

Center for Applied Energy Research



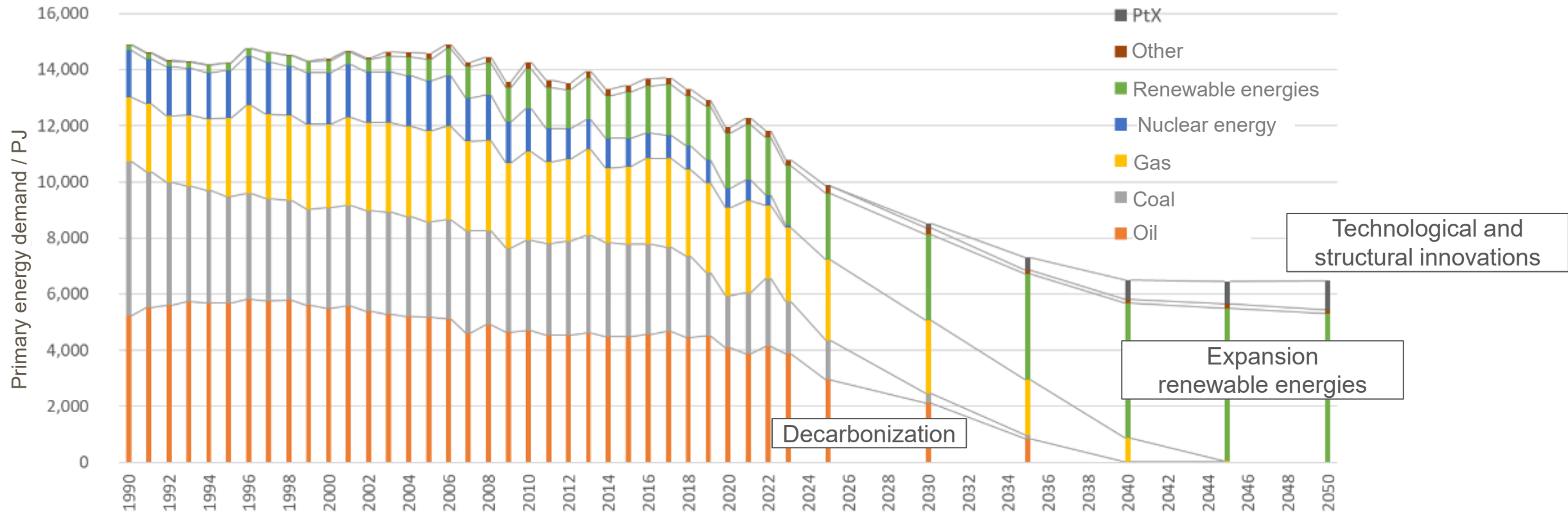
Intercomparison of the Specific Heat Capacity of Heat Transfer Fluids

