# Technical and economic analysis of different solar cooling systems

## Summary of IEA Task 53 results

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Task 53

# 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

    T53 **E**nergy **E**fficiency **E**conomy **E**valuation Tool
  - Assessment based on (monthly) energy balances
  - Measured or simulated (sub) system

# Technical Key Figures

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- 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 (e.g. natural gas, etc.)
  - Primary energy conversion factors
    electricity: $\varepsilon_{el}$ = 0.4 $kWh_{Use}/kWh_{PE.NRE}$
    natural gas: $\varepsilon_{in}$ = 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

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- Standardized Task 53 reference system
  - Natural gas boiler
  - Air cooled vapour compression chiller
  - Calculation of $PER_{NRE.ref}$

- 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)

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

# 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)**

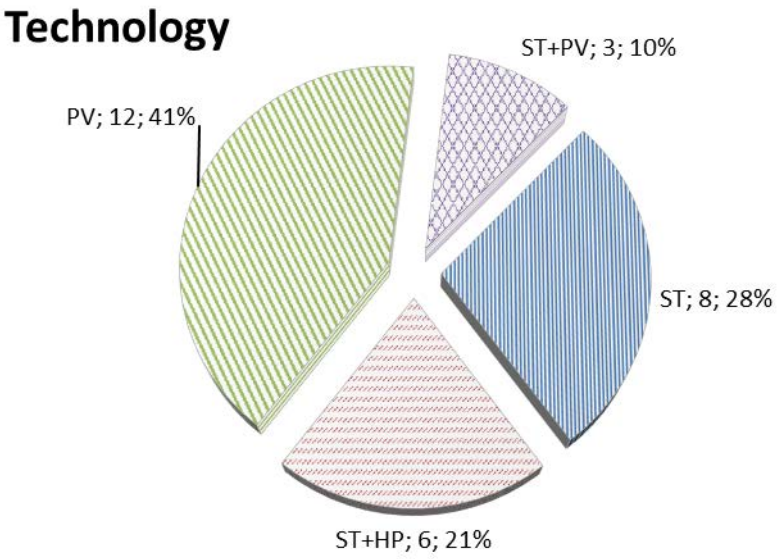
$$\text{CostRatio(CR)} = \frac{annualized\ costs\ SHC}{annualized\ cost\ REF}$$

