Activity C3 main results
Analysis of 29 SHC plants

Daniel NEYER, Rebekka KÖLL

Introduction

- Solar cooling and heating can be complex
  - Solar Thermal or Photovoltaic driven
  - Demands (domestic hot water, space cooling, …)
  - System design & configurations (backups, storages,…)
  - Boundaries (system and time)
  - …

→ Assessment in a common comparable format

  - T53E4 Assessment Tool
  - Assessment based on (monthly) energy balances
  - Measured or simulated (sub) system

Technical Key Figures

- Non-renewable primary energy ratio **(PER_{NRE})**
  - Useful energy (Q_{use}):
    space heating, cooling, domestic hot water, …
  - Energy input / effort (Q_{in})
    electricity (el),
    energy carrier (in e.g. natural gas, etc.)
  - Primary energy conversion factors
    electricity: e_{el} = 0.4 $kWh_{Use}/kWh_{PE.NRE}$
    natural gas: e_{in} = 0.9 $kWh_{Use}/kWh_{PE.NRE}$

$$PER_i = \frac{\sum Q_{use}}{\sum \left(\frac{Q_{el,in}}{\varepsilon_{el}} + \frac{Q_{in}}{\varepsilon_{in}} \right)}$$

Technical Key Figures

- Non-renewable primary energy savings ($\mathbf{f_{sav.PER\text{-}NRE}}$)
  - Comparison of non-renewable Primary Energy (PER_{NRE})
  - Solar (SHC) vs. predefined reference (ref)
  - Standard in T53E4 Tool
    - natural Gas
    - air cooled vapour compression chiller

$$f_{sav.PER-NRE} = 1 - \frac{PER_{NRE.ref}}{PER_{NRE.SHC}}$$

Economic Key figures

- Annuity method & input values based on EN-standards
- Standardized (data base) to calculate annualized costs
  - Investment, replacement & residual value
  - Maintenance & service,
  - Operational costs (energy, water)
  - Solar Heating and Cooling and Reference

→CostRatio (CR)

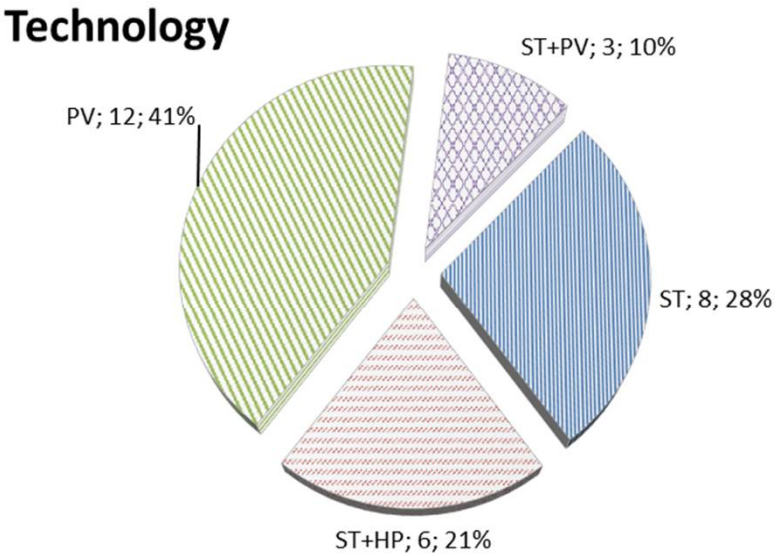
$$\text{CostRatio(CR)} = \frac{annualized\ costs\ SHC}{annualized\ cost\ REF}$$

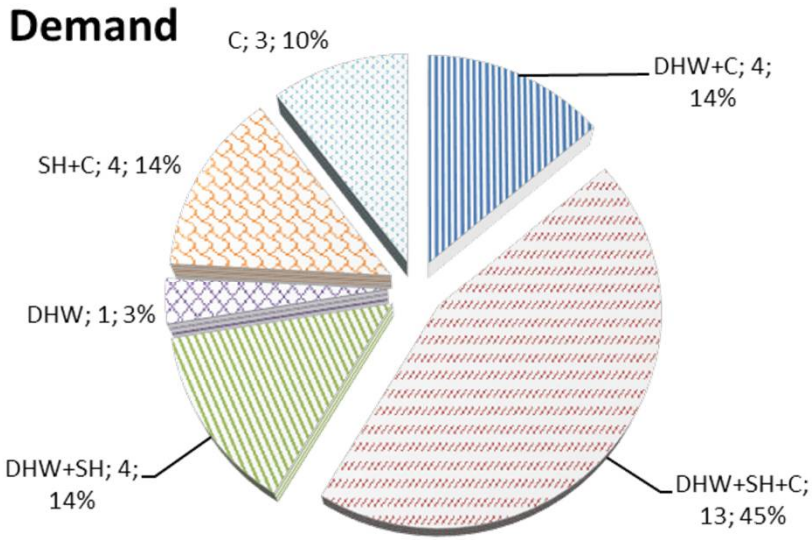
Results obtained

- Assessment of 29 SHC plants with T53E4 Tool
  - Technical analysis
    - Energy balance check
    - Comparison to T53 Standard
    - System & Subsystem Analysis
    - PER_{NRE}, $PER_{NRE.ref}$, $f_{sav.NRE}$, SPF_{equ}
  - Economic analysis
    - Investment, Replacement & Residual
    - Maintenance, Energy (electricity, natural gas,…)
    - Comparison to T53 Standard
    - Spec. Invest, $LCOE_{SHC}$, $LCOE_{REF}$, CR
- Trend analysis
- Sensitivity analysis

Overview Examples

- 17 examples (29 configurations)