Hans-Peter Ebert, Michael Brütting

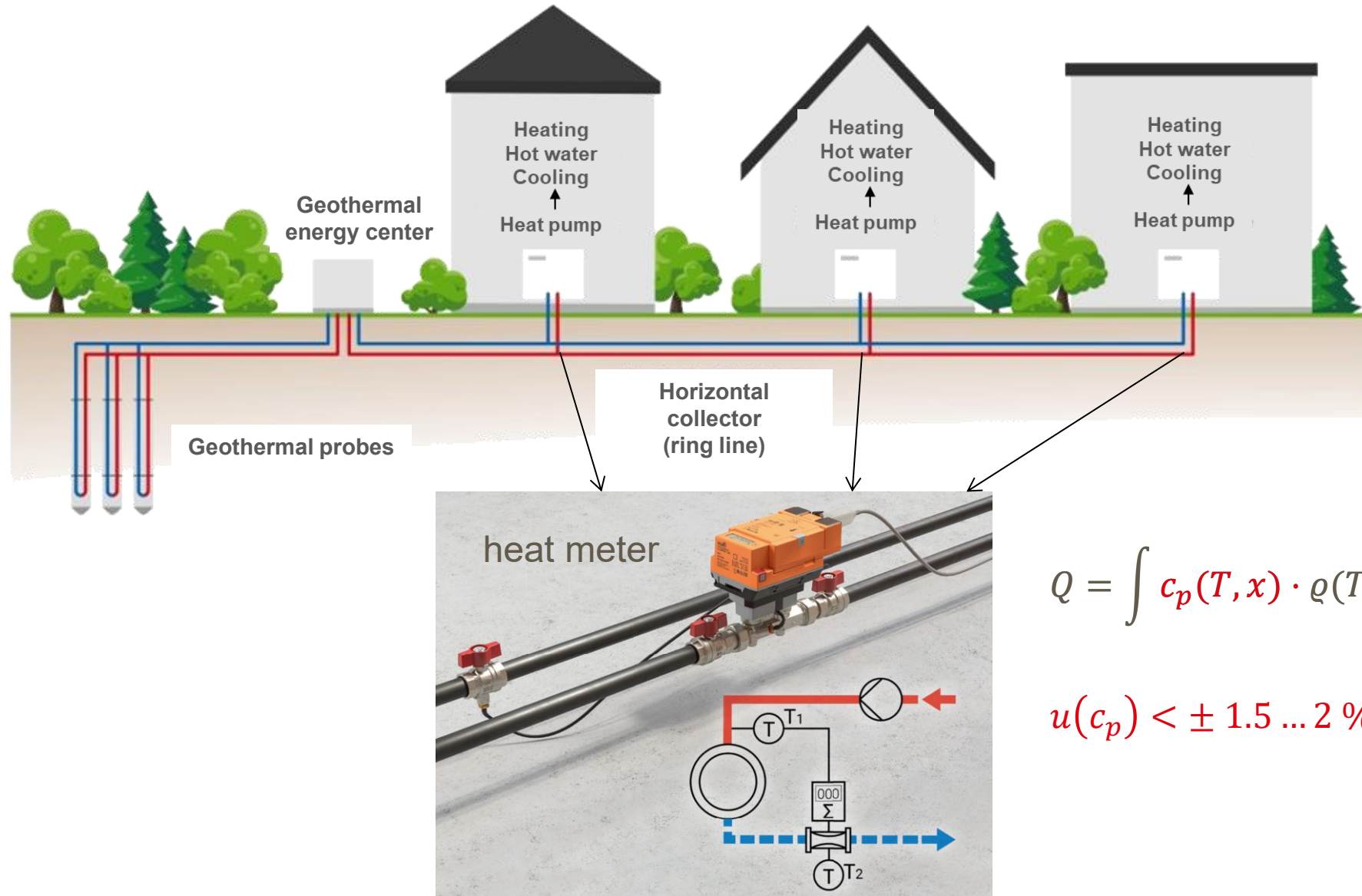


Target data for climate neutrality in Germany

Primary energy demand



5th generation district heating networks



$$Q = \int c_p(T, x) \cdot \rho(T, x) \cdot \dot{V} \cdot (T_2 - T_1) dt$$

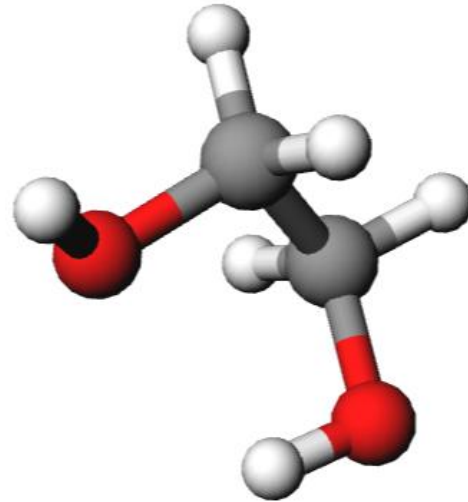
$$u(c_p) < \pm 1.5 \dots 2 \%$$

Investigated heat transfer fluids

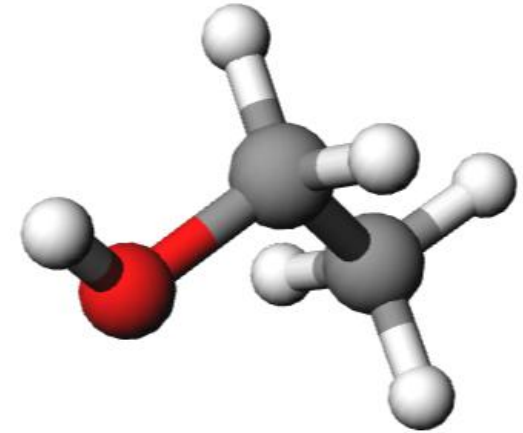
Water



(Mono-)Ethylenglycol - Water



Ethanol - Water



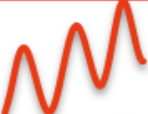
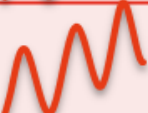
Samples

Fluid	Supplier	Specification	Temperature range / °C
Water	aqua concept GmbH	fully demineralized water	5 to 95
Ethanol-Water Mixture	aqua concept GmbH	23 % / 77 % (mass fraction)	-10 to 30
Monoethylene-glycol-water Mixture	Clariant International Ltd.	43 % / 57 % (mass fraction)	-10 to 95

Participants

- Acqua concept Gesellschaft für Wasserbehandlung GmbH, Germany
- Austrian Institute of Technology GmbH (AIT), Austria
- Belimo Automation AG, Hinwil / Switzerland
- Center for Applied Energy Research e.V. (CAE), Germany
- German Aerospace Center (DLR), Germany
- Institut für Luft- und Kältetechnik gGmbH (ILK Dresden), Germany
- Netzsch-Gerätebau GmbH, Germany

Measurement Methods

Measurement Method			Specimen Volume	Device	Crucible
DSC constant heating rate			35 µl	NETZSCH DSC 204 F1 Phoenix	Aluminium
DSC constant heating rate			35 µl	NETZSCH DSC 204 F1 Phoenix	Aluminium
DSC constant heating rate			850 µl	Setaram calorimeter, MicroDSC7 Evo-1A.	Hastelloy C276
DSC modulated temperature			40 µl	TA Instruments Q2000	Aluminium
DSC modulated temperature			40 µl	Mettler Toledo DSC2/700	Aluminium
DSC stepwise heating			850 µl	Setaram calorimeter, MicroDSC7 Evo	Hastelloy C276
Dynamic Hot-Wire Method according to ASTM D7896-14			>15000 µl	Commercial	not relevant

