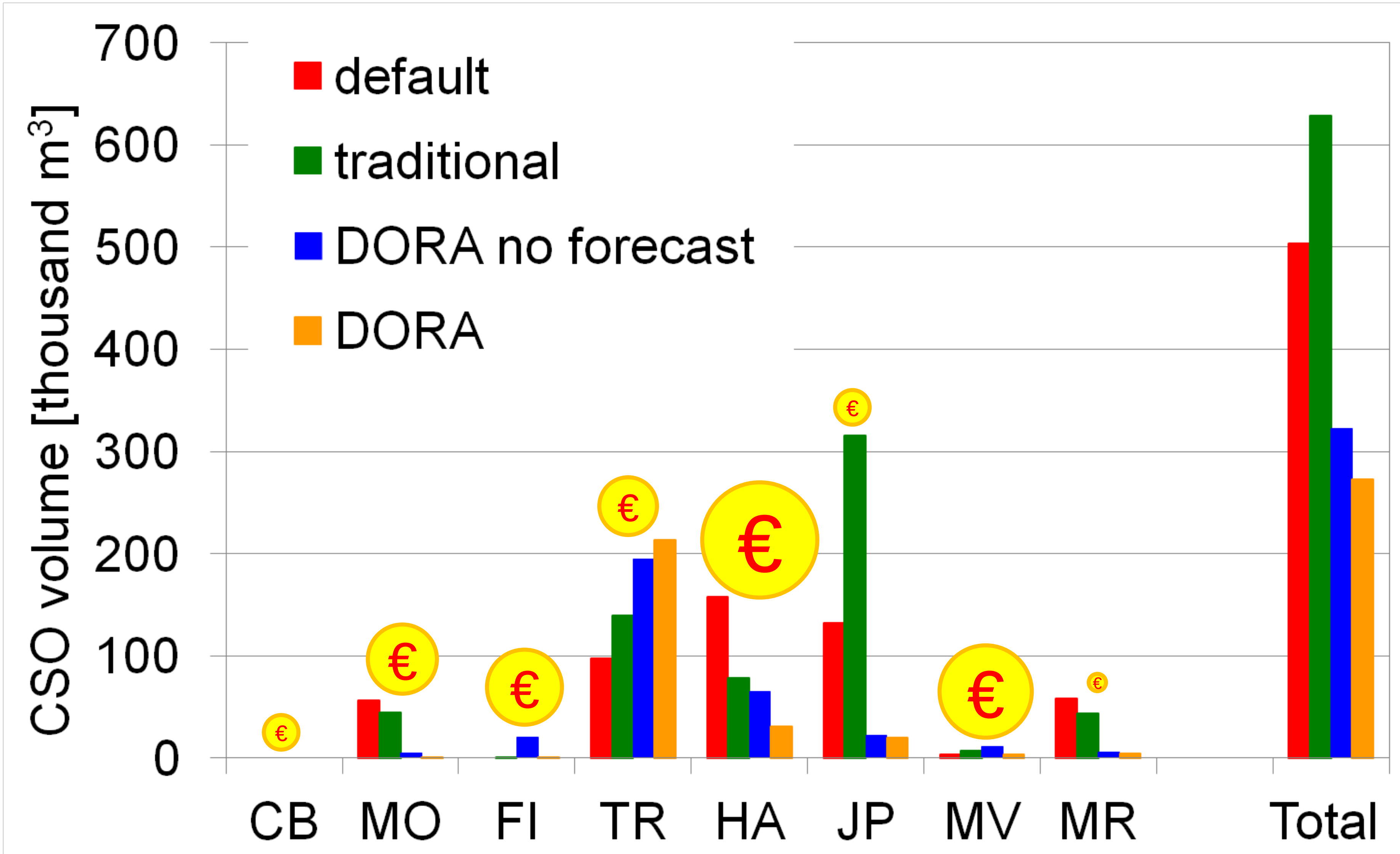
Aarhus – case study
Priority of basins



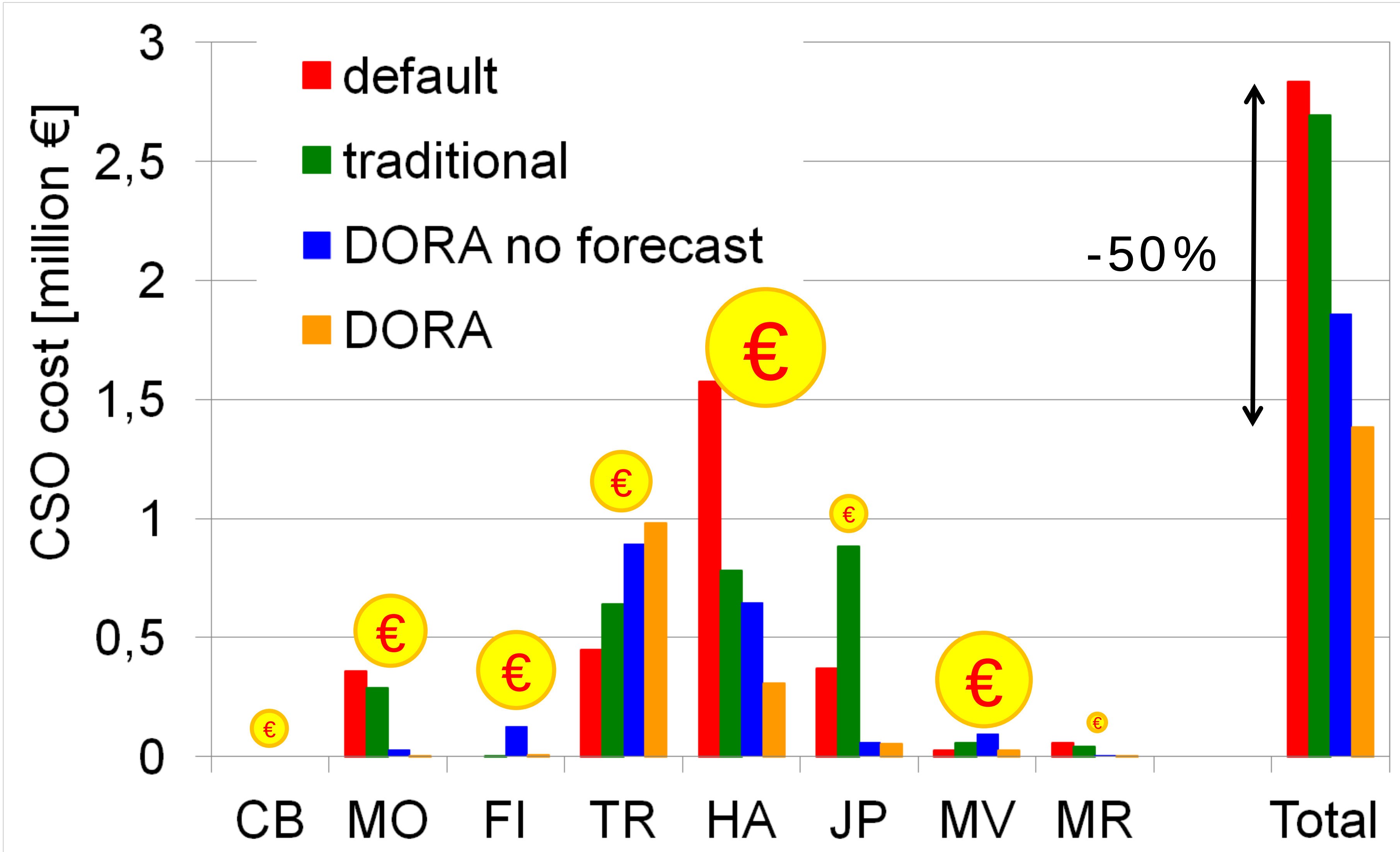
Analysis of MPC in Marselisborg

- Simplified model
  - *Wateraspects (hydrological model)*
  - *Perfect forecast (same data used for forecast and runoff)*
- Analysis based on a 5-year period
  - *25 biggest overflow events simulated*
- Four scenarios
  - *Default*
  - *Local control (based on water level in connected basins)*
  - *DORA without rain forecasts*
  - *DORA with forecasts*