Overview Examples

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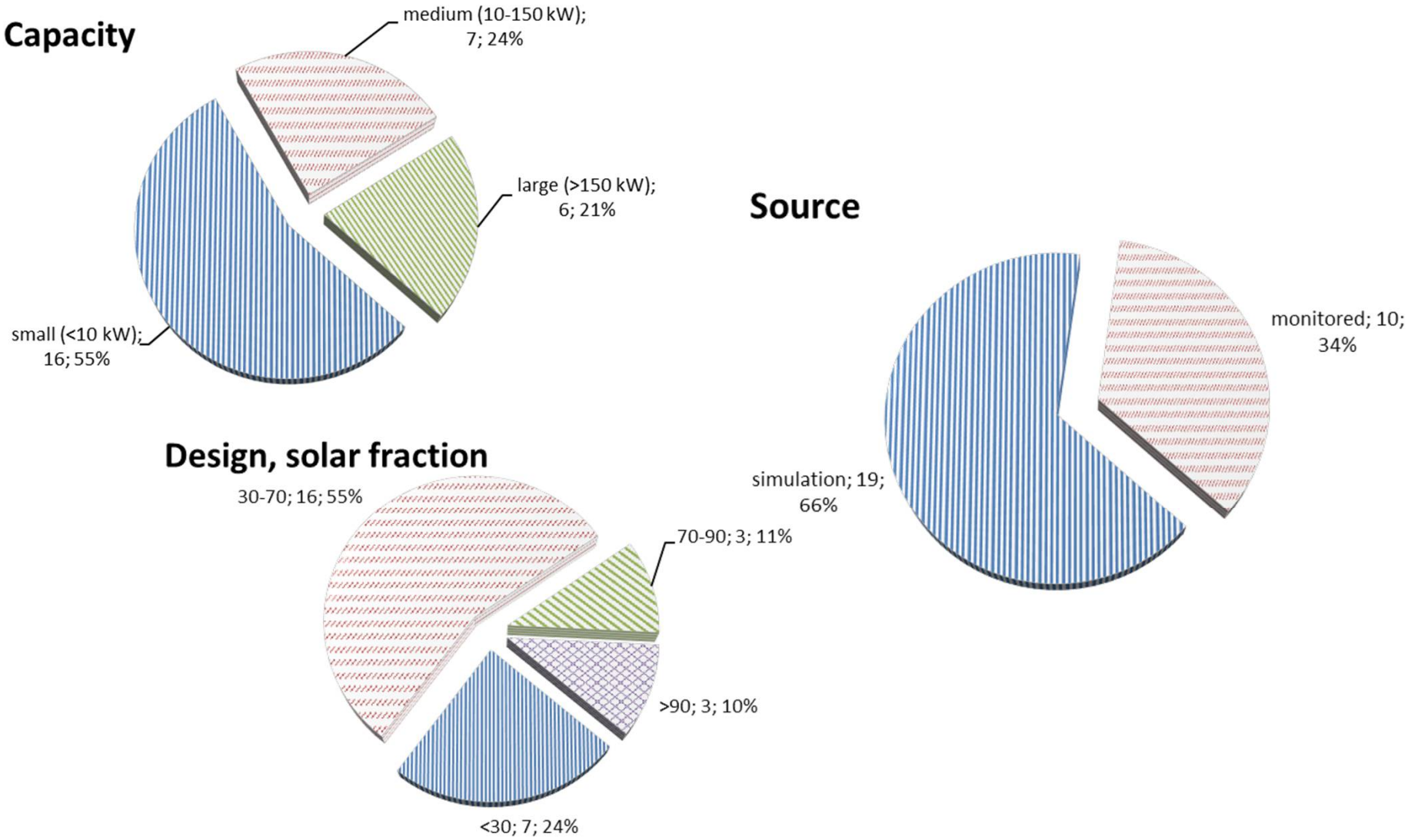
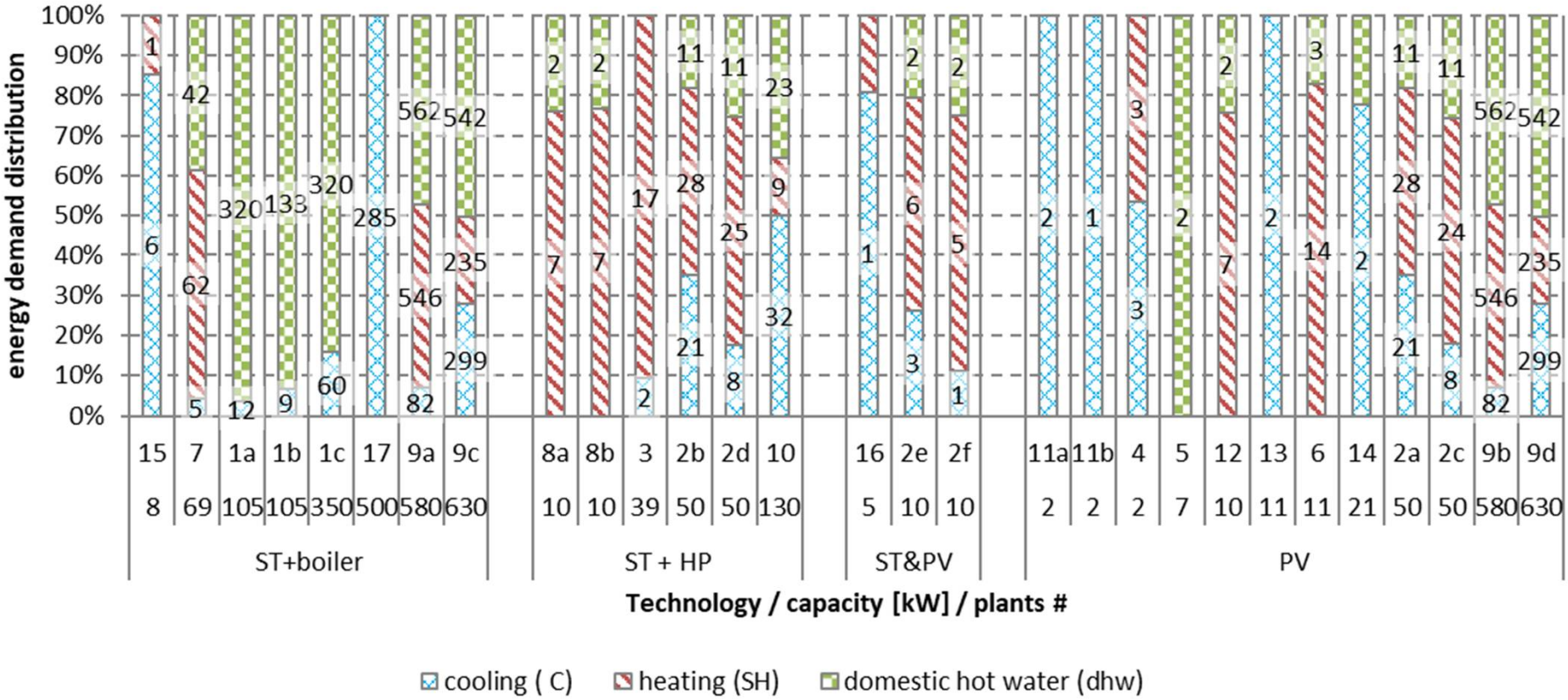