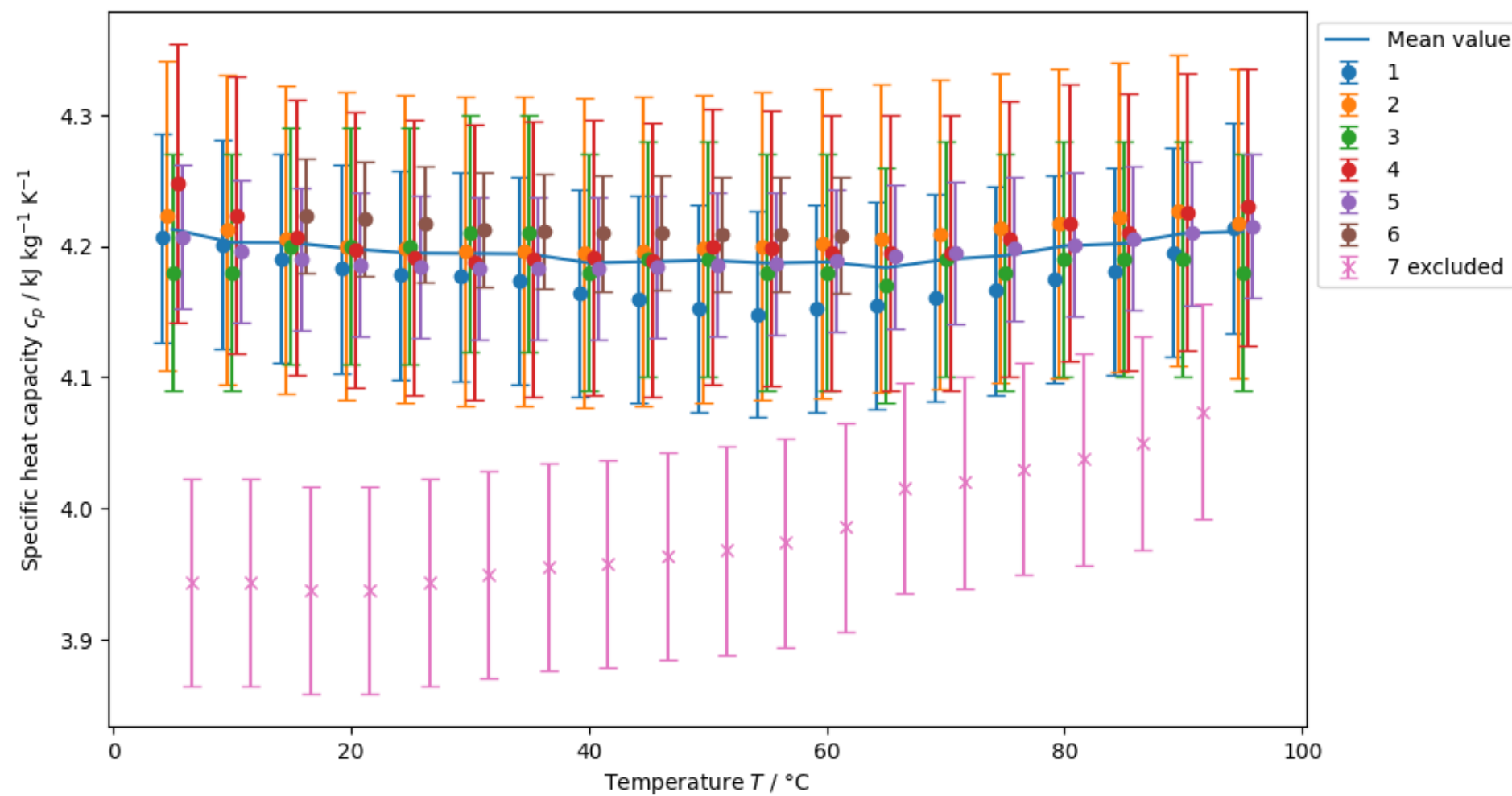
Evaluation procedure

- Indication of the measured values in **5 K steps**
- Requirement: **Uncertainties** for measurement results according to **GUM**
- The arithmetic mean and the associated uncertainty were calculated from the results for each temperature point.
- This was used to calculate the **normalized error function for each measurement point**:

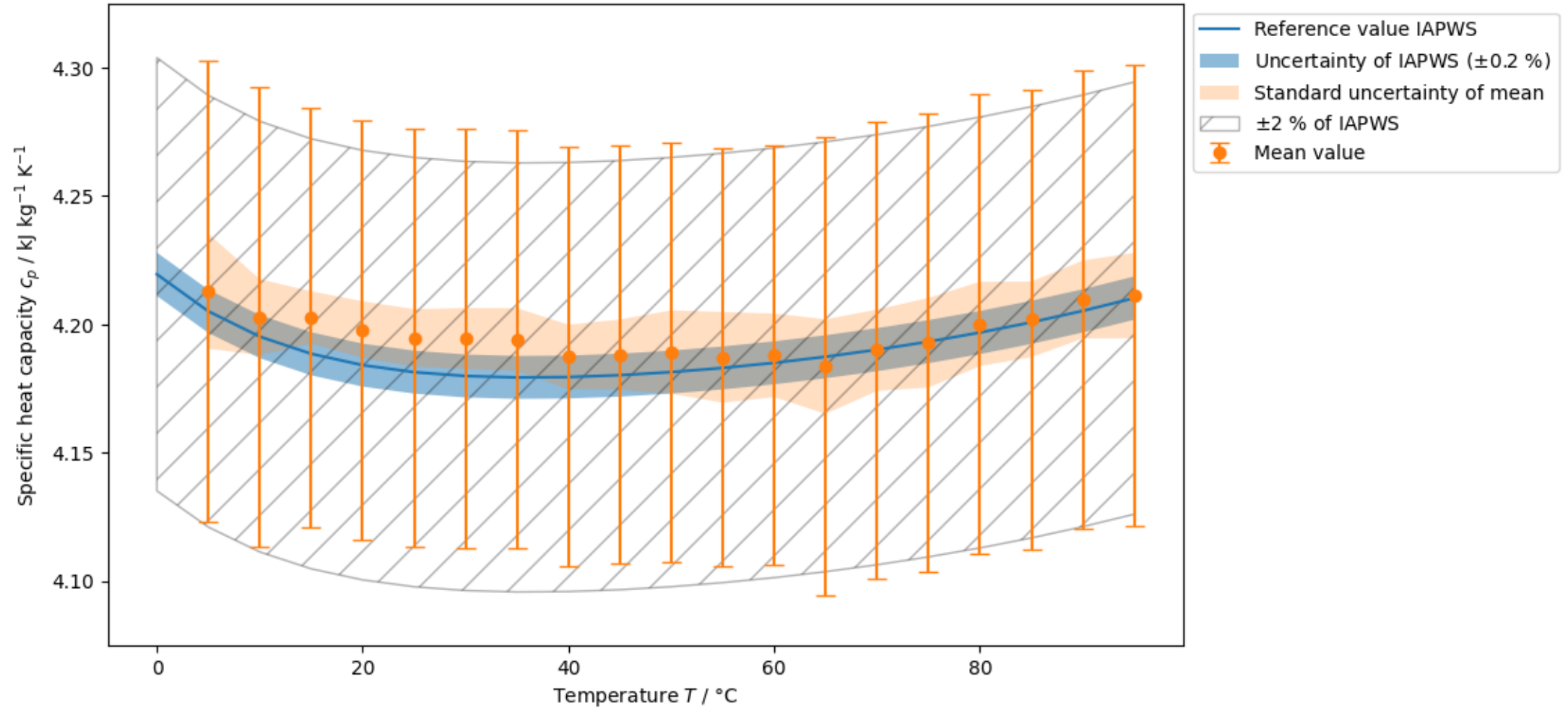
$$E_n = \frac{x_{lab} - x_{mean}}{\sqrt{(U_{lab}^2 + U_{mean}^2)}} = \frac{\text{Deviation from the mean value}}{\text{Uncertainty of the deviation}}$$