Aarhus – Volume reduction
25 events

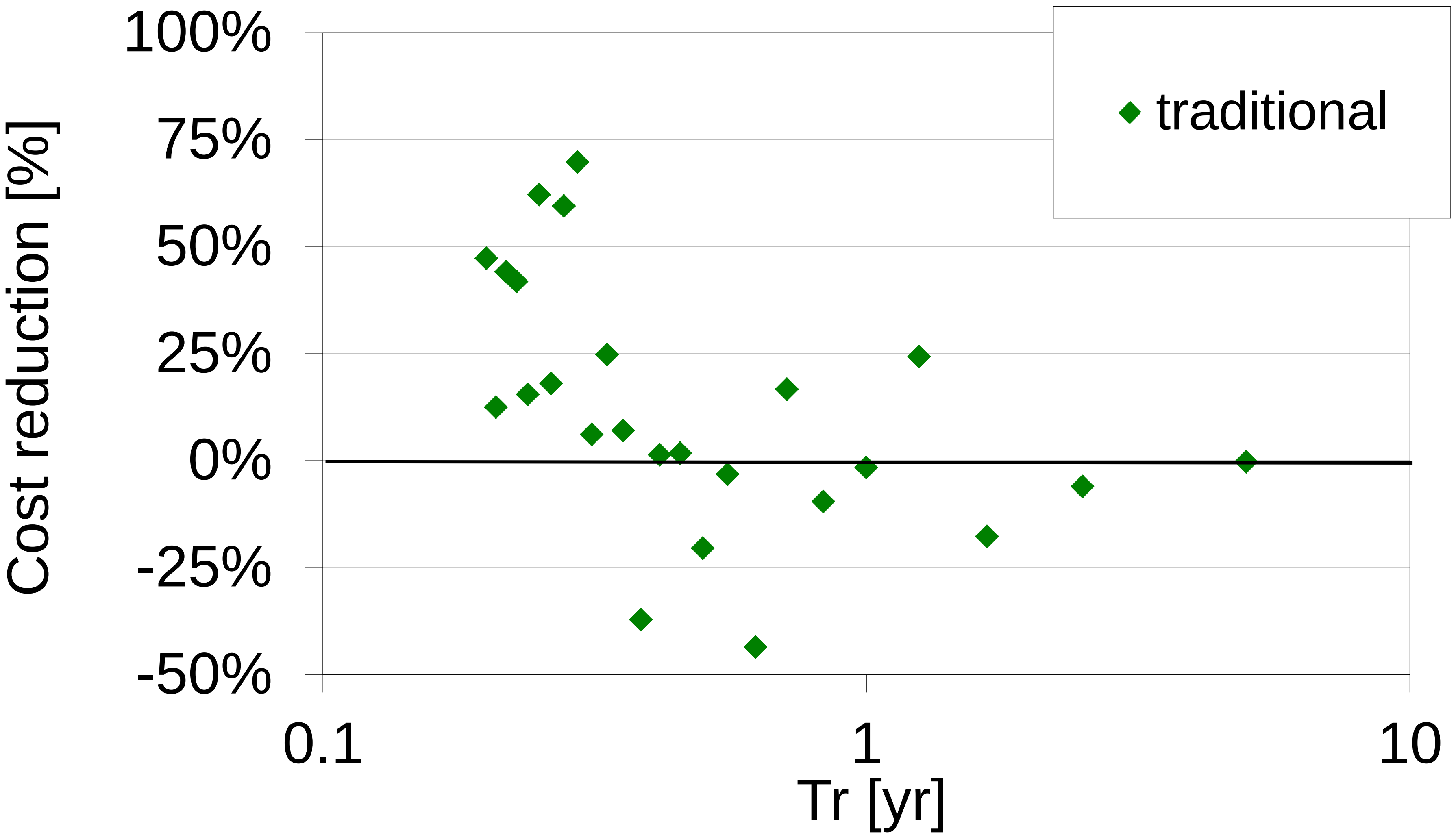


Aarhus – Cost reduction
25 events

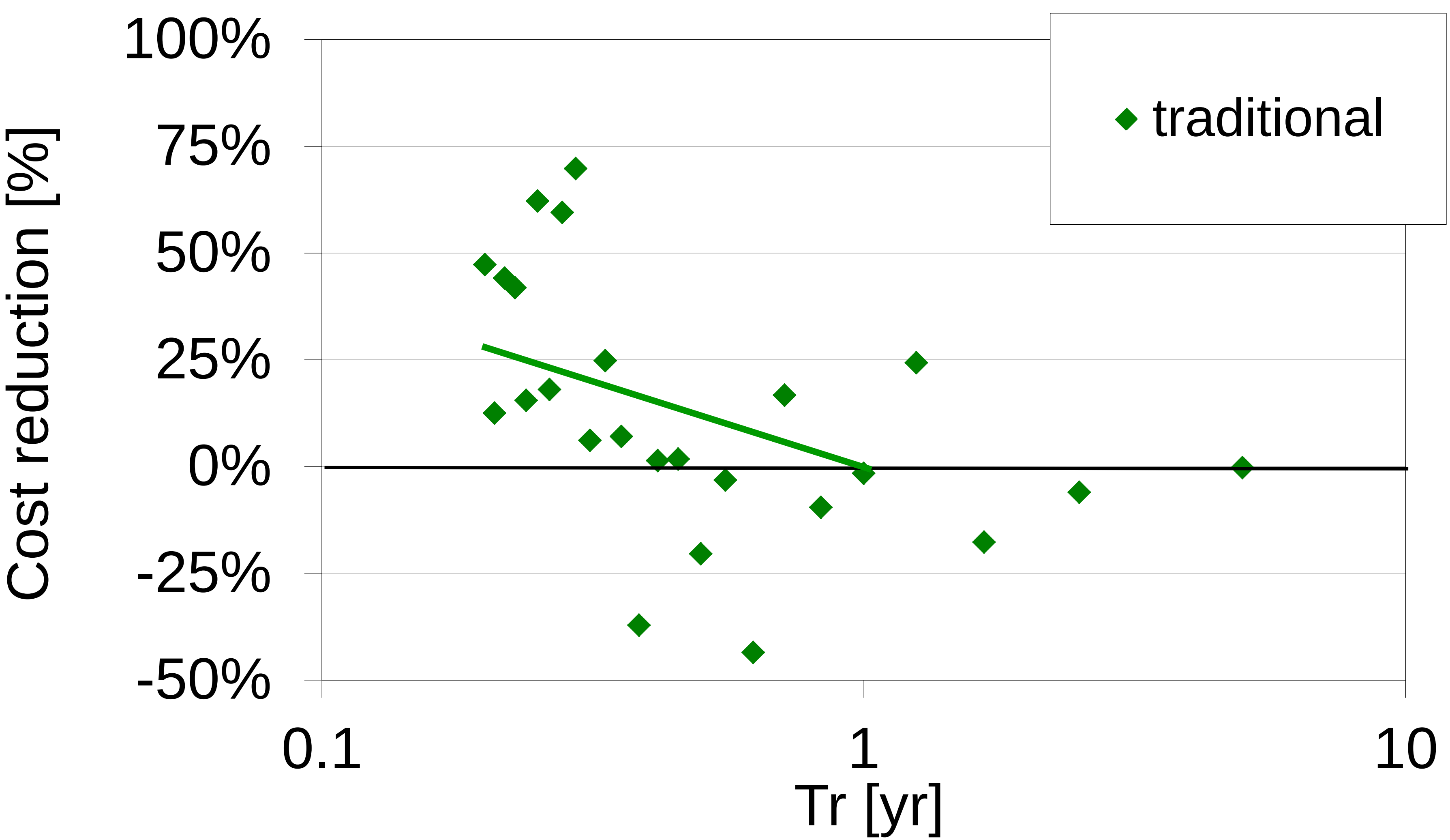


Performance against return period

Cost reduction

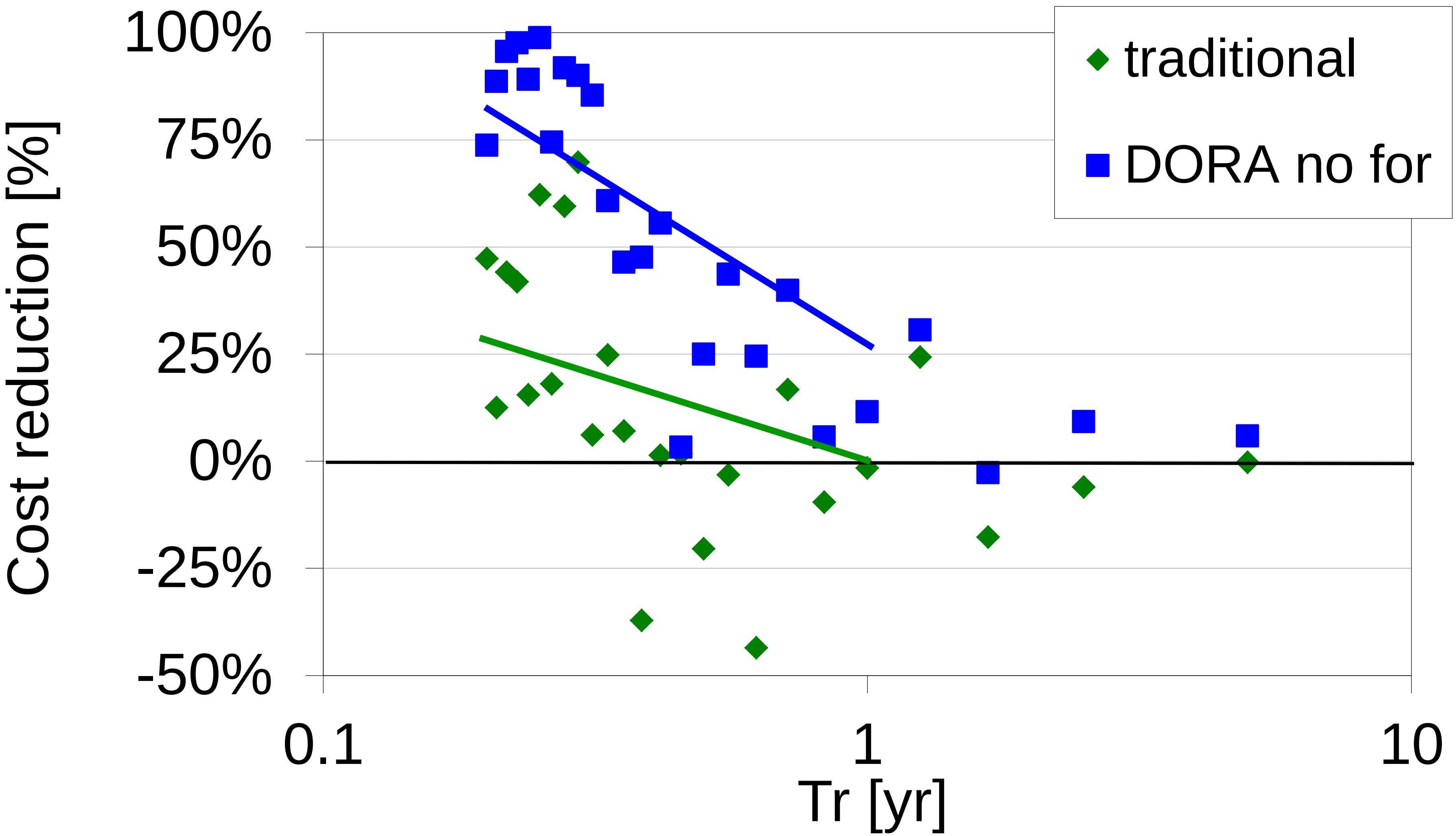