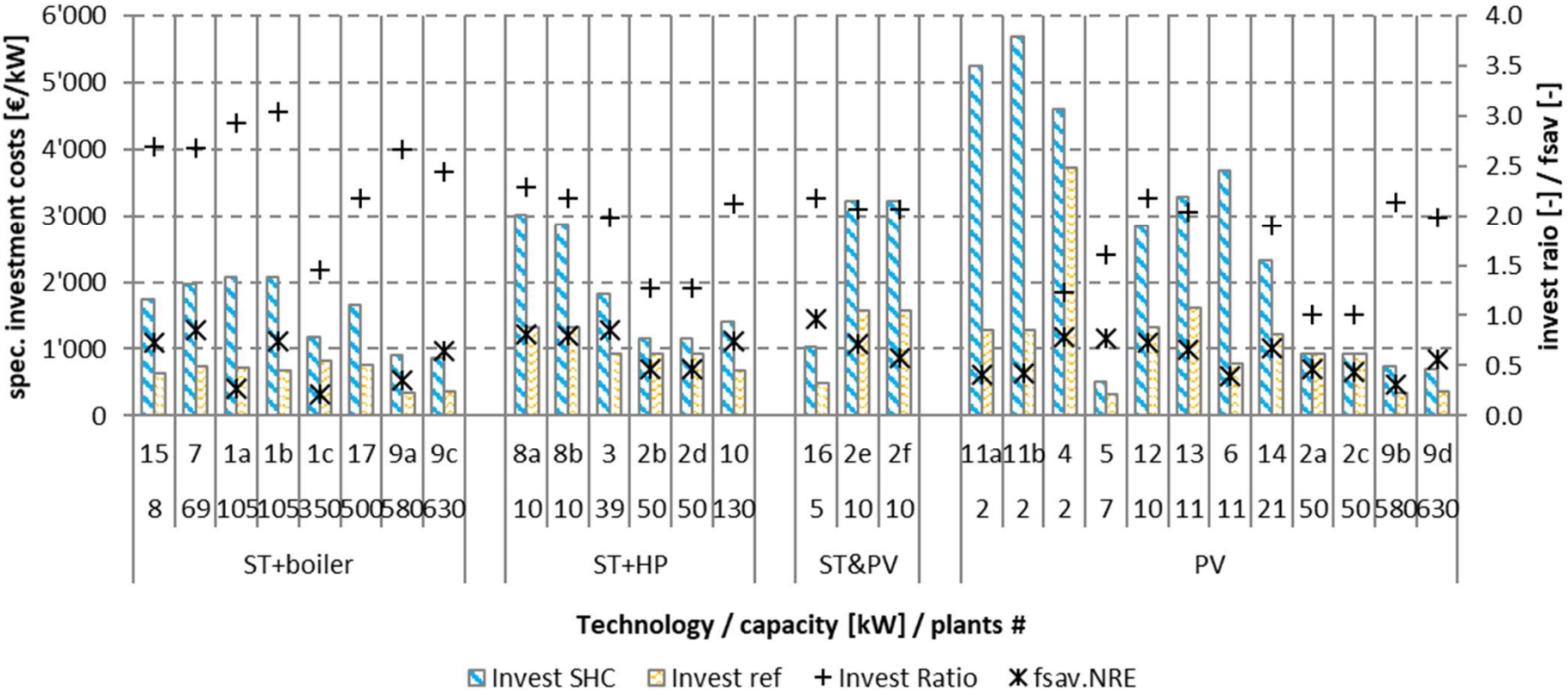
Energy Supply

- Mainly 2 / 3 applications
- Huge difference in amount of energy!



Investment Cost

- Investment of SHC compared to reference
  - + 60% (7)
  - + 60 -120% (12)



