Introduction

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

Component ↔ System ↔ Building

Conventional chiller and gas heating system  Solar heating and cooling component

Building Heating, Cooling & Hot Water System
Introduction

\[ SPF_{th} = \frac{\sum Q_{out}}{\sum Q_{in}} \]

\[ SPF_{el} = \frac{\sum Q_{out}}{\sum Q_{el, in}} \]

\[ PER = \frac{\sum Q_{out}}{\sum \left( \frac{Q_{el, in}}{\varepsilon_{el}} + \frac{Q_{in}}{\varepsilon_{in}} \right)} \]

\[ f_{sav, PER} = 1 - \frac{PER_{ref}}{PER_{i}} \]

\[ \Delta SPF_{SHC} = \frac{Q_{WD, system} + Q_{HD, system} + Q_{loss} - Q_{HB, system} \times (1 - \%H.B.C) + Q_{HP, system}}{\frac{Q_{HB, system} \times \%H.B.C \times \varepsilon_{el}}{\varepsilon_{EC} \times \eta_{b}} + E_{aux, SHC}} \]

\[ SPF_{equ} = \frac{PER_{NRE}}{\varepsilon_{el}} \]

\[ PER_{NRE, ref} = \frac{\sum Q_{out}}{\sum \left( \frac{Q_{out, heat} + Q_{loss, ref}}{\varepsilon_{in} \times \eta_{HB, ref}} + \frac{Q_{out, cold}}{SPF_{C, ref} \times \varepsilon_{el}} + \frac{Q_{el, ref}}{\varepsilon_{el}} \right)} \]

\[ CAP_{solar} = \frac{\left( \frac{Q_{CD, system} + Q_{loss} - Q_{CB, system}}{EER_{ref} \times f (kW)} - \frac{Q_{HB, system} \times \%H.B.C \times \varepsilon_{el}}{\varepsilon_{EC} \eta_{b}} + \Delta E_{aux, C} \right)}{t} \]
Subtask C: ASSESSMENT and TOOLS

General Objectives

• Update / merging of **useful tools** for design & assessment
• Establishing / adapting of **assessment method** and benchmarking (incl. reference system in different locations)
• Create **common data base** for technical, environmental and economic assessment for the participating countries
• Analyses of **Subtask B results and benchmarking** against reference systems and different renewable and solar solutions
• **Sensitivity analyses** of high influencing parameters on the technical / economic / environmental assessment
Task 53 - Tool

Assessment in a common comparable format

- Energetic, ecological, economic, evaluation
  → T53E4 Assessment Tool
- Assessment based on (monthly) energy balances
- Measured or simulated (sub-) systems
- **Data base** for technical and economic assessment
# Systems & components

- Technical and economic data available for

<table>
<thead>
<tr>
<th>Components</th>
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</table>
| **Solar thermal collectors (SC)** | • Flat plate collector  
• Evacuated tube collector |
| **Photovoltaic (PV)** | • Photovoltaic panels  
• BOS (balance of system) -components |
| **Heating (H1, H2)** | • Natural gas boiler  
• Pellets boiler  
• Heat pump (not reversible/reversible)  
• Absorption heat pump (not reversible/reversible)  
• Combined heat & power plant  
• District heating (as heat source) |
| **Cooling (C1, C2)** | • Air-cooled vapour compression chiller  
• Water-cooled vapour compression chiller  
• Absorption chiller (single & double effect)  
• Adsorption chiller  
• District cooling (as cold source) |
| **Storage (HS, CS, BS)** | • Hot storage  
• Cold storage  
• Battery storage |
| **Heat rejection (HX)** | • Wet cooling tower  
• Dry cooling tower  
• Hybrid cooling tower |
Boundary - solar cooling
## Primary energy

- Annual non-renewable primary energy conversion factors

<table>
<thead>
<tr>
<th></th>
<th>T53 standard</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary energy factor for electricity $\varepsilon_{el}$</td>
<td>0.40</td>
<td>kWh$<em>{el}$/kWh$</em>{pr}$</td>
</tr>
<tr>
<td>CO$_2$ factor for electricity</td>
<td>0.55</td>
<td>kg/kWh$_{el}$</td>
</tr>
<tr>
<td>Efficiency of the natural gas boiler $\eta_{HB}$</td>
<td>0.9</td>
<td>-</td>
</tr>
<tr>
<td>Primary energy factor for natural gas $\varepsilon_{EC}$</td>
<td>0.9</td>
<td>kWh$<em>{el}$/kWh$</em>{pr}$</td>
</tr>
<tr>
<td>CO$_2$ factor for natural gas</td>
<td>0.26</td>
<td>kg/kWh$_{el}$</td>
</tr>
<tr>
<td>Efficiency of the pellets boiler $\eta_{HB}$</td>
<td>0.86</td>
<td>-</td>
</tr>
<tr>
<td>Primary energy factor for pellets $\varepsilon_{EC}$</td>
<td>10</td>
<td>kWh$<em>{el}$/kWh$</em>{pr}$</td>
</tr>
<tr>
<td>CO$_2$ factor for pellets</td>
<td>0.05</td>
<td>kg/kWh$_{el}$</td>
</tr>
</tbody>
</table>