Performance against return period
Cost reduction

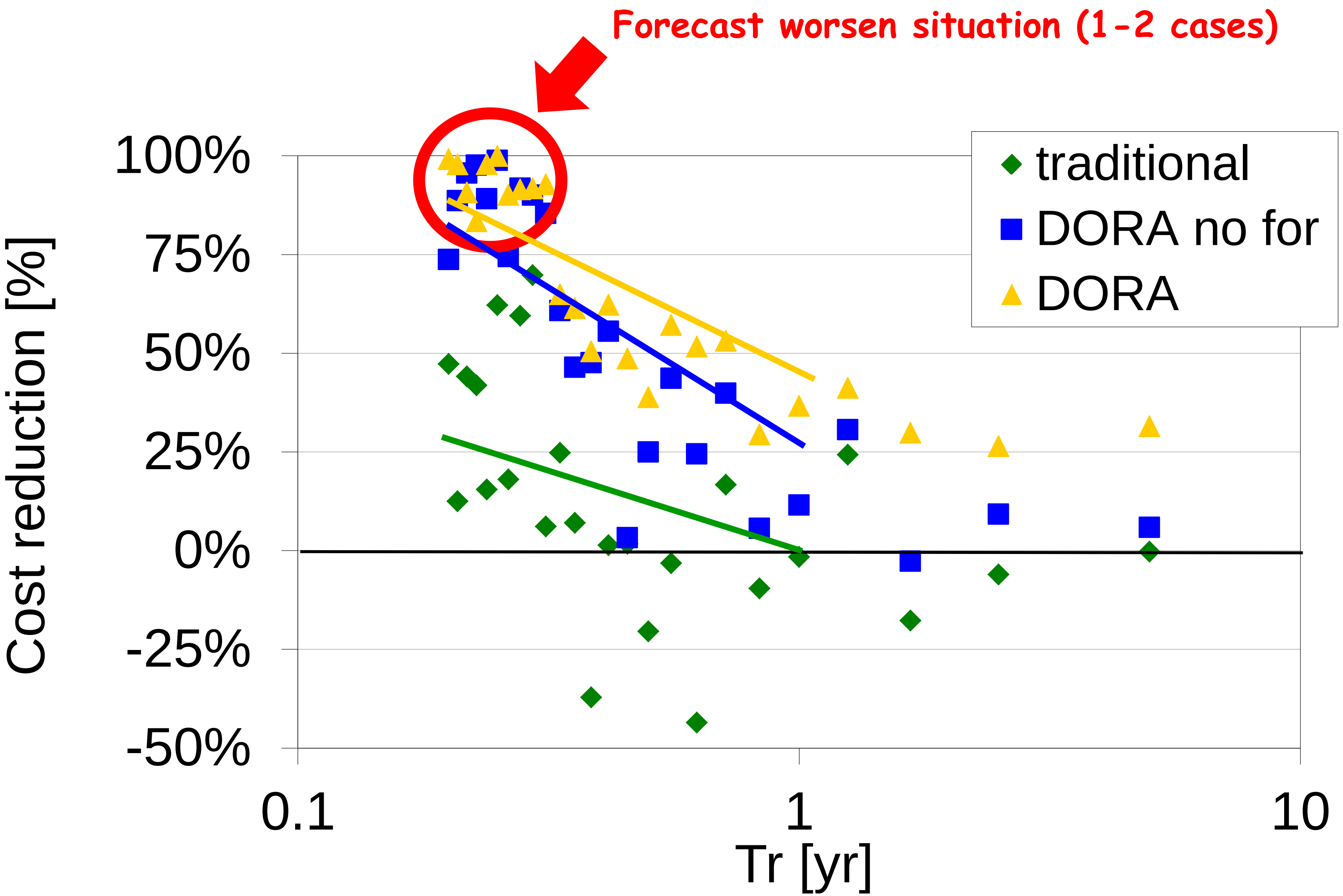


Performance against return period

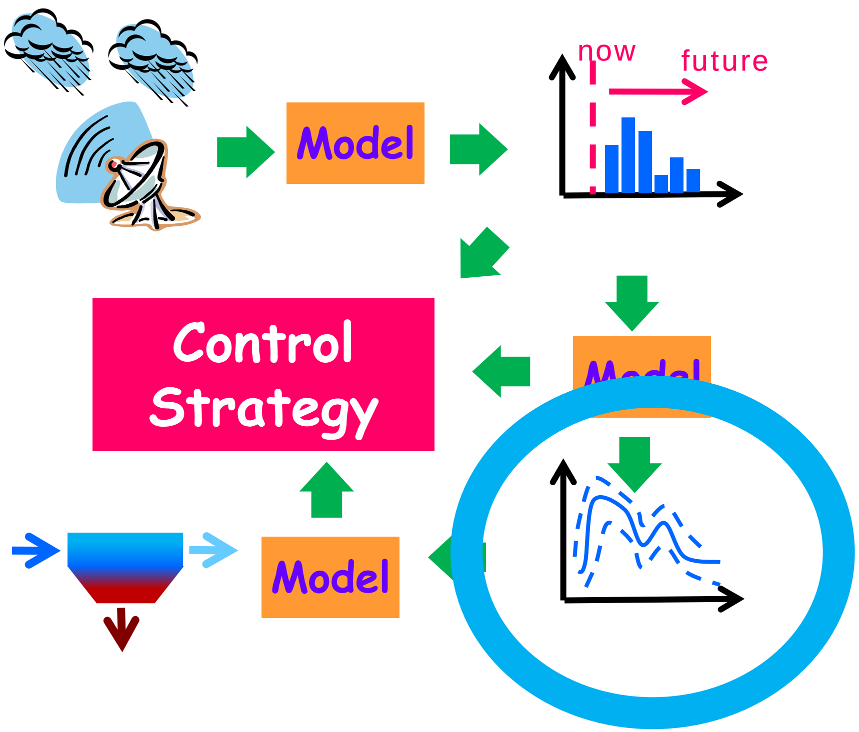
Cost reduction



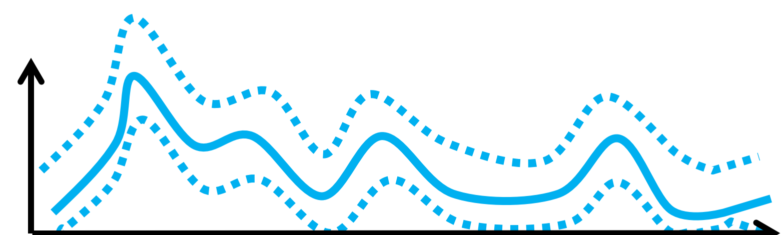