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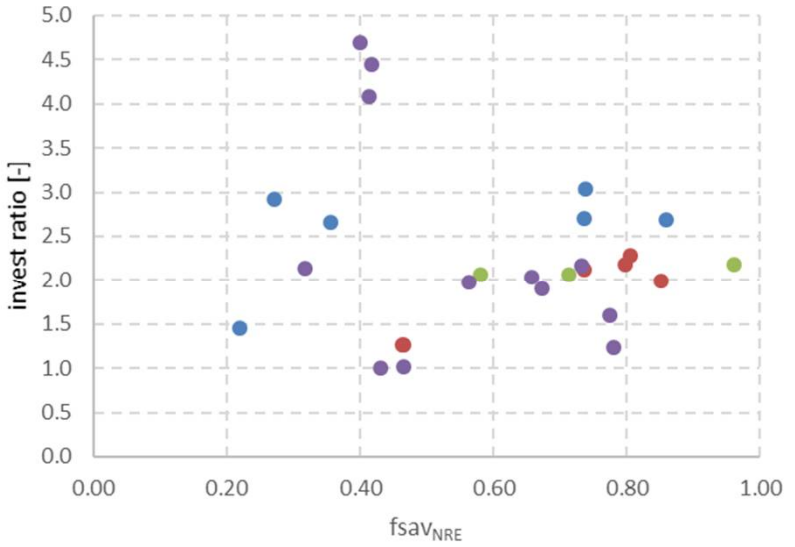
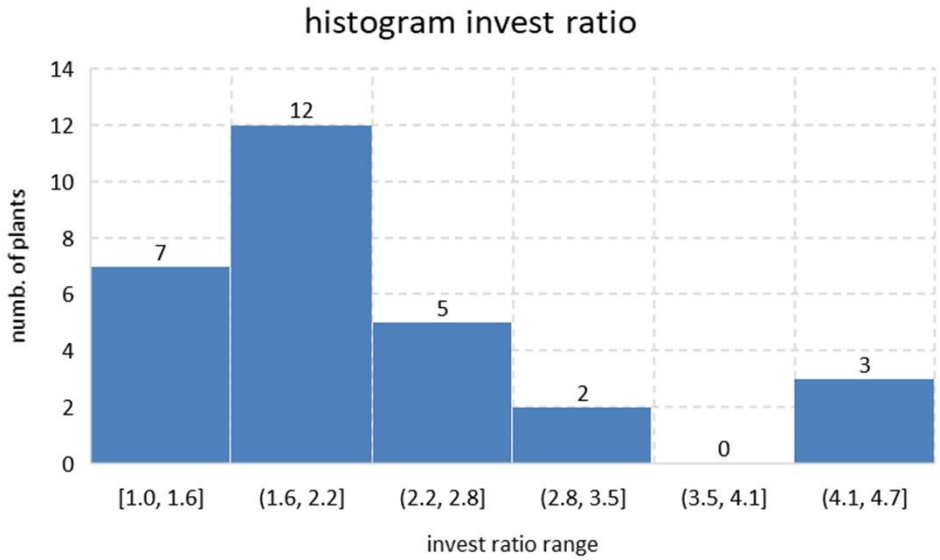
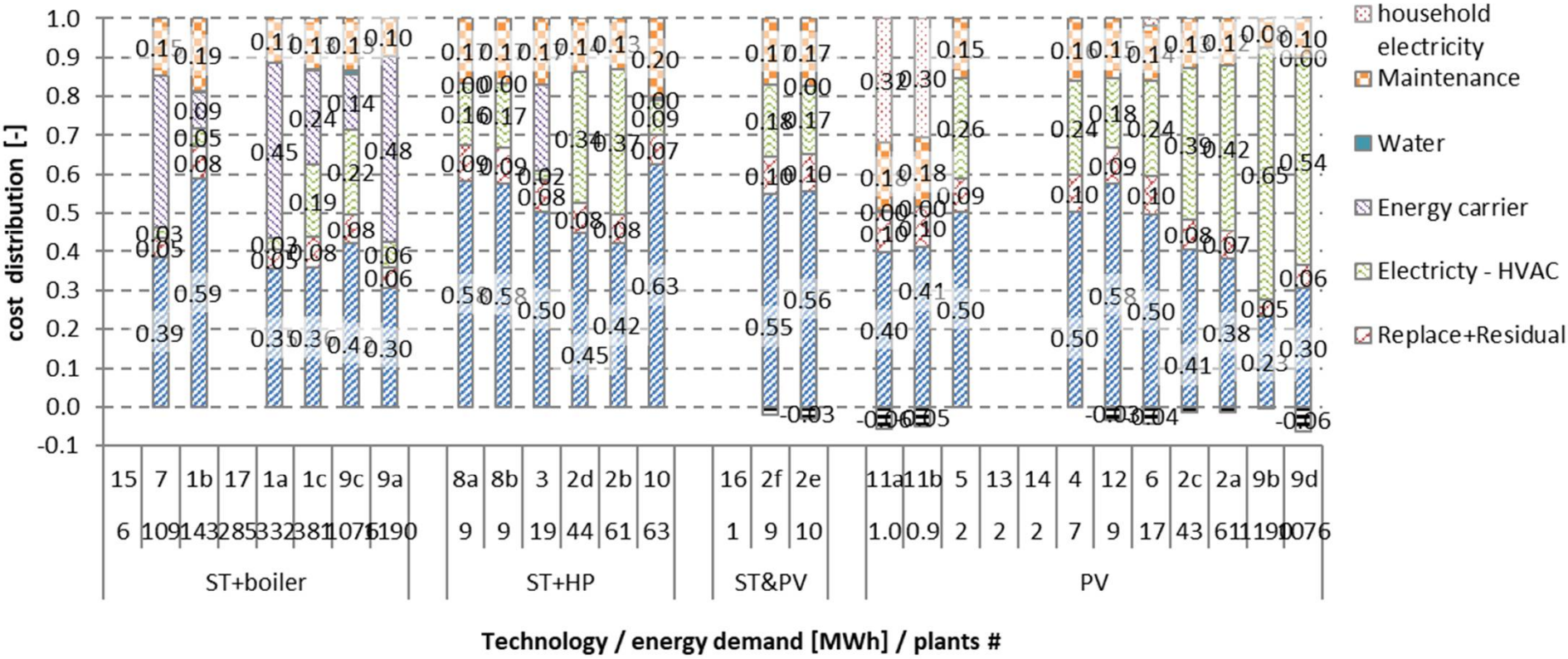