- $E_n < 1$
- $E_n > 1$ Data point removed and E_n recalculated

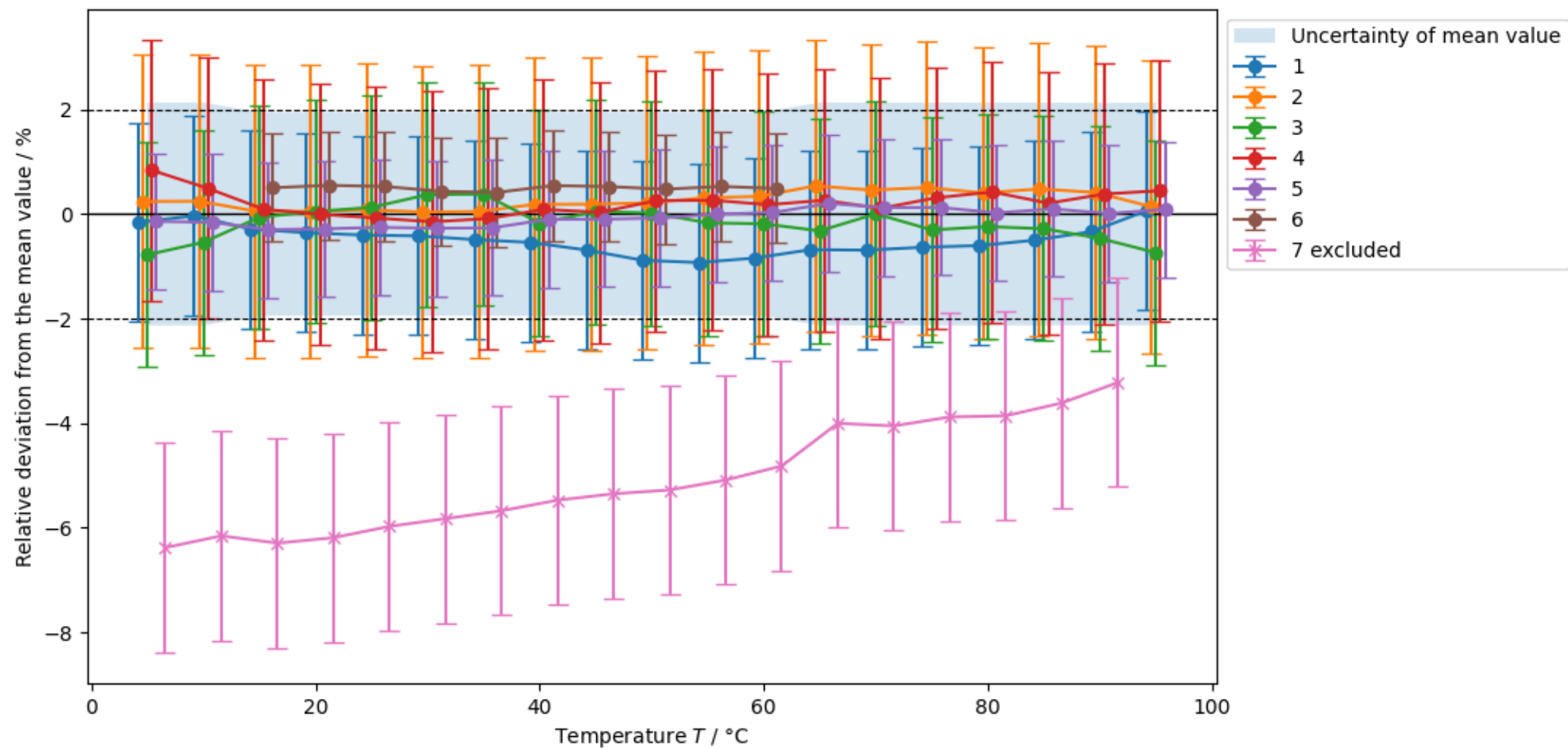
Results: Water



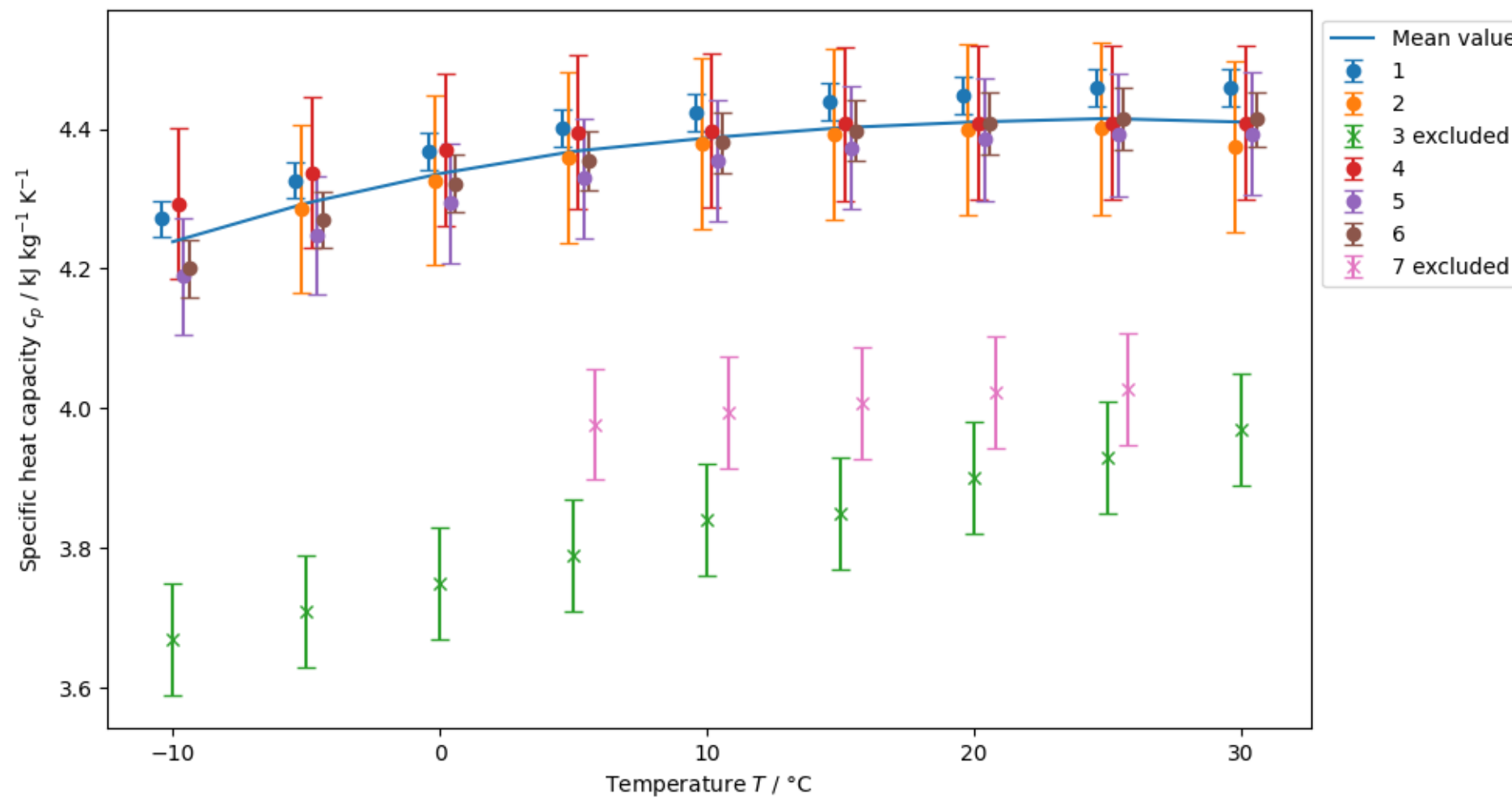
Reference data for water: International Association of Properties for Water and Steam



