Heat Roadmap Europe: Methodologies for Spatial Analysis in Demand and Resource Mapping

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Background - General

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 695989.

DH Urban Res. & Service
Sector 2010, by EU27 MS

Heat generation

Heat distribution

Heat use

www.heatroadmap.eu

Sweden
Estonia
Lithuania
Denmark
Finland
Latvia
Slovak Republic
Poland
Bulgaria
Austria
Czech Republic
Romania
Slovenia
Hungary
EU27
Germany
France
Netherlands
Luxembourg
Greece
United Kingdom
Belgium
Portugal
Italy
Spain
Malta
Ireland
Cyprus
Background - General

Primary Energy Supply: Natural energy flows (solar irradiation, geothermal heat, kinetic energy and potential energy), Fuels (chemical energy) and Nuclear energy.

Total Primary Energy Supply

Emissions

Energy sector:
Central energy conversion to electricity, heat, cold and refined fuels.

Heat losses

Distribution of electricity, district heat and district cold.

Heat recycling

Final energy consumption

Emissions

All use sectors:
Local energy conversion to electricity, heat, cold and power in local power plants, boilers, heat pumps, chillers and vehicle engines.

Heat losses

Heat recycling

Heat losses

All use sectors: Final energy use within the industrial, transport, residential, service and agricultural sectors.


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Background - General

Background - Conceptual

• Traditional energy systems
  – High energy density fossil fuels
  – Flexibility by fuel properties
  – Carbon dioxide emissions
  – Low conversion efficiencies
  – Unutilised energy/heat losses

• Smart energy systems
  – Renewable energy sources!
  – Flexibility by system integration
  – Distinction: Urban/rural
  – CHP/Heat pumps/electro fuels
  – Recovery of energy/heat losses

Background - Conceptual

- **Energy storages**
  - Access upon demand (flexibility) is a key property of any energy system!
  - Smart energy systems provide flexibility by **increased transferability** between main infrastructures (power grids, gas networks, thermal networks)
  - Gas and power infrastructures are **continental**!
  - Heat infrastructures are **local**!
  - Feasible heat distribution in **cities**
  - Cities and urban zones have **lead roles to play in energy**

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Main methodological approach

- Heat Roadmap Europe

- European studies combining mapping of local conditions with energy system modelling to identify, quantify, and assess cost- and resource efficient solutions for the

  - **Opportunities for district heating, excess heat recovery, and renewable heat sources are present on local scales!**

  - **How to include local conditions in energy system modeling?**

  - **Spatial mapping and use of GIS!**
Series of studies

- **HRE1** (2012) – The role of district heating in decarbonising the EU energy system
  - Benchmark: Energy Roadmap 2050
- **HRE2** (2013) – The balance between heat savings and heat supply at an EU level
  - HRE2 (2013) – The balance between heat savings and heat supply at an EU level
    - **Benchmark: Energy Roadmap 2050**
- **HRE3, Stratego** (2014-2016)
  - Heating and cooling strategies for 5 MS
- **HRE4** (2016-2018) – Current project!
  - Heating and cooling strategies for...
Volumes and locations…

• **Demands**
  • Heat demands for SH and DHW: Residential and service sectors
  • Heat demand densities by square kilometre resolution
  • Cool demands: Service sector

• **Resources**
  • Excess heat from energy and industry sectors
  • Excess heat from Waste-to-Energy facilities
  • Potential assessments of renewable heat

• **District heating and cooling systems**
  • The Halmstad University DHC database (HUDHC)

• **Regional heat balances**
  • Strategic heat synergy regions for all of EU27

• **Demand and Resource Mapping**

*Transform available data and statistics to new information by developing novel concepts and theory!*
Demand and Resource Mapping

- Regional heat balances
Demand and Resource Mapping

- Regional heat balances

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Demand and Resource Mapping

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Heat demand by NUTS3 region
Adjusted by EHI [PJ/a]
- < 1
- 1 - 5
- 5 - 10
- 10 - 25
- 25 - 50
- > 50
- Non EU27

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Demand and Resource Mapping

- Key energy modelling outputs
- End use building heat demands in 2050 (HRE2)
  - EU-EE: 5.7 EJ (high energy savings scenario)
  - HRE-EE: 9.5 EJ
Demand and Resource Mapping

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  - Costs for heating and cooling of buildings
    - Avoids most expensive end use efficiency investments
    - ~15% lower total heat sector costs
Demand and Resource Mapping

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  - **Total energy system costs**
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Demand and Resource Mapping

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Energy efficiency measures introduced on **both supply and demand sides** of the energy system results in equal decarbonisation as heat savings alone - but at lower total energy system costs!
Demand and Resource Mapping

- European Waste-to-Energy plants
  - HRE WTE list v5!
  - Oct, 2013 (Ref. year 2010)
  - **432** facilities in operation
  - Capacity: ~86 Mt/a

![Graph showing Incinerated and landfill volumes with EU28 Waste-to-Energy facilities by capacity (Mt/a)](image)
Demand and Resource Mapping

- European Waste-to-Energy plants
- Investigating model projections for future EU MSW generation
  - EU ref. model (Sc. 4), 2030: **294 Mt treatment** (308 Mt generation, 95.6%)
  - Linear interpolation:
    - 70% recycling: **206 Mt**
    - 5% landfilling: ~**15 Mt**

![Graph showing waste management projections from 1995 to 2030]
Demand and Resource Mapping

