Data and process analysis for energy systems

Haibing Shao (UFZ), Thomas Nagel (UFZ), Markus Lauer (DBFZ), Detlev Heinemann (DBFZ), Guido Blöcher (GFZ), Veit Hagenmezer (KIT)
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• **What existing data is telling us?**
  Distribution of Renewable Energy Demand and Supply over Germany

• **Data used in process understanding**
  Optimization of Ground Source Heat Pump Systems and also its environmental impact

• **Simulated prognosis data showing the environmental impact**
  Modelling study on the Aquifer Thermal Energy Storage
Germany’s power demand distribution
Same dataset treated with statistics (Gi-Bin function)

The total RES-E supply distribution treated with statistics

Fullfillment of the Smart Renewable Power Provision (SREPP) Indicator

Energy transition monitoring

Input data
- REA weather data
- RE-plant data sets
- Feed-in RE-plants
- Power consumption

Energy transition maps
Spatio-temporal resolved

Modelling
- Wind to power generation
- Photovoltaic generation
- Biomass power generation
- Consumption modelling

Outreach
- Status of the energy transition
- Fulfillment of climate objectives
- Trend & development of RE

Target groups
- Federal states & communities
- Academia & industry
- Governance

Year: 1990

(In preparation for 2018) M. Eichhorn, M. Scheftelowitz, M. Reichmuth, Ch. Lorenz, K. Louca, R. Keuneke, M. Bauschmann, J. Ponitka, D. Thrän, Spatial distribution of wind turbines, photovoltaic field systems, bioenergy- and river hydro power plants in Germany, DATA MDPI

Energy transition is also the heat transition, and we are still largely missing the target in this sector.

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Quelle: Arbeitsgemeinschaft Energiebilanzen: Auswertungstabelle zur Energiebilanz der Bundesrepublik Deutschland 1990-2011, Stand 09/2012
Development of heat consumption from Renewables in Germany

Endenergieverbrauch Wärme in Milliarden Kilowattstunden

- biogene Festbrennstoffe*
- biogene gasförmige Brennstoffe***
- biogene flüssige Brennstoffe**
- Solarthermie
- tiefe Geothermie
- oberflächennahe Geothermie, Umweltwärme

* biogener Anteil des Abfalls

Years:
- 1990: 32,4
- 1995: 32,8
- 2000: 58,1
- 2001: 65,1
- 2002: 64,4
- 2003: 78,9
- 2004: 84,6
- 2005: 89,7
- 2006: 94,0
- 2007: 101,4
- 2008: 96,6
- 2009: 111,8
- 2010: 130,4
- 2011: 127,9
- 2012: 132,5
- 2013: 141,8
- 2014: 130,9
Integration of Data in the numerical model for the process analysis

- Monitoring and Modelling
- Data Driven Model Development
- Model Validation and Parameter Calibration
- Visualization and Analysis of Modelling Result
- Prognosis of System Performance and Environmental Impact
- Mechanistic Understanding of underlying processes
Process analysis on Ground Source Heat Pump (GSHP) systems – from process understanding to performance optimization

Main findings:

- Energy utilized by BHE coupled GSHP is coming from the sensible heat stored in the soil surrounding the BHE.
- The recharge of shallow geothermal energy is mainly from lateral thermal conduction.
- The efficiency of the heat pump system is dependent on the outflow temperature of circulating fluid from BHE. It will deteriorate if the BHE is over-loaded.

Environmental Impact: Case study near Köln

- Individual, property based shallow geothermal development and system installation
- No detailed hydro(geological) exploration (considering installation costs >450000 EUR)
- Aim: Investigation of the potential impact of the intensive thermal use of the shallow subsurface on groundwater temperatures

<table>
<thead>
<tr>
<th>Total systems installed</th>
<th>48 BHE-Systems (+ 3 open systems)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BHE installed</td>
<td>305</td>
</tr>
<tr>
<td>Total installation length [m]</td>
<td>11,174</td>
</tr>
<tr>
<td>Heat demand [kW]</td>
<td>452</td>
</tr>
<tr>
<td>Installation period</td>
<td>2010-2013</td>
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</tbody>
</table>
Environmental Impact: Case study near Köln

Intensive thermal use of the shallow subsurface impacts temperature regime!

Measurement data provided by: Thomas Vienken (UFZ)
Aquifer Thermal Energy Storage (ATES) can contribute significantly to heat transition

Installation
- „warm“ and „cold“ well
- Production and injection on both sides
- Each well need a submersible pump
- Bidirectional flow
- Subsurface open system

Operation Method
- Periodical charging and discharging
- Potential use of cold and heat storage
- Seasonal operation
- Capacity of storage (GWh)
ATES project in Berlin

Key activities
- Reliable and environmental friendly storage operation → Protection of ground water and geochemical interaction,…
- Energy supply of urban areas at high efficiency
- Development of methods for planning energy supply in urban areas based on ATES

Methods (general)
- Modelling and simulation
- Laboratory experiments and pilot plant station
- Scientific drill site and in situ experiments
ATES project in Berlin
Thermal-Hydraulic coupled simulation of 5 years operation

Simulation result provided by: Guido Blötcher (GFZ)
ATES project in Berlin
The numerical simulation tells us:

- Temperature of the warm and cold well varies between 17 dC and 82 dC.
- Area between temperatures represents charged (orange) and discharged (blue) energy.
- Storage capacity can reach ca. 700 MWh and maximum load capacity can be 200 KW.
- Maximum Flow rate is 5 m³/h
- Efficiency of ATES Berlin increases with each storage cycle
Summary and Outlook

• **What existing data is telling us?**
  The current renewable energy supply is not driven by the demand, but largely by the economics. Therefore it is not geographically produced at the most needed places.

• **Data used in process understanding**
  The amount of sustainably extractable shallow geothermal energy is not limited. The recharge of subsurface is slow and storage is needed to maintain a stable temperature level.

• **Simulated prognosis data showing us:**
  Energy system has very strong link and impact across different sectors. Interactions between social, economical and environmental effects have to be planned in systematic manner.