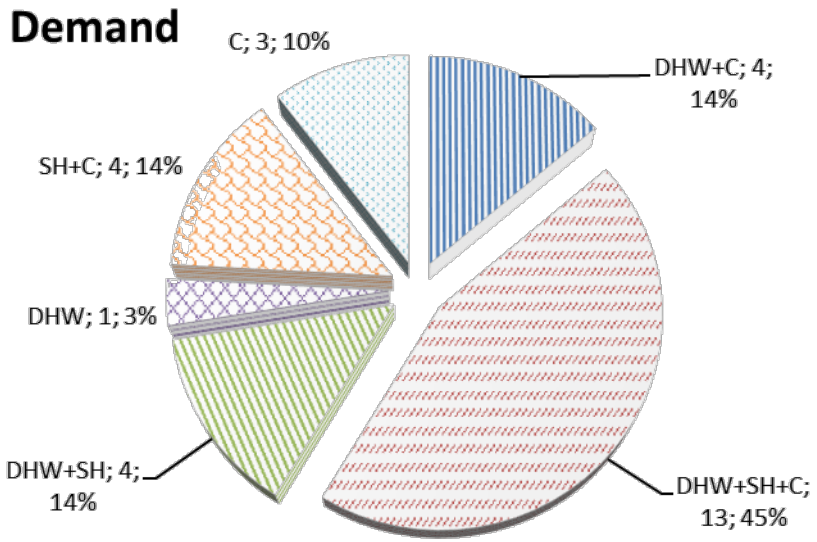
# Results obtained

- 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

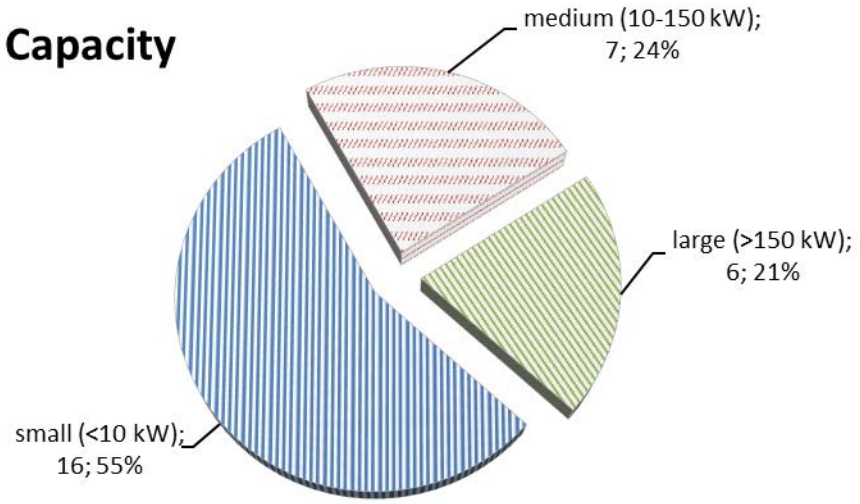
# Overview Examples

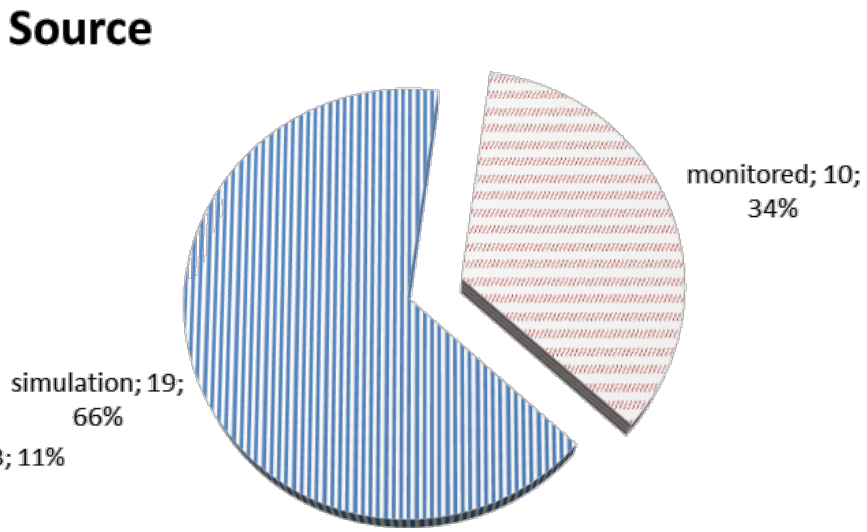
- Assessment of 29 SHC plants with T53E4 Tool
  - 17 examples (29 configurations)
  - System & Subsystem Analysis
  - Trend analysis
  - Sensitivity analysis