- European Waste-to-Energy plants
- Investigating model projections for future EU MSW generation
  - EU ref. model (Sc. 4), 2030: 294 Mt treatment (308 Mt generation, 95.6%)
  - Linear interpolation:
    - 70% recycling: 206 Mt
    - 5% landfilling: ~15 Mt
    - 25% Incineration: ~74 Mt

HRE WTE List v5: 86 Mt EU27 capacity!
MSW incineration in 2010: 58-65 Mt
MSW Heat gen. in 2010: ~16 Mt (159 PJ)

η_{heat} → Heat recovery capacity!
Demand and Resource Mapping

- European Waste-to-Energy plants
- Spatial analysis
  - NUTS2 waste data (Eurostat)
  - Regional developments
  - Population and urbanisation trends
Demand and Resource Mapping

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- Spatial analysis
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  - Regional developments
  - Population and urbanisation trends
- Distribution of R1 capacity
  - Exports/Imports of waste?
  - Role of district heating systems?
Demand and Resource Mapping

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- Spatial analysis
  - NUTS2 waste data (Eurostat)
  - Regional developments
  - Population and urbanisation trends
- Distribution of R1 capacity
  - Exports/Imports of waste?
  - Role of district heating systems?

District heating systems – key infrastructures for higher heat recovery efficiencies in WTE!

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Demand and Resource Mapping

- Heat demand density
  - Main input to assess DHC investment costs
  - Cost-supply curves

![Diagram](image)

Source: Stratego, WP2, Background report 6, 2016
Demand and Resource Mapping

- **Heat demand density**
  - Main input to assess DHC investment costs
  - Prospective DH systems/areas

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Demand and Resource Mapping

• Cooling demands
  • Specific space cooling demands in service sectors
  • Estimated from measured district cooling deliveries and ECI for 80 locations
  • Main hurdle: Electricity for cooling purposes generally not specified

Figure 6. The average specific cooling demands in kWh/m² for service sector buildings for various locations in Europe. The map has been generated by using the red average line in Figure 5 together with estimated ECI for 80 different locations according to (Dalin et al., 2005).

Source: Stratego, WP2, Background report 4, 2015
Demand and Resource Mapping

- Cooling demands
  - Specific space cooling demands in service sectors
  - Estimated from measured district cooling deliveries and ECI for 80 locations
  - Main hurdle: Electricity for cooling purposes generally not specified
  - Current cooling demands found to be somewhat lower than other estimations

Assessment of full cooling demand

Source: Stratego, WP2, Background report 4, 2015
Demand and Resource Mapping

- Cooling demands
  - Specific space cooling demands in service sectors
  - Cool demand density by km2
<table>
<thead>
<tr>
<th>Type</th>
<th>Aim</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat demands</td>
<td>Include industrial building and process heat demands (process heat characterised by temperature levels)</td>
<td>Previous HRE studies have targeted residential and service sector buildings only.</td>
</tr>
<tr>
<td>Heat demand density</td>
<td>Increase spatial resolution to hectares</td>
<td>The Pan-European heat atlases from HRE2 and HRE3 are at km2 resolution.</td>
</tr>
<tr>
<td>Cool demands</td>
<td>Profiling service sector cooling demands</td>
<td>In HRE3, service sector cooling demands were assessed indirectly.</td>
</tr>
<tr>
<td>“Real” vs. “Calculated” demands</td>
<td>Assess real demands as if completely met</td>
<td>All previous assessments based on energy statistics (delivered volumes).</td>
</tr>
<tr>
<td>Excess heat activities</td>
<td>Use of latest year emission data (E-PRTR v9) and develop complementary approach based on NACE categories</td>
<td>Data up to 2010 in previous studies will now be replaced by 2013/2014 data. New approach based on association of processes and temperatures to given NACE activity categories.</td>
</tr>
<tr>
<td>Allocation of excess heat to DH systems</td>
<td>Spatial allocation analyses and algorithms to systematically distribute available excess heat to nearby DH systems</td>
<td>Not done systematically before.</td>
</tr>
<tr>
<td>Boundaries of prospective DH areas at different distribution costs</td>
<td>Convert DH system point sources to heat demand density polygons and sum calculated DH distribution costs per area to allow classification by total cost levels</td>
<td>In PETA3, prospective DH areas constitute the sum of in-polygon heat demands, but there is no classification by different distribution cost levels.</td>
</tr>
<tr>
<td>Building typologies</td>
<td>Connect building typologies to the mapping to identify e.g. service sector heating and cooling demands</td>
<td>Building typologies have not been part of HRE1-HRE3.</td>
</tr>
<tr>
<td>Renewable resources – Solar thermal and biomass</td>
<td>Identify technical potentials for solar thermal and biomass resources in current and future DH systems</td>
<td>In previous studies, only general potentials have been identified.</td>
</tr>
<tr>
<td>Urban/rural</td>
<td>In model analysis, divide demands and resources by typologies: urban, semi-rural, and rural</td>
<td>Urban and rural and not full quantification for rural assets.</td>
</tr>
<tr>
<td>Future modelling</td>
<td>In HRE4, future scenarios for 2050 will be assessed using transient simulations</td>
<td>Not previously done.</td>
</tr>
</tbody>
</table>
Some comments…

• District heating may realistically contribute to improved energy system efficiency and reduced carbon dioxide emissions in future Europe

• Efficient energy system design
  • Energy efficiency measures on both the demand and the supply side is a more cost-effective and resource-efficient solution
  • Urban/Rural – Structural/Individual – Flexibility/Complexity

Location data and spatial analysis decisive to properly map and model local resources, technologies, and opportunities.
Thank you for your attention!