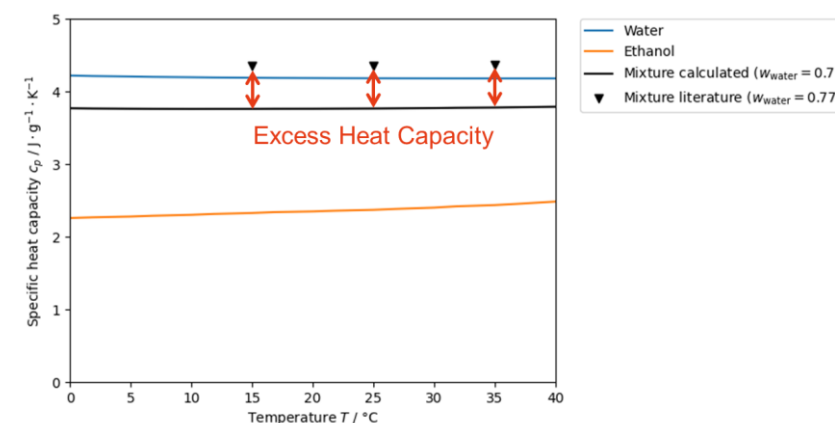
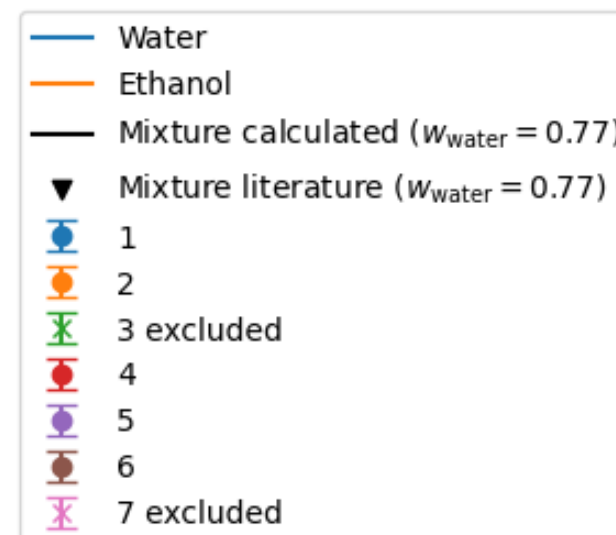
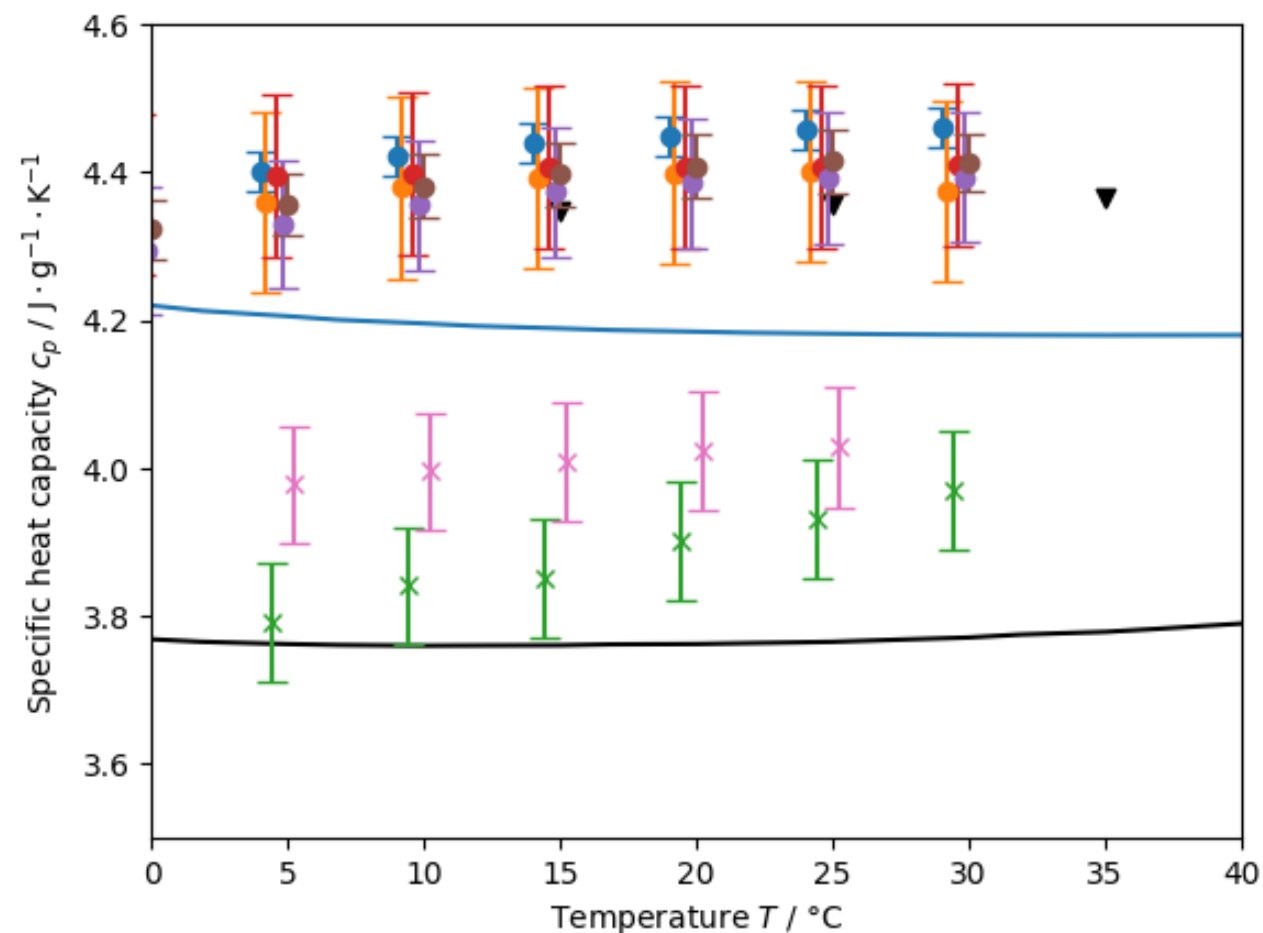
Results: Relative deviation from mean value for water