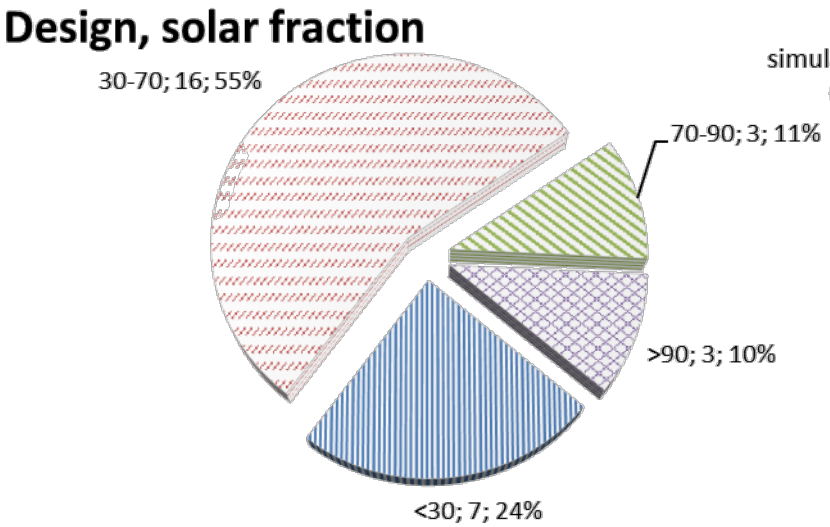


# Overview Examples

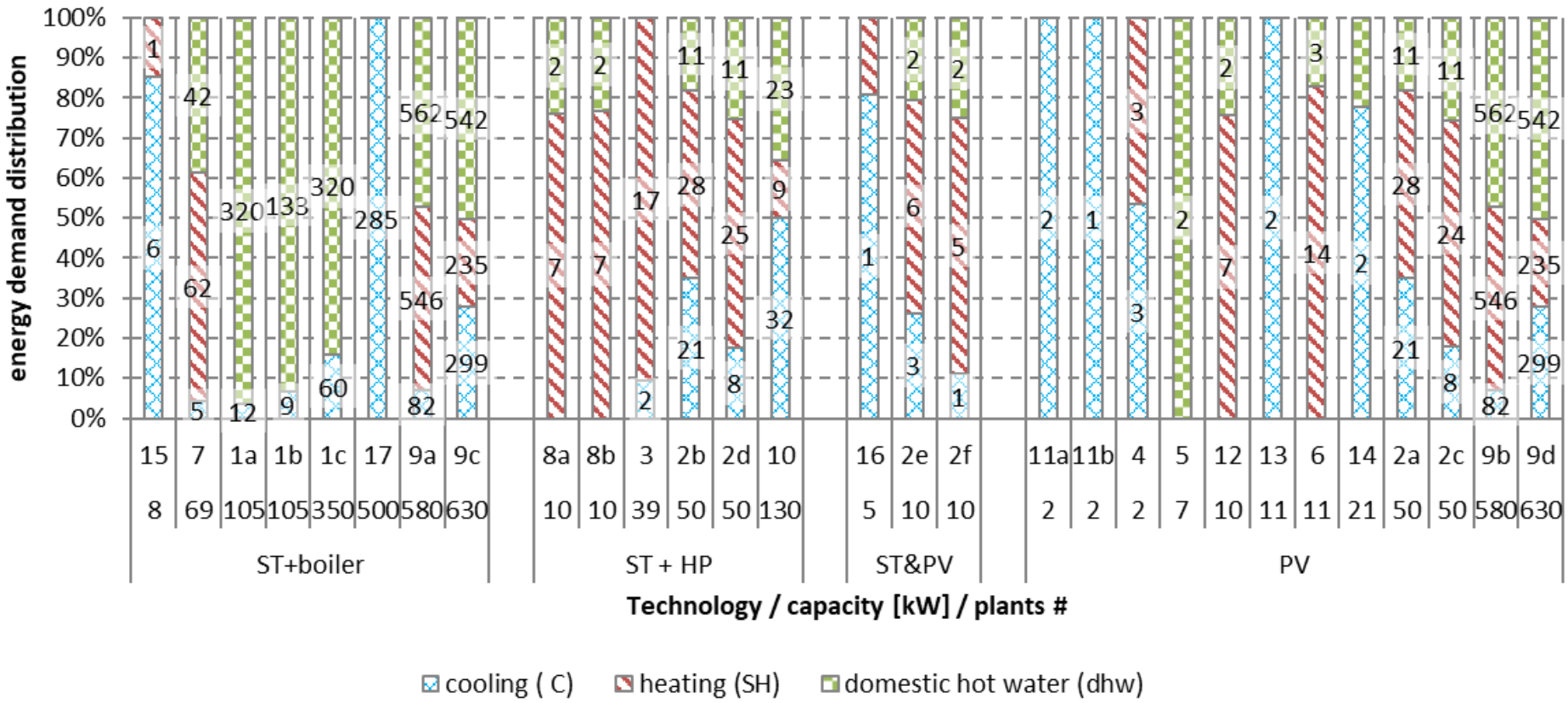