Performance against return period
Cost reduction



Coming soon...

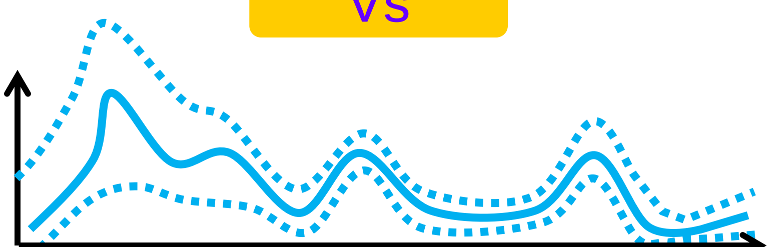


- How does uncertainty in flow prediction affect the MPC integrated control?
- Which method for runoff flow prediction gives better results?



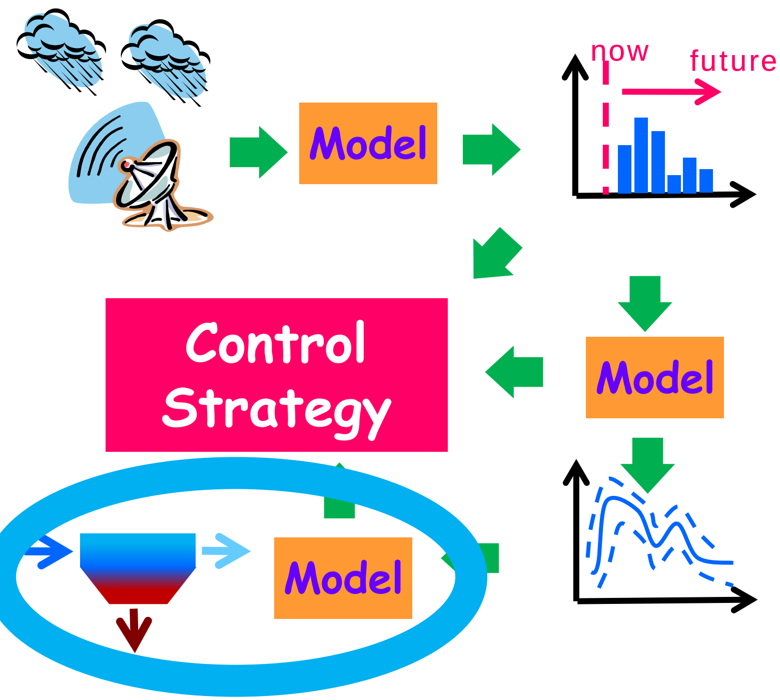
Fixed uncertainty bounds

Vs

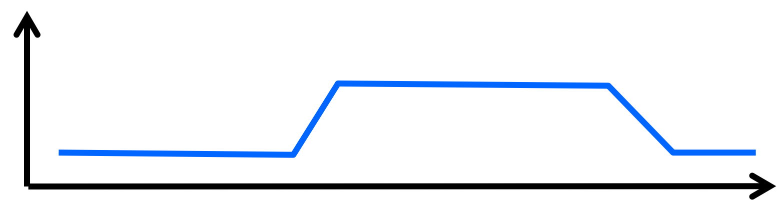


Dynamic estimation of uncertainty bounds (stochastic models – Löwe et al. Session 1.2)

Coming a little bit later...

