Integrative Smart City Planning – Energy system modelling for the city of Évora

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Luís Dias, Sofia Simões
Agenda

- **InSmart project**
  - Scope
  - Methods and tools
  - City energy planning structure

- **TIMES_Évora**
  - Sectors
  - Geographic representation
  - Time slices (nothing new there)
  - Zooming in: building sector (residential)
  - Zooming in: transport sector
  - Innovation – water & waste treatment

- Using TIMES_Évora

- Conclusion

- Further steps
European funded project (FP7) [2013-2016] working in partnership towards a sustainable energy future.
Objective

• The InSMART concept brings together cities, scientific and industrial organizations in order to establish and implement a comprehensive methodology for enhancing sustainable planning addressing the current and future city energy needs through an integrative and multidisciplinary planning approach.

• This approach will identify the optimum mix of short, medium and long term measures for a sustainable energy future, addressing the efficiency of energy flows across various city sectors with regards to economic, environmental and social criteria and paving the way towards actual implementation of priority actions.

• Extensive technical expertise and specialized tools and models will be used to create a platform for implementation of the project idea. Each city’s energy system will be analysed, covering all relevant sectors and a comprehensive GIS energy database will be developed. Apart from being a valuable planning tool the GIS database will inform and be linked to the TIMES planning model.

• This model will be used to analyse the cost-optimal mix of measures required to meet sustainable energy targets taking into account exogenous parameters (e.g. environmental targets, city expansion).
Scope

VISION:
Cities sustainable energy future are achievable by:

• bringing together cities, scientific and industrial organizations,
• considering the integration of the components of the city’s energy system,
• selecting cost-effective options from multiple data sources and integrated tools,
• choosing the best social-accepted technologies and measures.

PURPOSE:

• Design comprehensive data-driven methods for enhancing the city’s sustainable planning addressing the current and future city energy needs,
• Implement an integrative planning tool to identify the optimum mix of short, medium and long term measures for a sustainable energy future for the city,
• Address the efficiency of energy flows across all city sectors taking spatial patterns and economic, environmental and social criteria
• Engage city agents to pave the implementation of priority actions.
Methods and tools

Integrative Smart City Planning – Energy system modelling for the city of Évora
City Energy Planning structure

Integrated City Energy Planning framework and major outcomes
TIMES_Évora: Sectors

- Transport
- Buildings
  - Residential
  - Commercial
  - Municipality
- Public services
  - Water system
  - Sewage system
  - Waste system
  - Public lighting
- Supply
- Industry
- Agriculture
Structure of TIMES_Évora

- Geographical representation

➢ Four regions: 3 urban and 1 rural
(Real) Time slices

Based on the quality of information that we had: **Big data** - 32 000 smart meter information on residential electricity consumption at 15 minutes and also PV powerplants electricity production profiles;

32 timeslices
- Seasons: **Summer; Winter** and interseasonal
- **Week days** and **week ends**
- **Day, night** and **peak**

Residential annual electricity consumption profile (urban vs rural dwellings per building age)
Zooming in on the building sector

**389 door-to-door surveys:** with 110 questions (June to September 2014)

- **Building characterization** (location, number of floors, area, construction structures, type of insulation, windows and rooftops)

- **Building occupancy characteristics** (persons per household, level of income, age and gender, level of education)

- **Technologies owned** (space heating and cooling systems and other electric equipment)

<table>
<thead>
<tr>
<th>Typology Number</th>
<th>Type of House</th>
<th>Period of Construction</th>
<th>Type of Roof</th>
<th>Number of Floors</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP1</td>
<td>Detached House</td>
<td>Until 1945</td>
<td>Sloped</td>
<td>1 floor</td>
<td>Rural</td>
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<tr>
<td>TP2</td>
<td>Detached House</td>
<td>1946-1990</td>
<td>Sloped</td>
<td>1/2 floors</td>
<td>Rural/Urban</td>
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<td>TP3</td>
<td>Detached House</td>
<td>After 1991</td>
<td>Sloped</td>
<td>1 floor</td>
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<td>TP4</td>
<td>Semi Detached House</td>
<td>Until 1945</td>
<td>Sloped</td>
<td>1 floor</td>
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<td>TP5</td>
<td>Semi Detached House</td>
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<td>Sloped</td>
<td>1/2 floor</td>
<td>Rural/Urban</td>
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<tr>
<td>TP6</td>
<td>Semi Detached House</td>
<td>After 1991</td>
<td>Sloped</td>
<td>2 floors</td>
<td>Urban</td>
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<td>TP7</td>
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<td>Until 1945</td>
<td>Sloped</td>
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<td>TP8</td>
<td>Terraced House</td>
<td>1946-1990</td>
<td>Sloped</td>
<td>1/2 floors</td>
<td>Rural/Urban</td>
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<td>TP9</td>
<td>Terraced House</td>
<td>1946-1990</td>
<td>Flat</td>
<td>2 floors</td>
<td>Urban</td>
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<td>TP10</td>
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<td>After 1991</td>
<td>Sloped</td>
<td>1/2 floors</td>
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</tbody>
</table>