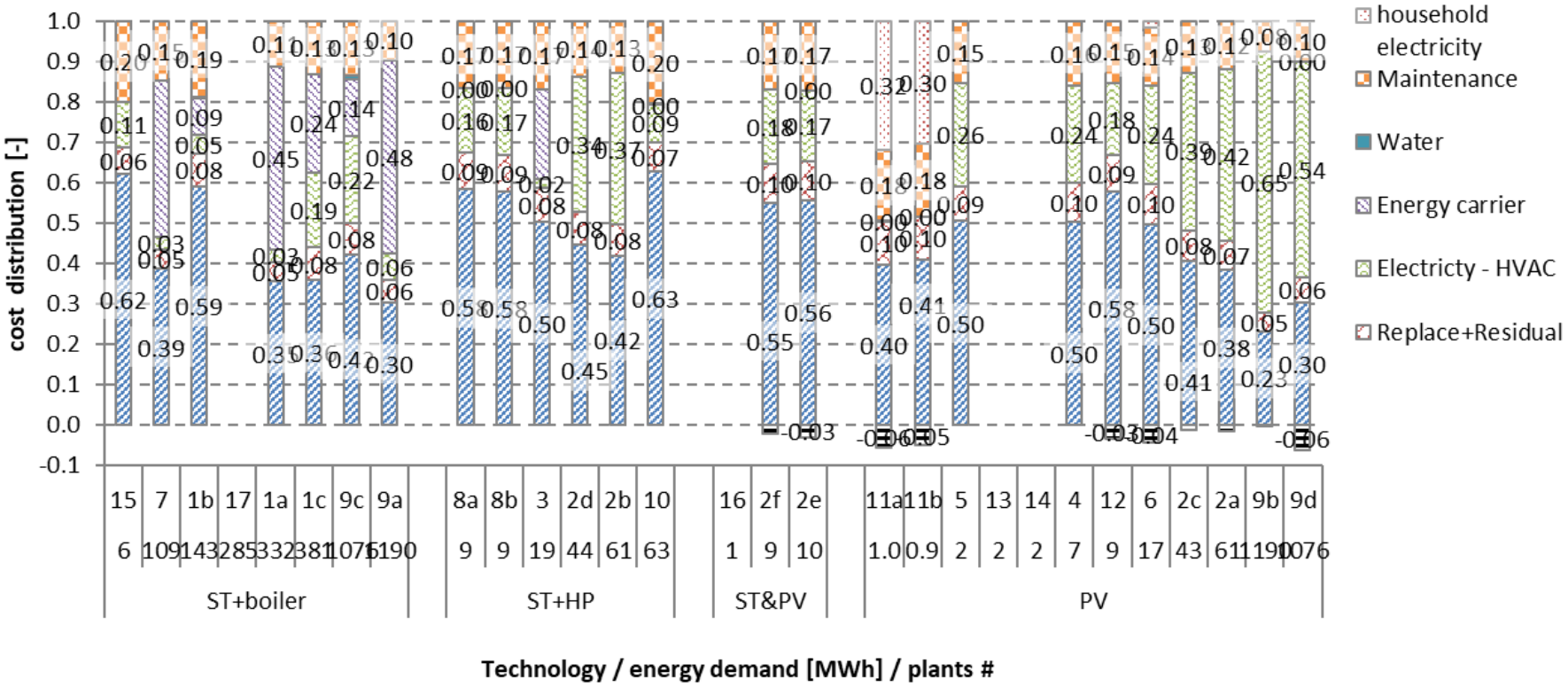
# Energy Supply

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



# Total Annualized Cost