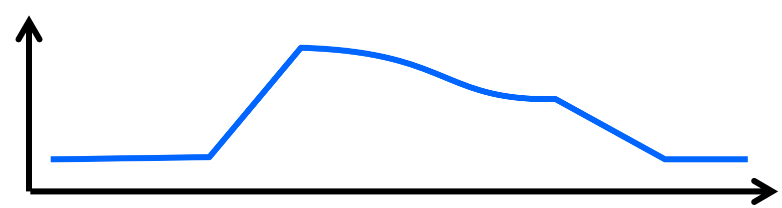


- Can we predict the WWTP capacity in the next hours?
- Can modelling of WWTP capacity improve the performance of the system?



Fixed WWTP capacity

Vs



Dynamic estimation of WWTP capacity (based on capacity of biology and of clarifier)

Conclusíon

- A generalized approach for control of urban water system including uncertainty is now available
- DORA allows the prioritization of discharge points
- Analysis on a theoretical catchment showed the benefit of global control with respect to local RTC
- Multi-objectives cost functions can be used according to the major issues in the system (flooding, energy saving, pollution, etc.)
- DORA allows the development of integrated dynamic Model Based Control (SWI concept)

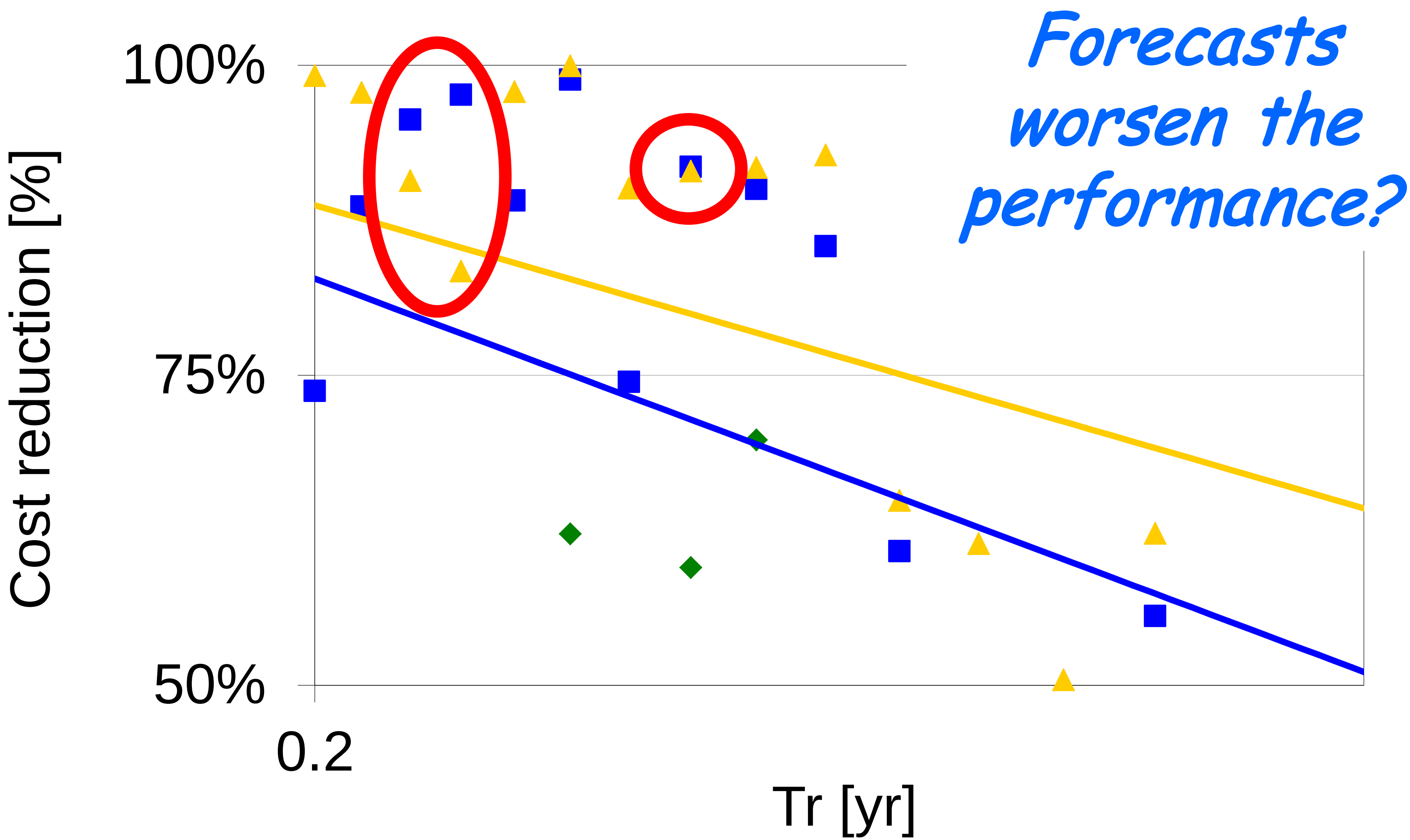
More will come…stay tuned on SWI

Acknowledgments

- These results are obtained thanks to the following projects:
  - SWI (Storm- and Wastewater Informatics), supported by the Danish Agency for Science Technology and Innovation
  - MOPSUS (Model Predictive Control of Urban Water System under Uncertainty), supported by the Danish National Advanced Technology Foundation

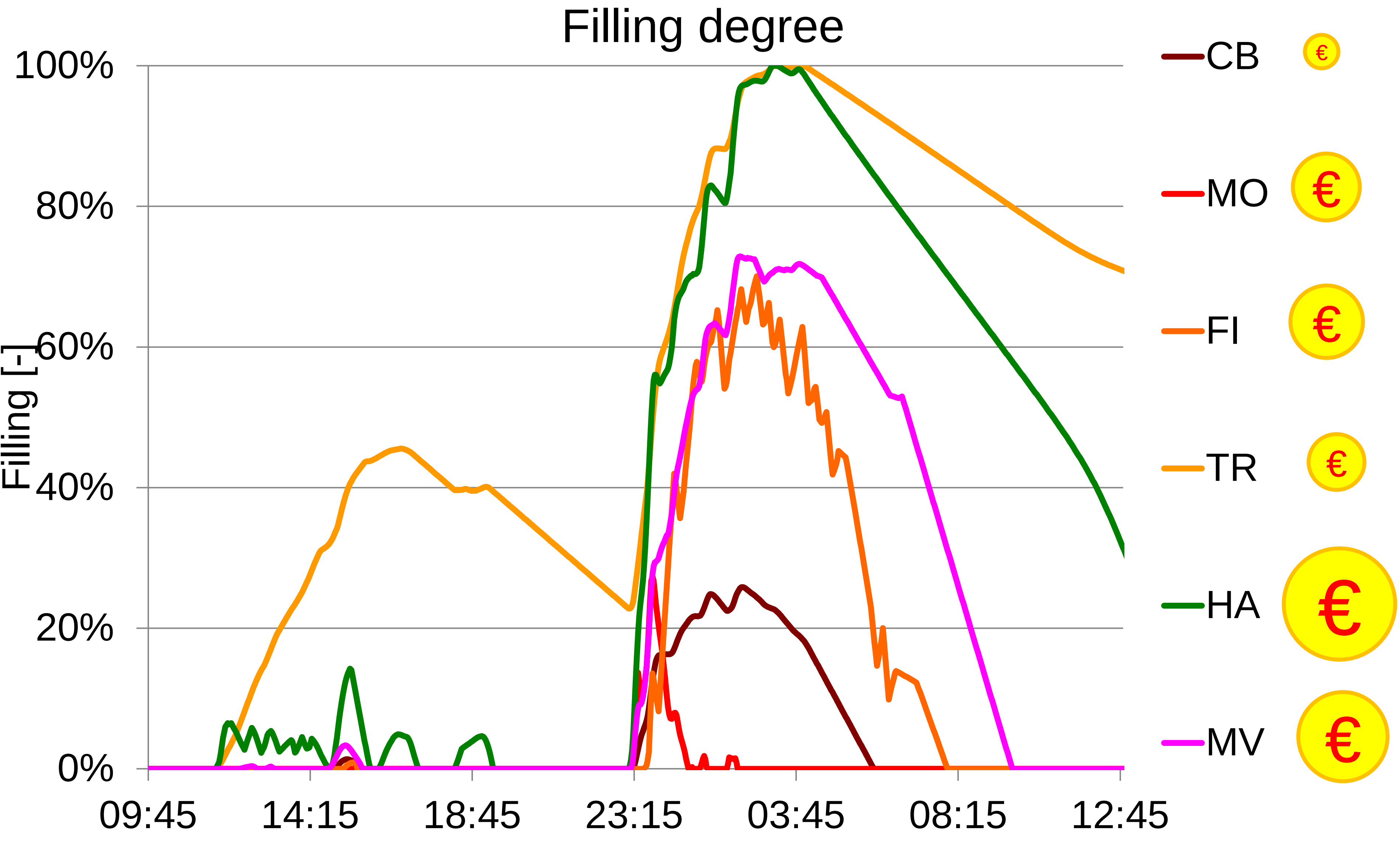
Performance against return period

Cost reduction



Event 1995-09-03

Without forecasts



Event 1995-09-03

With forecasts