Results: Ethanol - Water

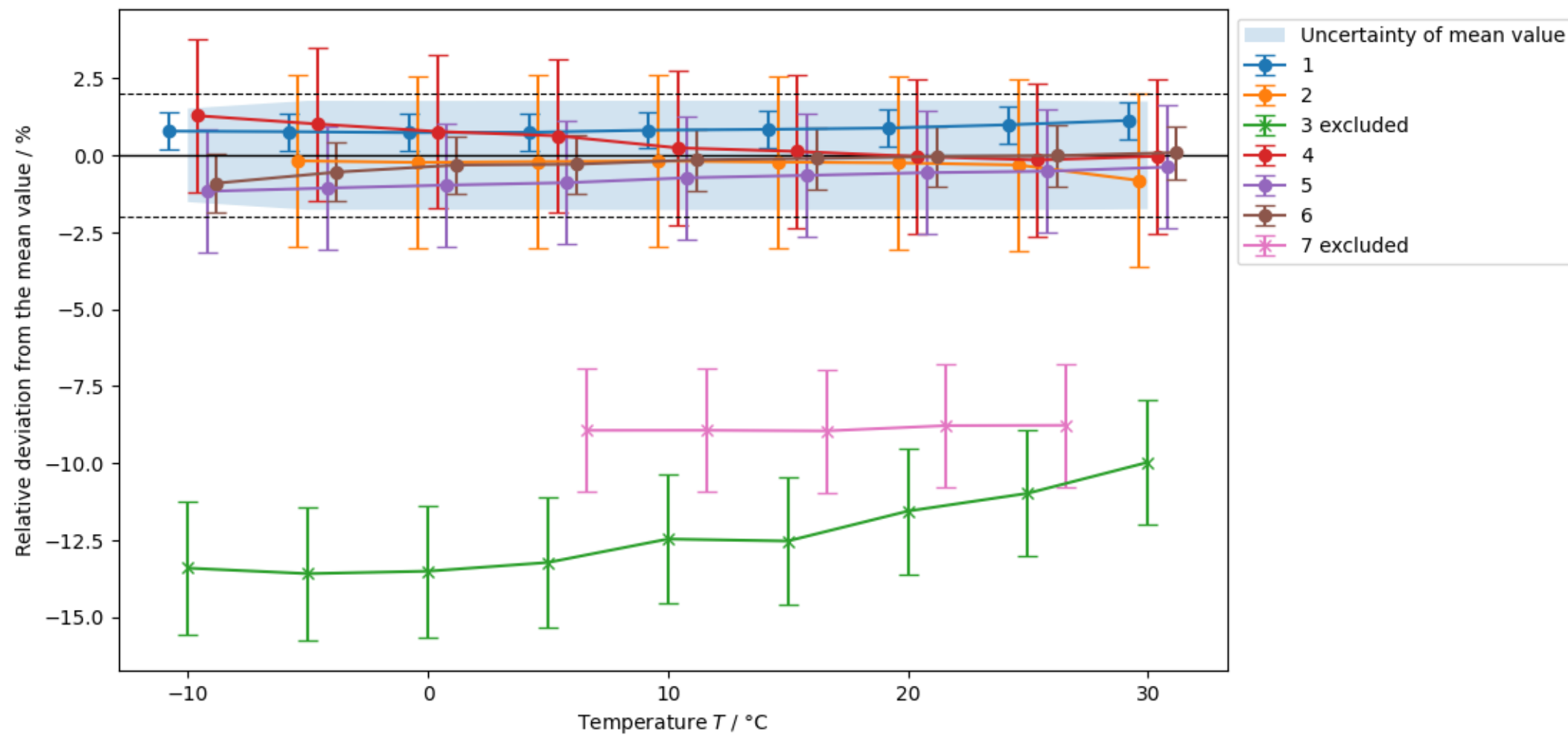


Results: Ethanol - Water

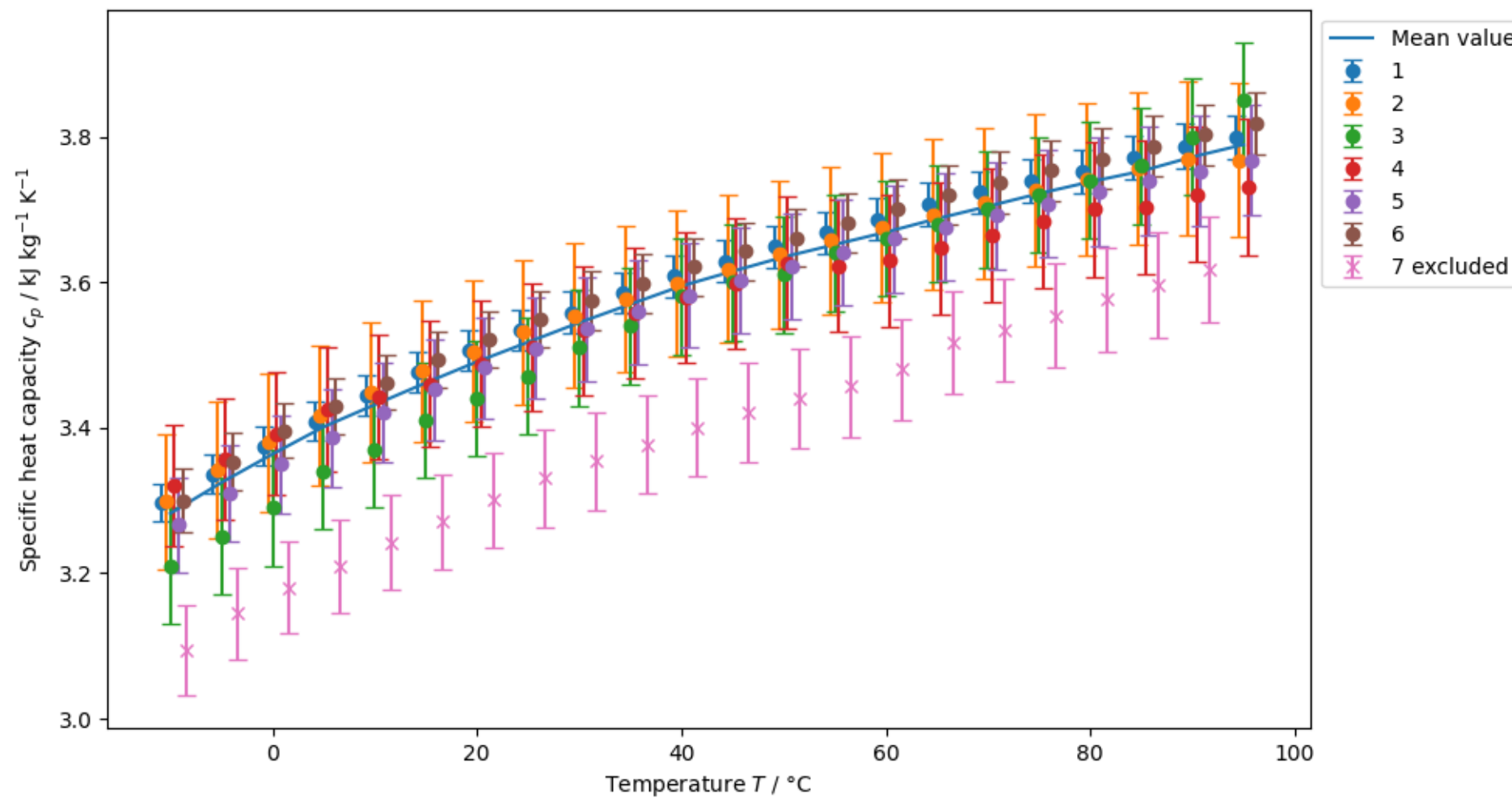


$$c_{p,\text{mix}} = c_{p,\text{water}} \cdot w_{\text{water}} + c_{p,\text{ethanol}} \cdot w_{\text{ethanol}}$$