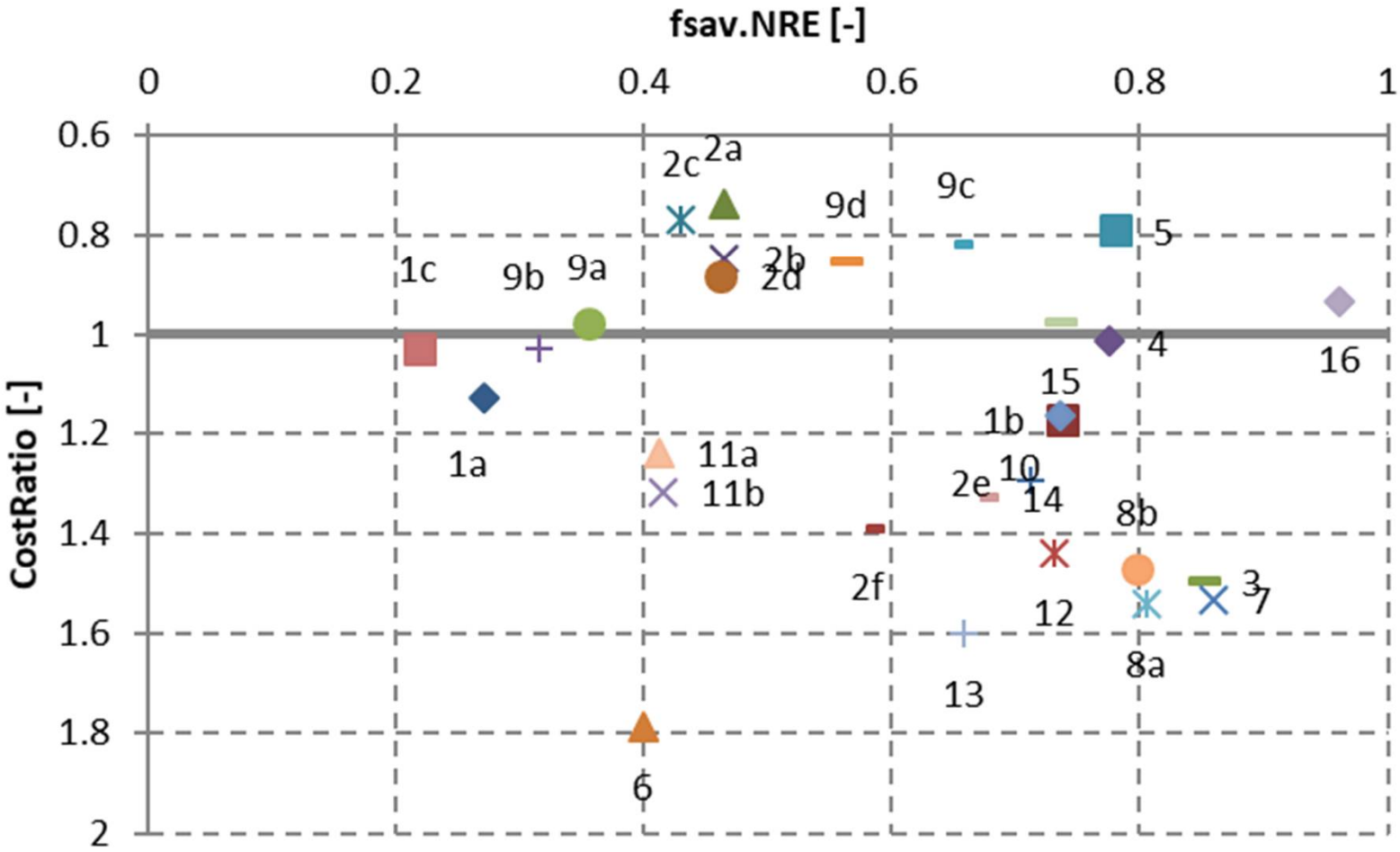


Total Annualized Cost

- Small scale mainly investment dominated
- Large scale energy costs dominated

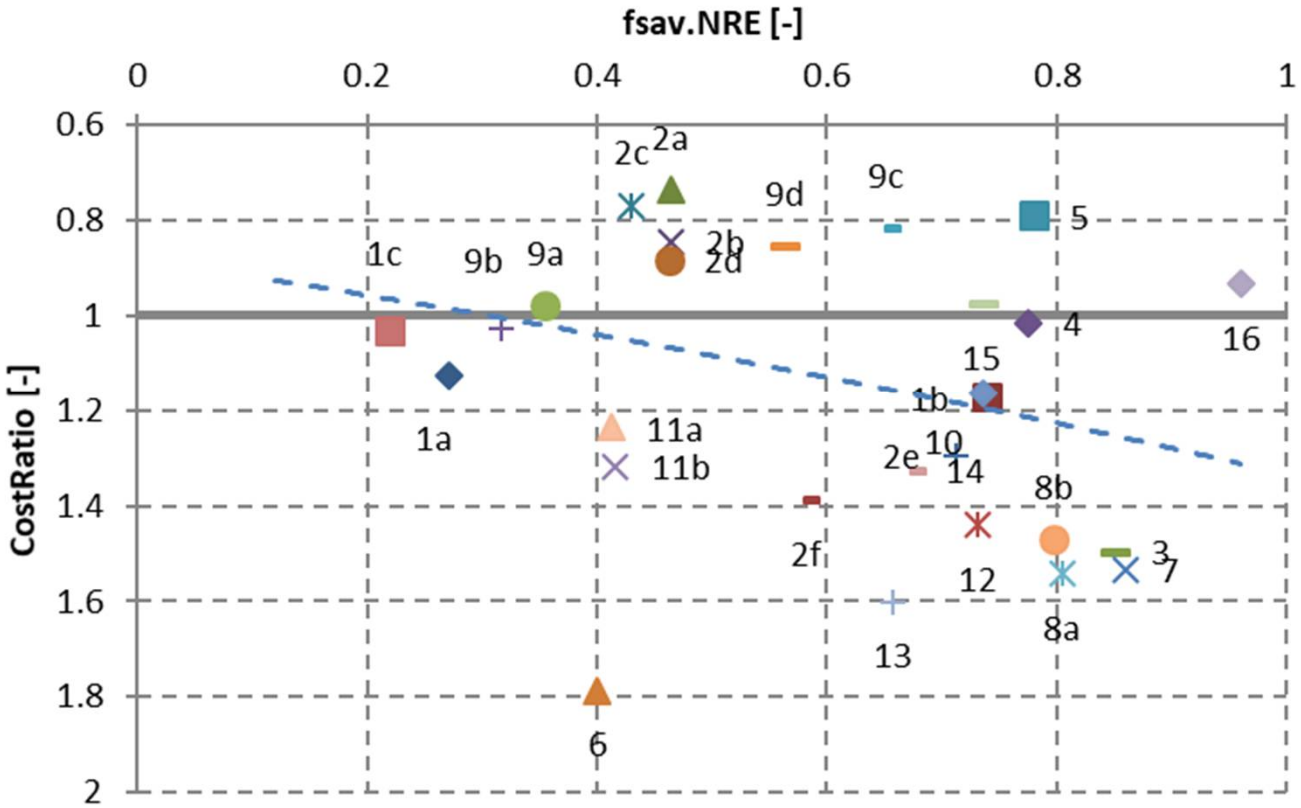


$f_{sav.NRE}$ vs. CR



Trends

- SHC overall
  - Exclude #13, 14, 16, 17 (no annual energy balance)



Trends

- South vs. North
- 2 vs. 3 applications (C, DHW, SH)
- ST vs. ST + HP vs. ST + PV vs. PV
- C vs. DHW vs. SH
- Simulated vs. monitored
- ST/PV combined with south/north
- to follow soon