**Évora building typologies** (based on WP1 and WP2)
Zooming in: building sector

Heating and cooling energy Services Demand Modelling (UoN) (DesignBuilder and Enegyplus)

Building energy performance (kWh/m$^2$/year) per typology and use (e.g. heating, cooling), and energy efficiency measure (e.g. insulation measures, windows change), per spatial unit.
Zooming in: transport sector

460 door-to-door surveys: with 20 questions (June to September 2014)

- Mobility patterns from daily travel
- Number of passenger cars per capita
- Mode share and average trip length information
- Journey purpose splits
Zooming in: Transport sector

Mobility and Energy Demand Modelling (Systra)

- Annual demand (people or vehicles) and distance travelled (pkm or vkm) per vehicle type.
- Annual number of public transport trips per capita
- Demand movements between sectors, by vehicle type.
- Total energy demand by fuel type, vehicle type and sectors.
- Emissions (CO2, NOX, etc.) by fuel type, vehicle type and sector

Mobility demand (origin and destination sectors)

Transport total energy consumption by city sector and origin (MJ)
New(?) – Getting closer to modelling behaviour

Modelling choices of households considering their income
New(?) – water & waste treatment

- Information on energy consumption at waste collection (per type of waste) and treatment phases.

Selected collection waste by city region in 2014

<table>
<thead>
<tr>
<th>City district</th>
<th>Type of material</th>
<th>Quantity (kg)</th>
<th>Quantity (kg/capita)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural</td>
<td>Plastic and metal</td>
<td>46.7</td>
<td>4.2</td>
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<td></td>
<td>Paper</td>
<td>84.8</td>
<td>7.5</td>
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<tr>
<td></td>
<td>Glass</td>
<td>86.3</td>
<td>7.7</td>
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<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>217.8</strong></td>
<td><strong>19.4</strong></td>
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<tr>
<td>Bacelo and Senhora da Saúde</td>
<td>Plastic and metal</td>
<td>122.7</td>
<td>6.7</td>
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<td></td>
<td>Paper</td>
<td>193.4</td>
<td>10.6</td>
</tr>
<tr>
<td></td>
<td>Glass</td>
<td>130.9</td>
<td>7.2</td>
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<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>447.1</strong></td>
<td><strong>24.5</strong></td>
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<tr>
<td>S. Mamede; Sé e S. Pedro and Santo Antão</td>
<td>Plastic and metal</td>
<td>31.3</td>
<td>6.6</td>
</tr>
<tr>
<td></td>
<td>Paper</td>
<td>62.5</td>
<td>13.2</td>
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<tr>
<td></td>
<td>Glass</td>
<td>38.1</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>131.9</strong></td>
<td><strong>27.8</strong></td>
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<tr>
<td>Malagueira and Horta das Figueiras</td>
<td>Plastic and metal</td>
<td>155.6</td>
<td>7.0</td>
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<tr>
<td></td>
<td>Paper</td>
<td>248.5</td>
<td>11.1</td>
</tr>
<tr>
<td></td>
<td>Glass</td>
<td>180.1</td>
<td>8.0</td>
</tr>
<tr>
<td></td>
<td><strong>Total</strong></td>
<td><strong>584.3</strong></td>
<td><strong>26.1</strong></td>
</tr>
</tbody>
</table>

Location of Évora waste treatment facilities
New(?) – water & waste treatment

Water system facilities

Wastewater system facilities
Using the TIMES_Évora

Generate Sustainable Future (2030) Energy (realistic) pathways

- Restrict cars in cities’ historical centers
- Expand individual mobility soft-modes
- Expand the use of electric vehicles (5-10% of vehicles)
- Energy efficiency measures in 70% of households (double glazing, insulation, shading devices)
- Smart-biomass heating systems (60% of fireplaces)
- 50% of households equipped with solar energy (PV and thermal)
- Reduce 30-50% of energy consumption
- Demo on Zero Energy Building

- Improve energy efficiency in waste water treatment plants
- Public lighting with 100% of LEDs
- Reduce 30% waste generation
Next steps

- Multi Criteria Decision Analysis
- City stakeholders validation
- ‘realistic’ action plans to support SEAP
Conclusions

- Challenge on passing the idea of “optimization scenarios” to municipalities teams. More concern to test ideas of specific measures, contrary to the support to define policy.
Zooming in on the building sector

Typology 8 (Sub Typology 82_1)

General
- Location
- Period of construction
- Foot print area
- Average household area
- Frequency

Geometry
- Type of building
- Number of floors
- Number of dwellings
- Height
- Room in the roof

Construction
- Bearing Structure
- Exterior wall type
- Roof type
- Wall insulation
- Glass type
- Window framing

Occupation
- Number of occupants
- Average income
- Occupation schedule
- Type of room heated

Equipment Ownership
- Refrigerators
- Coolers
- Washing machines (clothes, dishes)
- Fireplaces
- Solar thermal panels
- Air Conditioning
- Computers