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



# Primary Energy vs. Costs

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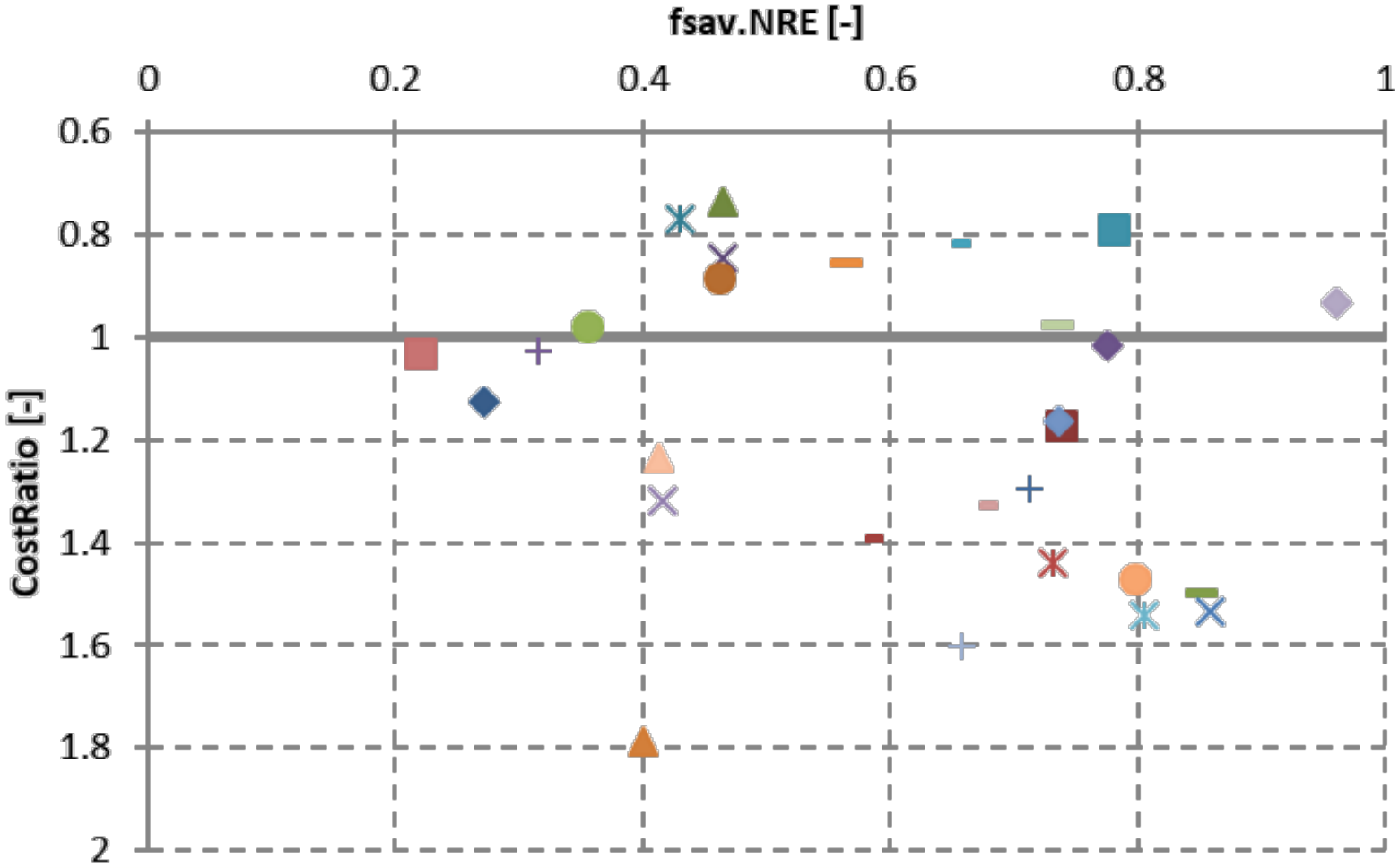
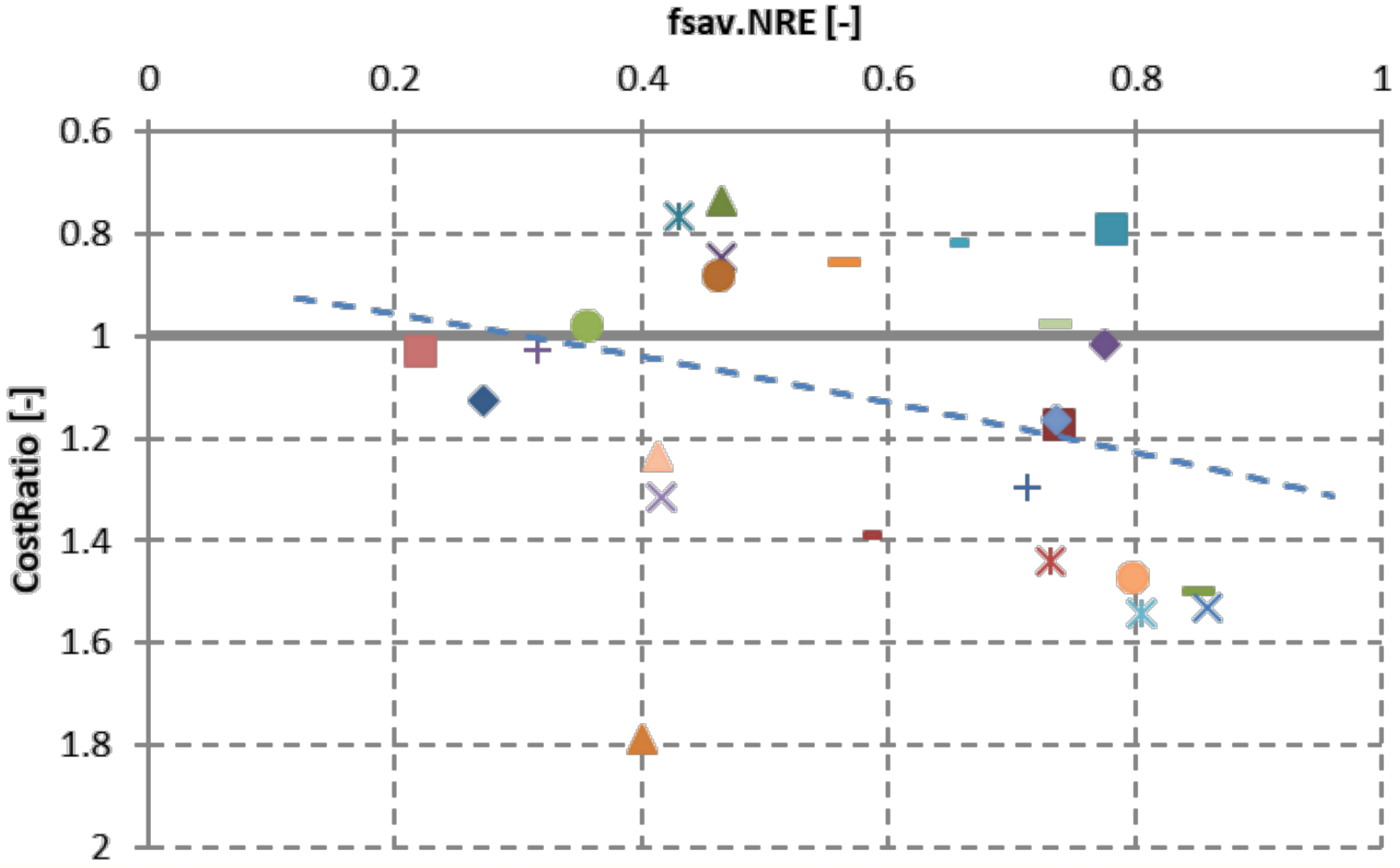
- $f_{sav.NRE}$ vs. CostRatio