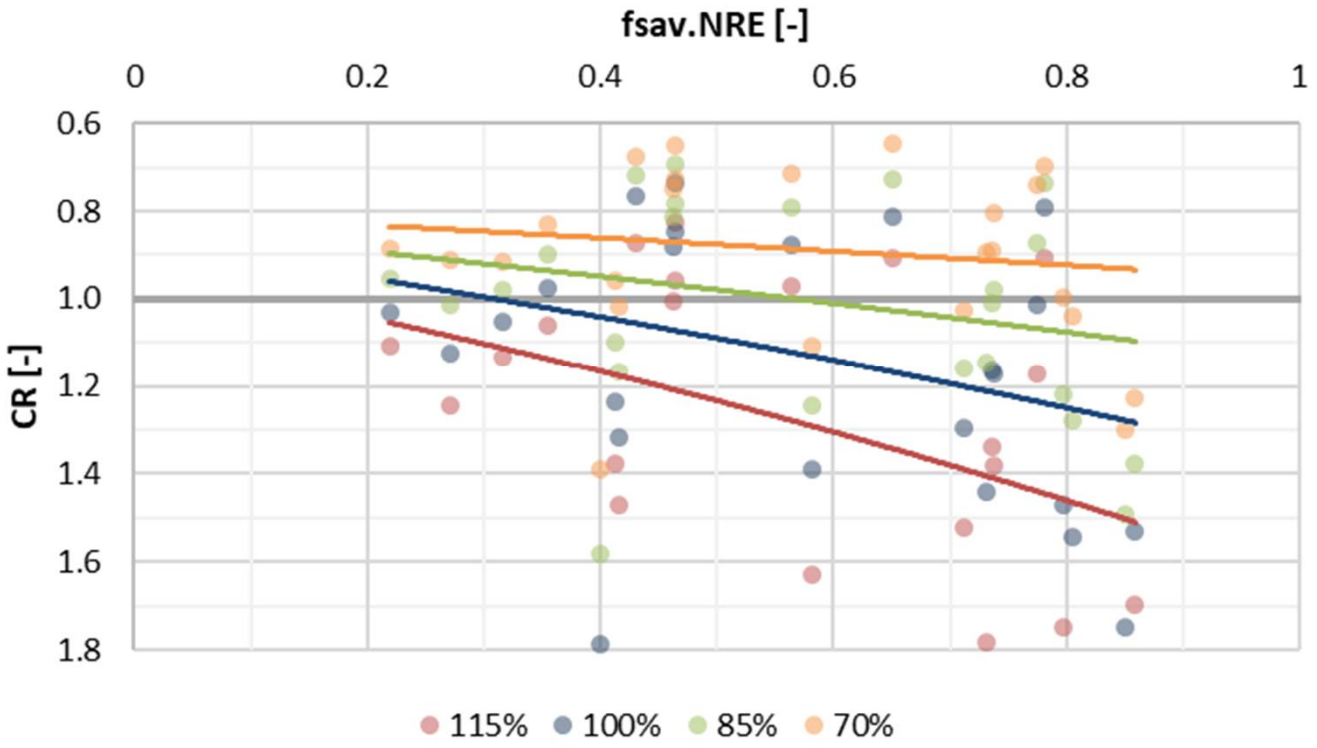
Sensitivity Analysis

- 6 Parameter with each 7 Variation

Investment Cost (€/kW)	40, 55, 70, 85, 100, 115, 130	[%]
Electricity price (10 ct/kWh)	50, 100, 150, 200, 250, 300, 350	[%]
Natural gas price (5 ct/kWh)	50, 75, 100, 125, 150, 175, 200	[%]
Auxiliary demand (kWh_{el})	50, 60, 70, 80, 90, 100, 110	[%]
Energy output (kWh_{use})	80, 90, 100, 110, 120, 130, 140	[%]
Conversion factor (0,4 kWh/kWh)	80,90,100,115,130,145,160	[%]

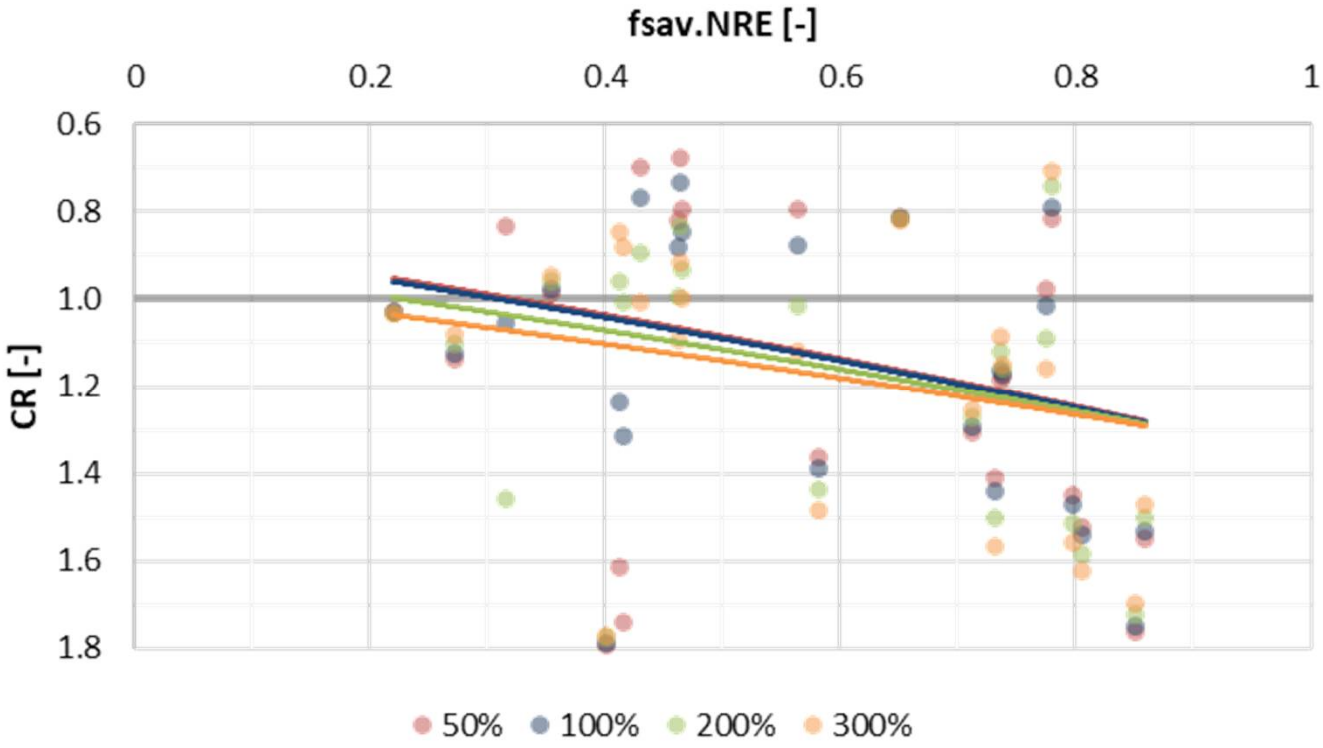
Sensitivity

- Investment cost
  - Only affect the CostRatio
  - Plants with higher $f_{sav.NRE}$ are more sensitive