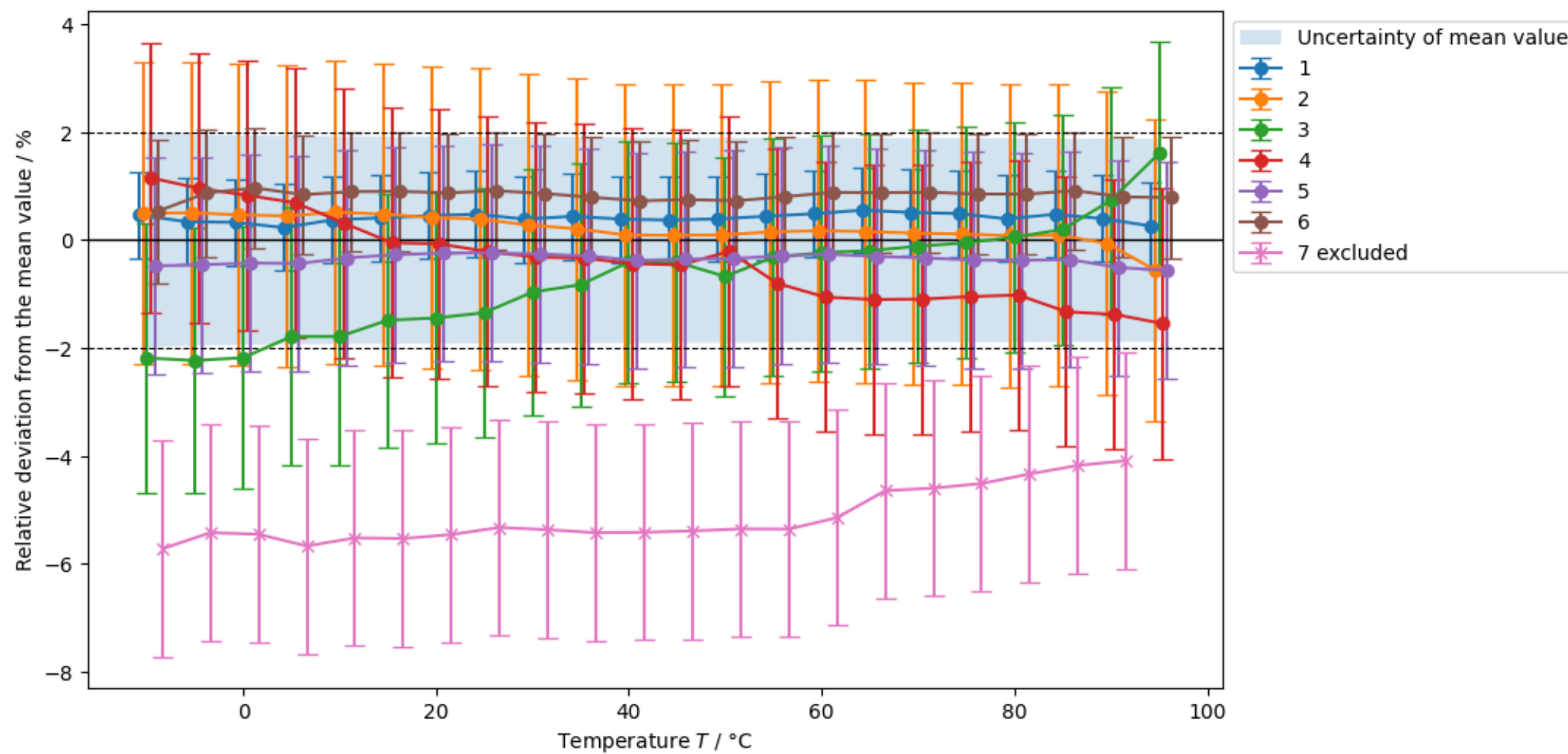
Results: Relative deviation from mean value for Ethanol - water