# Overall Trend

- Exclude plants with no annual energy balance



# Trend / Sensitivity Analysis

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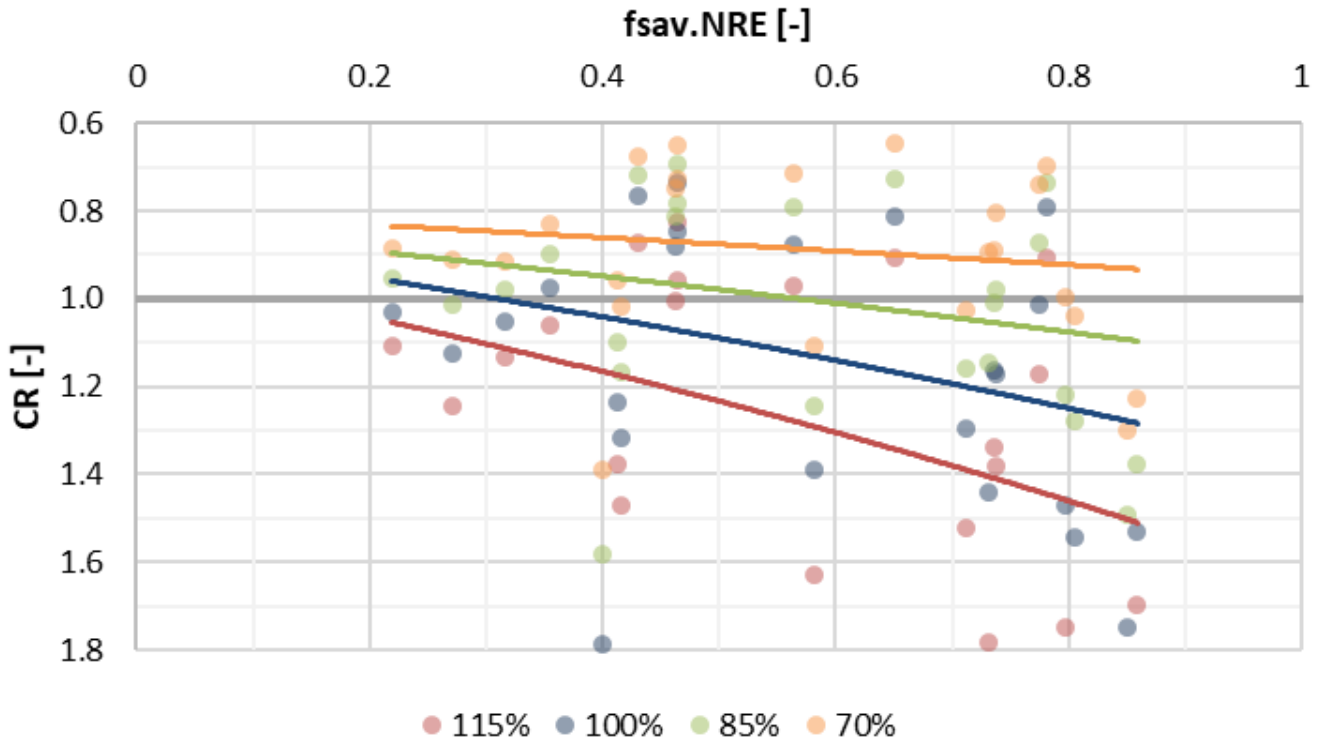
- Several trends can be shown
  - Location: south vs. north
  - Demand: DHW vs. Cooling vs. Heating
  - Technology: ST vs. PV
  - …

- Sensitivity: 6 Parameter with 7 Variations each

| | | |
|---|---|---|
| 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 $kWh_{el}/kWh_{NRE}$) | 80, 90, 100, 115, 130, 145, 160 | [%] |