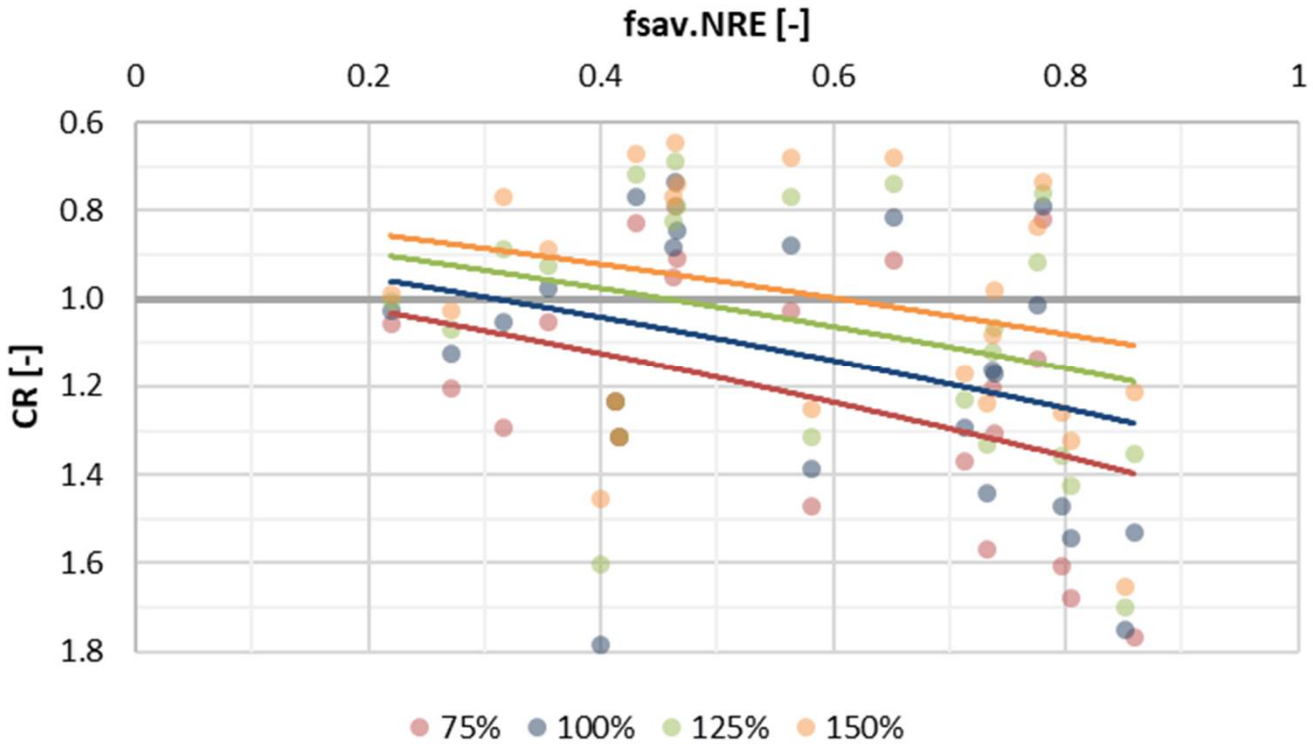
Sensitivity

- Electricity price
  - Only affect the CostRatio
  - Heat pump systems more affected
  - Higher $f_{sav.NRE}$ less sensitive



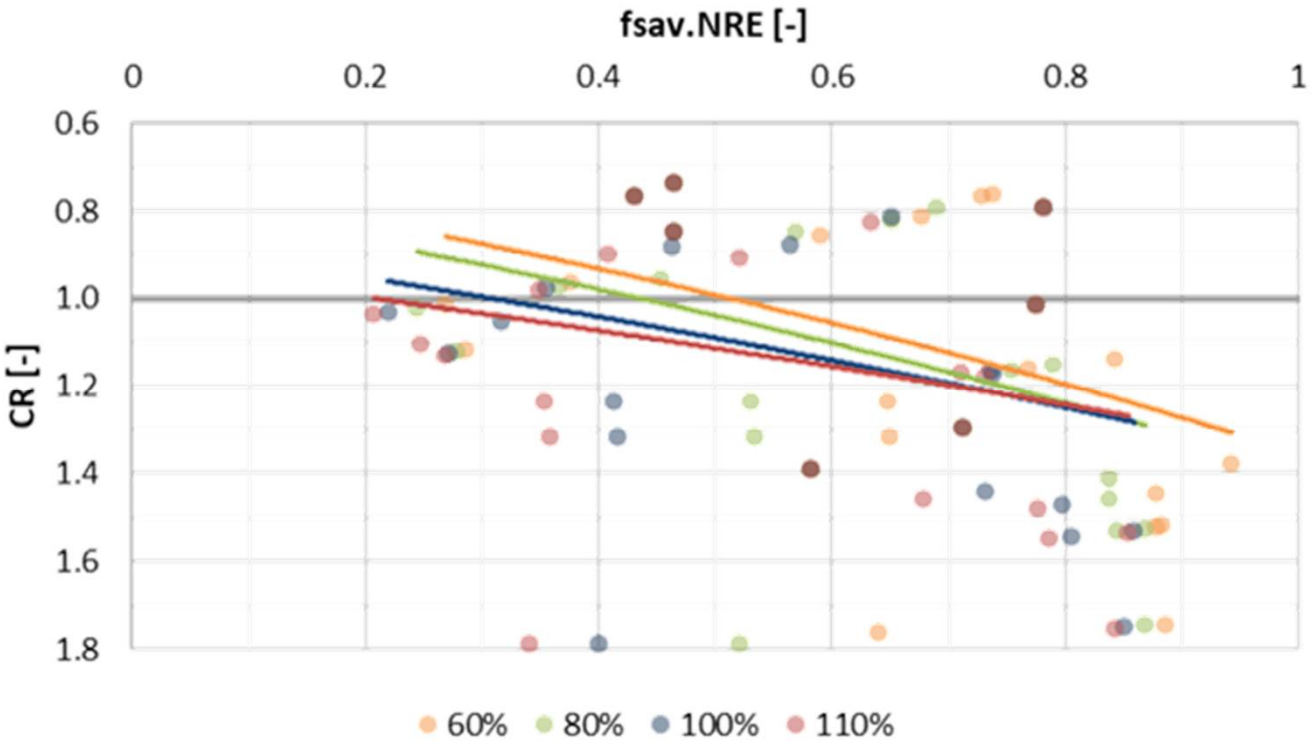
Sensitivity

- Natural gas price
  - Only affect the CostRatio
  - Affect reference and ST + natural gas boiler