→ Specific values country wise
Electricity

• Monthly T53 standard values for non-renewable primary energy and CO₂ emissions

• Example for Austria, based 2015
Technical key figures (I)

- Non-renewable primary energy ratio ($\text{PER}_{\text{NRE}}$)
  - Similar to SPF but energy input ($Q_{\text{in}}$) converted in non-renewable primary energy
  - e.g. electricity: $\varepsilon_{el} = 0.4 \text{kWh}_{\text{Use}}/\text{kWh}_{\text{PE.NRE}}$, natural gas: $\varepsilon_{in} = 0.9 \text{kWh}_{\text{Use}}/\text{kWh}_{\text{PE.NRE}}$

\[
\text{PER}_{\text{NRE}} = \frac{\sum Q_{\text{out}}}{\sum (\frac{Q_{el.in}}{\varepsilon_{el}} + \frac{Q_{in}}{\varepsilon_{in}})}
\]

- $\text{PER}_{\text{NRE}}$ calculation for
  - SHC system
  - Standardized Task 53 reference system (Ref.)
    - Natural gas boiler & air-cooled vapor compression chiller

→ Non-renewable primary energy savings ($f_{\text{sav.PER-NRE}}$)

\[
f_{\text{sav.PER-NRE}} = 1 - \frac{\text{PER}_{\text{NRE.ref}}}{\text{PER}_{\text{NRE.SHC}}}
\]
Technical key figures (II)

\[ SPF_{equ} = SPF \text{ in electrical equivalent units,} \]

PER converted into a comparable magnitude for vapour compression chiller / heat pump

\[
SPF_{equ} = \frac{PER_{\text{NRE}}}{\varepsilon_{el}} = \frac{\sum Q_{out}}{\sum \left( Q_{el,in} + \frac{Q_{in}}{\varepsilon_{in}} \cdot \varepsilon_{el} \right)}
\]

to compare the overall heating / cooling system with a vapour compression chiller / heat pump
Economic key figures

- **Annuity method** & input values based on EN-standards and **experiences** of IEA Task experts

- **Standardized data base** to calculate annualized costs
  - Investment, replacement & residual value
  - Maintenance & service,
  - Operational costs (energy, water)

- Calculation of levelized cost of energy for
  - Solar Heating and Cooling
  - Standardized Task 53 Reference

\[ \text{CostRatio (CR)} = \frac{\text{annualized costs SHC}}{\text{annualized costs REF}} \]
Investment costs

• For all main components
  • Size dependent incl. economy of scale
  • E.g. vapour compression / absorption chiller
Life cycle analyses (I)

- Initial investment
- Running costs (energy, maintenance, …)
- Re-investment
- Amortization
Life cycle analyses (II)

→ COST RATIO

...difference in life time...
IEA SHC Task 53

- Assessment of 28 SHC configurations
  - 17 examples (incl. simulation: 28 configurations)
  - System & subsystem analysis
  - Trend analysis
  - Sensitivity analysis

Technology
- PV; 12; 43%
- ST+PV; 3; 11%
- ST; 7; 25%
- ST+HP; 6; 21%

Demand
- DHW+SH+C; 13; 46%
- DHW; 1; 4%
- DHW+C; 3; 11%
- SH+C; 4; 14%
- C; 3; 11%
Result

Innovative examples!

→ cost and NRE savings
Sensitivity analyses

- Influence of chosen boundaries
  - Investment, electricity, natural gas price
  - Auxiliary demand, energy output,
  - Non-renewable primary energy conversion factors

-> Influence shown on trends
Summary

• Assessment
  • Based on a common comparable system view
  • including detailed sub-system knowledge is needed
  • Focus on
    • Non-renewable primary energy (fsav.NRE)
    • Cost Ratio
  → Adaptation of methods and data base in Task 65

• Outlook on Task 65 contributions
  • Comparison of different technologies (ST ACM, Hybrid, PV+VCC)
  • For different profiles & climates (public: hotel, hospitals, etc., residential)
  • With sensitivity analyses
  • …
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