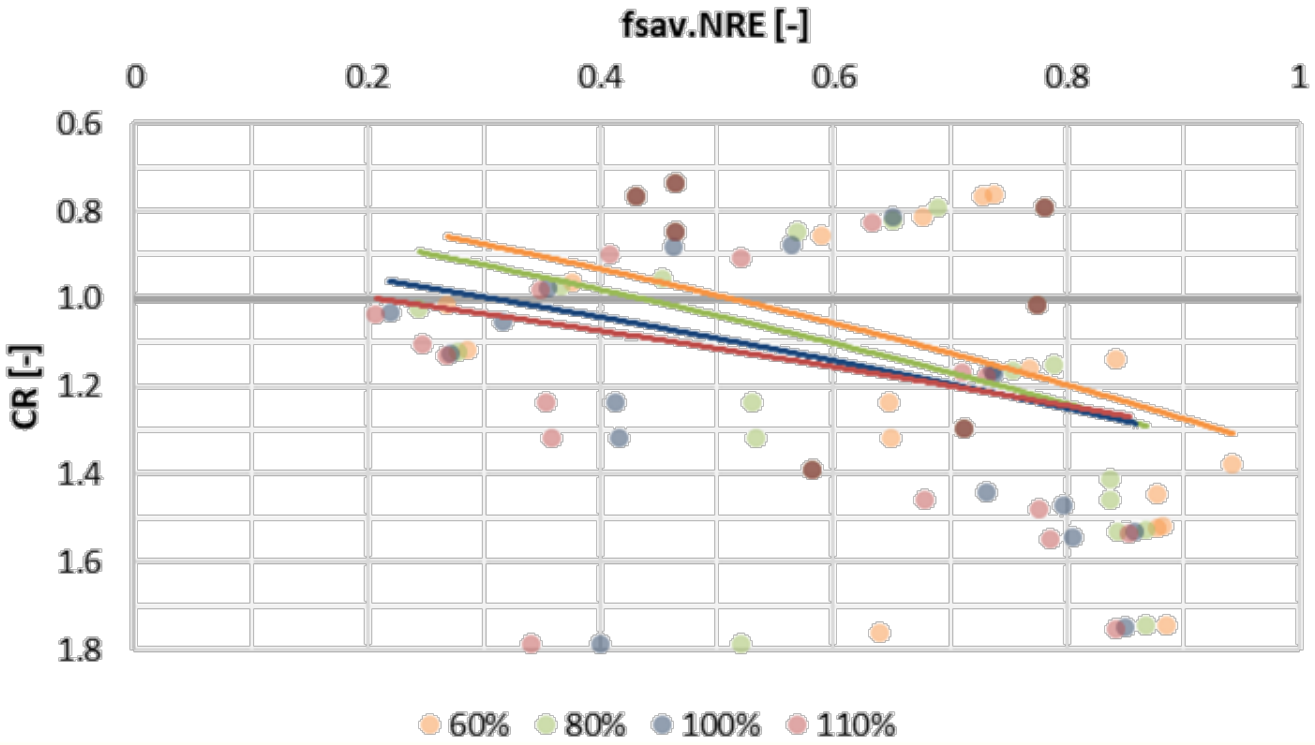
# Sensitivity

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



# Sensitivity

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



# Summary

- T53E4 Assessment Tool
  - Simplified analysis of system / subsystem
  - Useful for benchmarking against reference and other RE
  - Focus on
    - non-renewable primary energy
    - CostRatio

- Performance of SHC examples
  - Non-renewable Primary Energy Savings 40-80%
  - Higher savings lead to higher costs
  - Economics are mainly investment dominated

# Summary

- Sensitivity analysis
  - Effect of changes in boundaries
  - Trend wise comparison of results
  - Large differences for different systems

  →sensitivity for certain type of systems to follow soon
- Advantage of ST or PV is depending on …
  - Local conditions
  - System design & Application

**→ Both technologies can be optimized**

**→ Cost competitiveness can be reached**

Final reports to be expected in summer 2018
→ Update at SAC workshops
12th-13th Sept. @ EUROSUN, Rapperswil
3rd Oct. @ ISEC, Graz

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# Thank you for your attention!

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Task 53