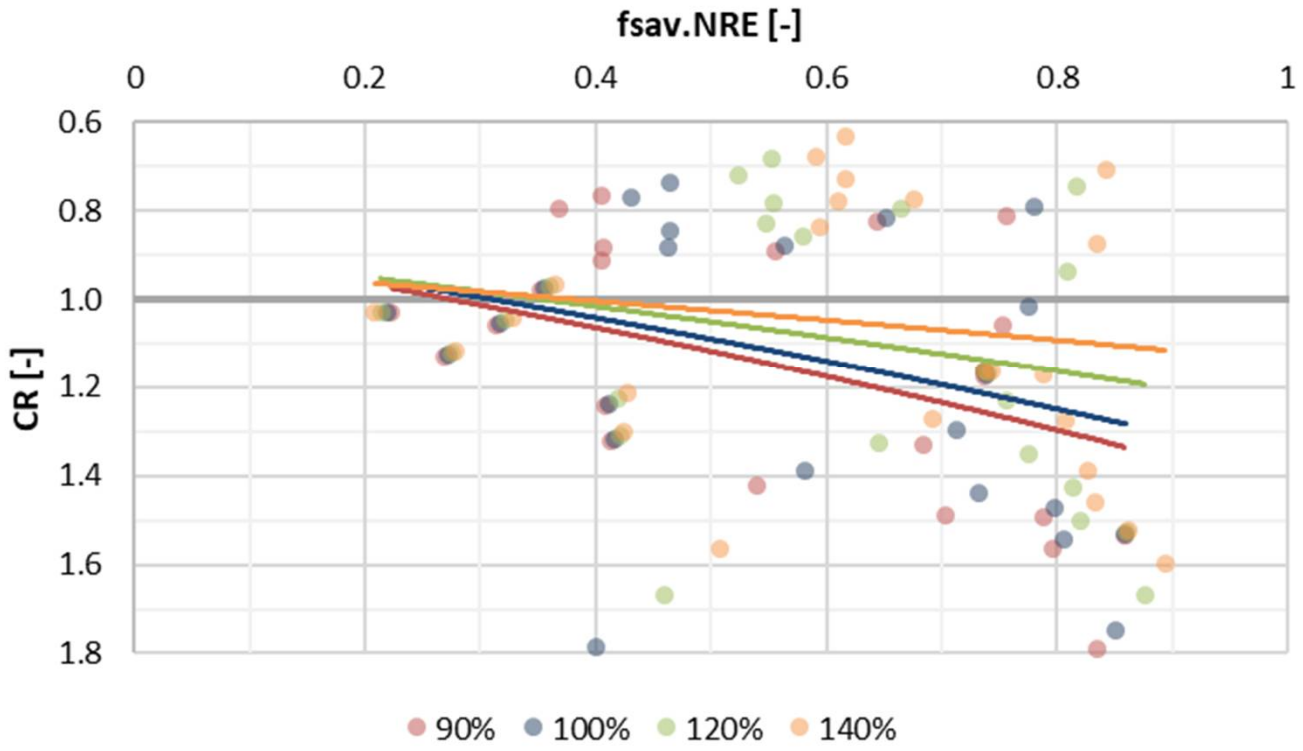
Sensitivity

- Auxiliary demand (electricity)
  - Affects CostRatio and $f_{sav.NRE}$
  - Heat pump systems more affected
  - Higher $f_{sav.NRE}$ less sensitive



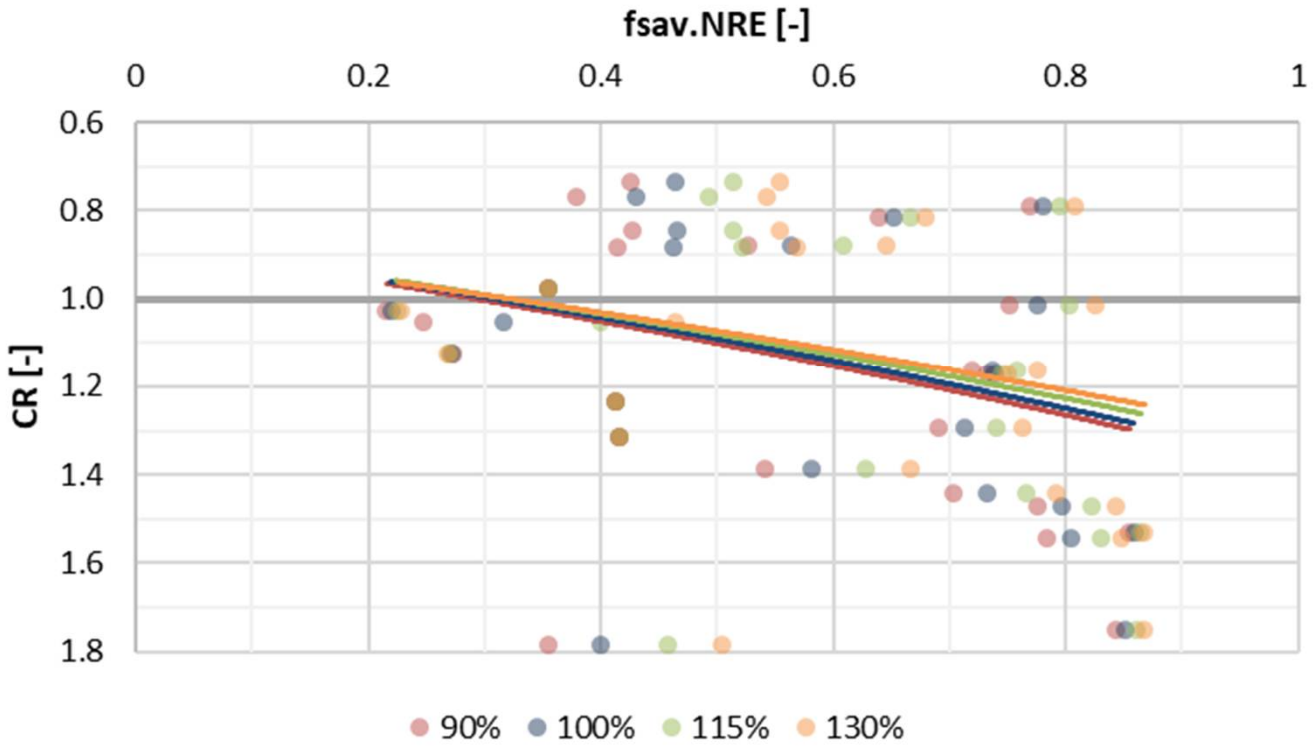
Sensitivity

- Energy output
  - Affects CostRatio and $f_{sav.NRE}$
  - Higher $f_{sav.NRE}$ more sensitive



Sensitivity

- Conversion factor electricity
  - Only affect the $f_{sav.NRE}$
  - Electricity based systems are more affected



Summary

- T53E4 Assessment Tool
  - T53E4 Tool simplified analysis for trend-wise comparison
  - Based on monthly energy balances
  - Focusing on non-renewable primary energy
- Performance of examples
  - Non-renewable Primary Energy Savings > 30%
  - Higher savings lead to higher costs
  - Economics are investment dominated

Summary

- Trends
  - Indication for optimization potential
  - Simplified comparison of different boundary conditions
- Sensitivity
  - Effect of changes in boundaries
  - Large differences for different systems
  - → sensitivity for certain type of systems to follow soon
- Next steps
  - Finalize sensitivity analysis
  - Finalize report → to be expected in summer 2018

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THE CYBERNETICS
OF RENEWABLE ENERGY
AND EFFICIENCY.

oberradin 50
6700 bludenz
austria
+43 664 28 26 529
daniel@neyer-brainworks.at
www.neyer-brainworks.at

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Task 53