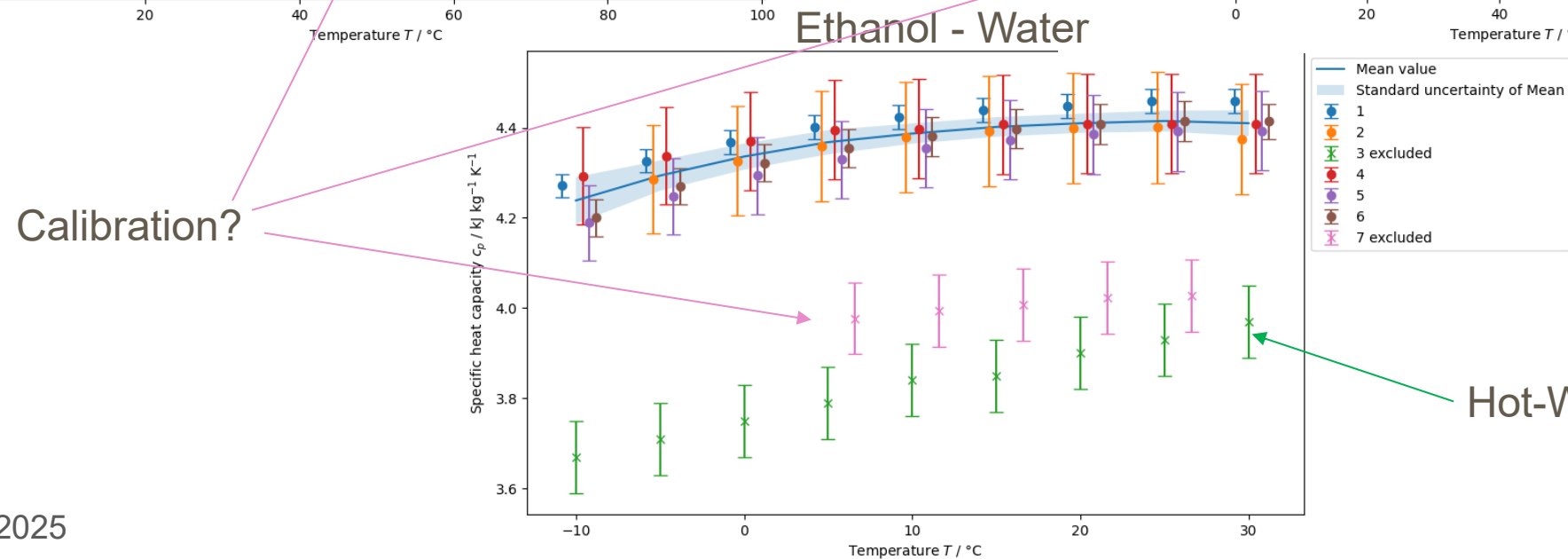
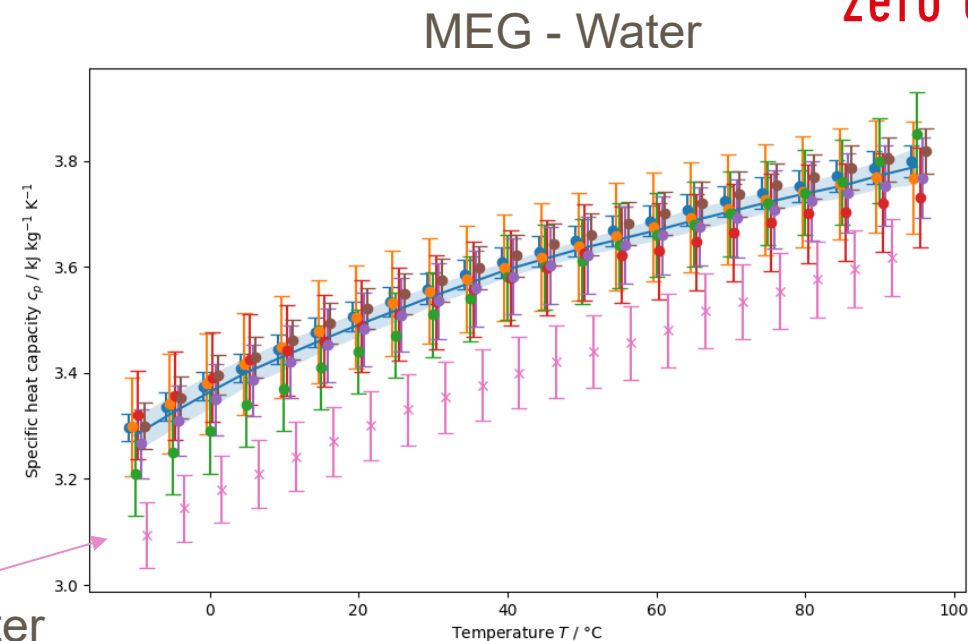
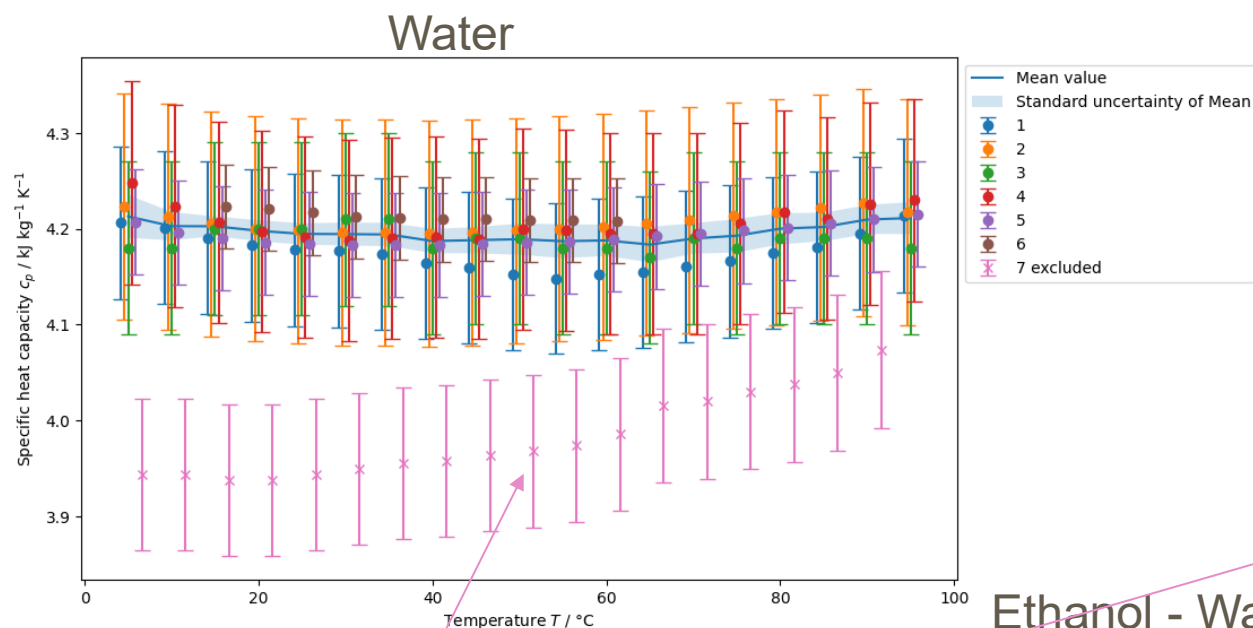
Results: (Mono-)Ethyleneglycol - Water



Results: Relative deviation from mean value for MEG-water



Stated measurement uncertainty / standard uncertainty



Calibration?

Hot-Wire Method

Lessons learned

- **Uncertainty $< \pm 2\%$ is achieved.**
- **Ensuring correct calibration of the calorimeter**
Calibration of the calorimeter must be carried out carefully and correctly to ensure the reliability of the measurements.
- **Ensure tight closure of the sample containers :**
The crucibles must be tightly sealed to prevent the heat transfer fluids from evaporating during the measurements.
- **Optimum filling of the sample containers**
The crucibles should be filled as completely as possible to minimize evaporation within the crucible.
- **Consistent results of the DSC methods**
Differential Scanning Calorimetry (DSC) methods provide consistent and reproducible results for all heat transfer fluids tested, proving the reliability of this technique.
- **Deviations in the results of the dynamic hot-wire method :**
In the indirect determination using the dynamic hot-wire method, significant deviations were found in the results of the ethanol-water mixture compared to the DSC.

Special Thanks

