A Danish Heat Atlas, or how existing public databases can be used for energy planning

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Major challenges towards zero-carbon energy systems

- Constrained renewable energy sources necessitate severe energy savings; at least 50%.
- Fluctuating renewable energy sources require flexible energy systems, e.g., by using district heat.
- The scale of some renewable energy sources like geothermal heat requires extensive supply systems.
- The spatial nature of all zero-carbon energy system elements requires location-specific solutions.
Methodological considerations

- We must be able to:
  - Quantify energy saving potentials and their costs
  - Specify possible supply strategies
  - Put figures on renewable energy sources

...for all buildings, on a large scale!
Small scale, large scale
and the mapping of sustainable energy systems

Large scale mapping describes the details, whereas small scales aggregate information.
Large scale mapping of energy system opportunities

- If using national statistics and generic modelling, local opportunities and constraints will not show up:
  - Where can we build district heating systems?
  - How much of end-use demand can be saved?
  - What is the level of sustainable use of renewable energy?
  - Who will invest in and own these things?

- This is a major setback if these are to be the main components of future energy systems.

- Large scale mapping addresses small, distributed opportunities and solutions
Considerations for a heat atlas

- Spatial distribution (postal address level)
- Calculated heat demand (room heat + hot water)
- Calculated annual heating costs
- Calculated saving potentials (20% and 50% scenarios)
- Modelled possibilities to connect to district heating
- Allow for enrichment with other data: demographics, socio‐economics, renewable energy sources by availability and distance etc.
Preconditions

- Things must be mappable!
- Unique address codes and their coordinates
- Extensive public building registers
- Empirical models on heat demand, building performance improvements, costs etc.
- Spatial overlay and cost-supply analysis
The Danish buildings and dwellings register (BBR)

- Describes each building unit individually
- Originally implemented to raise property tax
- Since the late 1970s used to map heat demand
- During the 1990s developed to a coherent energy- and environmental database
- Open access for owners, research and businesses
- Preconditions for having such a database:
  - A data security act, a system of unique addresses, and a decentralised data flow in public administration
Registration of buildings in the BBR

"The real world"

Administration

Register

Building

Unit

Property

Unit address

House no., floor, side

Buildg. address

Road, house no., letter

Property number

Land survey reg.

Land survey code

Calculated address coordinates
BBR data by address point
Calculating heat demand using BBR data

- Empirical heat demand model by SBi
- Register data (BBR) are supplemented by energy audits
- Model calculates the specific heat loss (kWh/m²) by building type composed of:
  - Use (dwellings, offices etc)
  - Age (7 age classes)
- Model includes scenarios for energy saving potentials and costs.
Putting things on a map

• Geographical Information Systems (GIS) allow for more than "nice maps" of subjects.

• We use GIS as a tool to map and quantify
  – Amounts and costs by location
  – Costs induced by distances
  – Access to amounts by spatial distribution
  – Exclusion of areas and area competition
A heat atlas of Denmark

• A heat atlas maps:
  – Demand and savings
  – Supply options
  – Energy sources
  – Costs and investment

• It differentiates between the technical, economical and social potentials by mapping the energy system in the *context* of social conditions

• The spatial unit is the single address (2.5 Mio buildings)

• The data sources are extensive public registers and empirical data.
Examples of heat atlases used in research

• National studies:
  – Heat Plan Denmark, 2008 (AAU and Rambøll)
  – Efficient district heating in the future energy system, 2009 (EA Energy Analysis)
  – Health effects of energy systems, 2009 - 2012 (Ph.D. project, DTU Risø)
  – Studies on natural gas conversion, 2011 (Energinet.DK, national TSO)

• Regional studies:
  – Long-term heat plan for Greater Copenhagen, 2009 (EA Energy Analyses)
  – Mid-Jutland 2025 perspective plan (PlanEnergi, 2011)
  – The FlexEnergy project: 5 municipalities in Northern Jutland

• Municipal studies:
  – Frederikshavn, Brønderslev, Aalborg, Jammerbugt, Thisted, Morsø, Viborg, Mariagerfjord, Hedensted, Herning, Samsø, Ballerup...
Applications

- Mapping heat demand and supply
- Quantifying heat savings and investments
- Putting socio-economics of energy on the map
- Converting individual heat supply to district heat
- Mapping potentials and costs of renewable energy
- Anchoring systems analysis in the real world
- Crowd-sourced energy planning
Mapping heat saving potentials

- Using detailed physical building data
- Using authoritative heat saving models
- Challenges exist in terms of spatial disaggregation and data errors
The potential for achieving heat savings is not the same everywhere, and it comes at different costs!
Combining potential, costs and the geography of heat supply

Locating the “poor” building stock

- Positive correlation between wealth and energy performance of buildings
- Urban district heating areas score well due to lower heat prices
- The remote areas in the NW and SE are vulnerable and probably beyond scope for extensive energy efficiency programmes
- Yet they are attractive and part of the cultural landscape.
Equity and the ability to invest in energy savings

- The same picture here.
- Many of the most well-off areas have access to reasonably priced district heating, while poorer areas are reliant on expensive sources such as oil boilers.
- Ironically, low heating costs decrease feasibility of energy improvements, reducing the potentials particularly in wealthy cities.
Mapping municipal heat supply
### Production of a decision base for heat planning

**Nettoopvarmningsbehov, ingen besparelser [MWh/år]**

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<th>Forsyning</th>
<th>RP_omraade</th>
<th>Fjernvarme</th>
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<th>Halm</th>
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Spatial analyses of expanding district heating

- How much heat demand is within reach?
- Conversion of natural gas areas
- Connection to DH "on the fly"

Datakilder: MidtNord 2009 og KMS, G24-98
Spatially coherent data bases for systems analysis

To know the location of demand relative to supply, and to assess potentials by costs related to distance etc. is crucial for coherence between national aims and local means.
Mapping solar energy resources and costs

Solar radiation, conversion technologies and existing energy supply of buildings are mapped using elevation data and the heat atlas.
Mapping CO$_2$-footprints

CO$_2$-emissions related to heat supply calculated for Copenhagen

- The heat atlas allows for large scale maps of emissions and specific measures to reduce them as well as the associated costs.
Important messages

- Strategic energy planning requires all aspects mapped.
- Comprehensive and inconvenient tasks like substantial energy savings necessitate large scale data.
- Public registers and geo-data form the basis of information, and their value is overwhelming.
- They will gradually be improved and supplemented.
- Awareness of data availability and the power of data analysis is just being created.