Smart energy systems applied at urban level: the case of the municipality of Bressanone-Brixen
Introduction  Case study - Bressanone

- North of Italy. Region: Trentino-Alto Adige
- 20,000 inhabitants
- Alpine climate
- Joined Covenant of Mayors in 2013
- Sustainable Energy Action Plan (SEAP) developed by EURAC

Study purpose

• Analyse current energy system including district heating network
• Study solutions to increase overall system efficiency
• Develop future scenarios with high PV penetration
• Compare different peak shaving methods: electric vs thermal storage
• Best technology mix in terms of emissions and annual costs
The municipality is handled as a single node

The use of grid balances production surplus and deficits, (hence reducing the need for storage in the future). However, there might be the situation in which the closest regions are in the same condition, with high photovoltaics (PV) electricity production during the central hours of the day.

In order to achieve the objectives of the covenant of mayors the single municipalities have to carry out future scenarios studies and practical interventions to be more independent from the import and from the grid.

Storage systems required
Methodology

Reference scenario – electricity baseline

Control logic / priorities:
- The technologies with higher priority are those with a higher efficiency.
Methodology: Reference scenario – heat baseline

District heating

- CHP
  - P_el=9000 kW
  - P_th=21551 kW
  - 54.78 GWh/year

- Storage
  - 35.81 GWh/year
  - Network losses 14.4%
  - 0 GWh/year

- HPs
  - 0 GWh/year

- Boilers
  - 30.25 GWh/year

- DH network
  - 72.7 GWh/year

- Users
  - 81.2 GWh/year

Individual heating

- HPs
  - COP = 3
  - 3.2 GWh/year

- Oil Boiler
  - η = 0.85
  - 57.0 GWh/year

- LPG Boiler
  - η = 0.9
  - 5.4 GWh/year

- Biomass Boiler
  - η = 0.8
  - 12.9 GWh/year

- Solar thermal
  - 2.7 GWh/year

Control logic / priorities thermal storage:
- (loading) by increasing the use of HP in situations with electricity export
- (unloading) by reducing the use of heat pumps in situations of PP

Control logic / priorities DH:
- Solar thermal
- CHP
- Heat Pumps
- Peak load Boilers
Methodology

Reference scenario - energyPLAN

Reference scenario created and validated with energyPLAN

(112.5 kt CO₂ emissions SEAP document)
## Results

**PV potential and PV scenario**

<table>
<thead>
<tr>
<th>The PV Potential of South Tyrol: An Intelligent Use of Space</th>
</tr>
</thead>
<tbody>
<tr>
<td>(D. Moser, D. Vettorato, R. Vaccaro, M. Del Buono, and W. Sparber)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Solar tirol project</th>
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<tbody>
<tr>
<td>55 MW</td>
</tr>
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</table>

**PV potential**

<table>
<thead>
<tr>
<th>Brixen</th>
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<tbody>
<tr>
<td>53 MW</td>
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</tbody>
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**Graphs**

- **Left graph**: Renewable integration function $R(\gamma)$
- **Right graph**: Total annual costs vs. CO2 emissions [kt]

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**References**

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Results

The model

Why a different model?
To study the impact of additional parameters:
- Initial content of thermal storage ($I_{STO,DH}$)
- Thermal storage losses ($L_{STO,DH}$)
- Charging and discharging power of the thermal storage ($P_{STO,DH}$)

Model is composed by three blocks:

- Thermal demand analysis
- Excess electricity analysis
- Electricity demand analysis
Results

The model

Excess electricity analysis

<table>
<thead>
<tr>
<th>Priority:</th>
</tr>
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<tbody>
<tr>
<td>1) Heat pump</td>
</tr>
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</table>

Electricity demand analysis

<table>
<thead>
<tr>
<th>Priority:</th>
</tr>
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<tbody>
<tr>
<td>1) PV</td>
</tr>
<tr>
<td>2) Grid</td>
</tr>
</tbody>
</table>

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Results

The deterministic approach

- $C_{PV}$ is the only parameter that varies. The value of $C_{HPS}$, $C_{STO}$, $C_{p}$, $C_{t}$, $C_{STO,el}$ depends on the value of the $EEP_{PV}$ excess electricity production.
- The three scenarios are 3 extreme cases that don’t consider neither a different type of variables’ sizing nor hybrid solution with integration of electric and thermal storage.

<table>
<thead>
<tr>
<th>$C_{PV}$</th>
<th>$EEP_{PV}$ [GWh/year]</th>
<th>$C_{p}$ [kW]</th>
<th>$C_{t}$ [kw]</th>
<th>$C_{STO,el}$ [kWh]</th>
<th>$C_{HPS}$ [kW]</th>
<th>$C_{STO,DH}$ [KWh]</th>
<th>$V_{STO,DH}$ [m$^3$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
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<td>0</td>
<td>0</td>
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<tr>
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<td>17512</td>
<td>10991626</td>
<td>175866</td>
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<table>
<thead>
<tr>
<th>Electric storage</th>
<th>Thermal storage</th>
</tr>
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<tbody>
<tr>
<td>$C_{PV}$</td>
<td>$EEP_{PV}$ [GWh/year]</td>
</tr>
</tbody>
</table>
Results

The optimization approach

\[ \text{Surplus} = \text{Content}_{\text{storage, available}}(8784) - \text{Content}_{\text{storage, available}}(0) \]

Constraint: \[ 0 \leq \text{Surplus} \leq \frac{C_{STO}}{100} \]
Results

The optimization approach

![Graph showing total annual costs vs. CO₂ emissions with various scenarios indicated.]
Results

The optimization approach

P1  \( C_{PV} = 33000 \text{ kW} \)

\( C_{HPs} = 3000 \text{ kW} \)

\( C_{STO} = 750000 \text{ kWh} \)

\( I_{STO,DH} = 0 \text{ kWh} \)
Results

The optimization approach: P1

Spring week

Summer week

electricity demand

electricity demand

Storage content

Storage content

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Conclusions

• The case study of Bressanone-Brixen has been analysed starting from the creation of the **reference scenario** in energyPLAN.

• A **model** to describe the **interactions** between **PV**, **large heat pumps** and **seasonal thermal storage** has been developed.

• A **deterministic approach** has been used to **compare** different **peak shaving solutions**: thermal (analysed with the created model) and electric storage (inspected with energyPLAN). The two scenarios have been created varying only the installed capacity of PV and calculating the size of the others variables in order to cover the entire excess electricity production without exchanges with the grid. For this reason the two scenarios describe the **extreme cases**.

• A **Multi Objective Evolutionary Algorithm** has been used to study the best intermediate solutions of the “**PV + thermal storage**” scenario, finding out the pareto front of best technology mix.

• A solution on the pareto front (P1) has been chosen as solution that permits to save more annual CO₂ emissions without increasing the annual costs of the energy system compared to the reference scenario.

• Further studies could focus on the analysis of the best hybrid solutions between electric and thermal storage systems.
Thanks for the attention!

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