Flexible spatial distribution of electricity demand for energy system models

Kais Siala*
Also contributed: Fernanda Sanchez, Stephany Paredes, Sergio Huezo
Technical University of Munich
Chair of Renewable and Sustainable Energy Systems

38th IEW @IEA, Paris, June 5, 2019

Supported by:

on the basis of a decision by the German Bundestag
Motivation

- Electricity system optimization models require information about the load, usually in the form of time series.

- Such information is usually available on a country level or on a sub-national level (federal states, counties, or balancing areas of utilities).

- However, this data resolution might not be adequate for research questions where the desired model region is different.

→ Method to distribute the electric load spatially, while preserving the important characteristics for energy system models (total demand, profile shape, peak)?
Proposed workflow

In the general case:

Resolution of input data

High resolution

Desired resolution

GitHub tools:

- tum-ens/
  renewable-timeseries
- tum-ens/
  generate-models/
  generate_load_timeseries
- tum-ens/
  geoclustering
How the tool works

Shapefiles

Initial time series

Global maps: land use and population

param: sectors, sector shares, sector to landuse matrix, typical load profiles

paths: to files saved locally

GitHub:

```
tum-ens/
generate-models/
generate_load_timeseries
```

Time series
Maps of demand distribution
generate_load_timeseries
generate_load_timeseries
Sectorial disaggregation

Typical load profiles

Sector Share

20% Residential
30% Commercial
50% Industrial

Load Time Series

Scaled Sectors Load Profiles

Normalized Sector Load Profiles

Load per sector
**Spatial disaggregation**

**generate_load_timeseries**

- **Raster**

  ![Population Grid](image)

  - **Residential Load**
    - Load per person
    - Load Hours

  ![Graph](image)

  - **Load per person**
    - Load Hours
    - Load
generate_load_timeseries
Spatial disaggregation

Raster

Assumptions

Forest 2
30% Commercial
70% Industrial

Urban 3
80% Commercial
20% Industrial

Sea 3
0% Commercial
0% Agriculture

C. pixels = 0.3 \times 2 + 0.8 \times 3 = 3

Commercial Load per pixel
generate_load_timeseries
Spatial disaggregation

Raster

<table>
<thead>
<tr>
<th>Land use</th>
<th>Forest 2</th>
<th>30% Commercial</th>
<th>70% Industrial</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Urban 3</td>
<td>80% Commercial</td>
<td>20% Industrial</td>
</tr>
<tr>
<td></td>
<td>Sea 3</td>
<td>0% Commercial</td>
<td>0% Agriculture</td>
</tr>
</tbody>
</table>

Commercial Load per pixel

Commercial Load - Forest

Commercial Load - Urban

Forest Load

Industrial Load - Forest

Industrial Load - Urban
Validation

Regions studied:
Norway
- 5 Bidding zones
Sweden
- 4 Bidding zones
Denmark
- 2 Bidding zones
Germany
- 4 Transmission Systems Operator
France
- 12 Administrative areas
Validation
Yearly electricity demand

Relative Error per country
Scenario: Land Use Assumptions vs Population
Validation
Load profile correlation

Correlation comparison

<table>
<thead>
<tr>
<th>Country</th>
<th>Status Quo</th>
<th>Land Use</th>
<th>Assumptions share</th>
<th>Corrected Input</th>
<th>Population 75%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denmark</td>
<td>0.9000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>France</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Germany</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Norway</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Validation
Load profile correlation

Kais Siala, M. Sc. (TUM) | Chair of Renewable and Sustainable Energy Systems
Validation
Peak load

Peak Load Comparison

The order of the comparison scenarios are as follow for each region: Status Quo, Corrected Input, Country Sector Share, Land use Assumptions, Population 75%

The black line in each region represents the real peak value.
Use cases

GitHub: tum-ens/generate-models/generate_load_timeseries

- Generation of load time series for any user-defined regions, particularly cities
- Generation of high resolution electricity demand map
- Application of sector-specific assumptions, so that the total load, its peak and its shape can be varied for the future
Impact of the Choice of Regions on Energy System Models

Kais Siala, Mohammad Youssef Mahfouz
Technical University of Munich, Chair of Renewable and Sustainable Energy Systems

Highlights

• We develop a spatial clustering method for high resolution data.
• We cluster rasters of load density distribution and solar and wind potentials.
• We create energy system models with different shapes for the regions in Europe.
• Comparison with models based on countries show large discrepancies for the future.
• We use the method for a geographic sensitivity analysis to derive robust results.
Accepted publication at ESR
Summary and next steps

Empirical method allows the obtention of electricity time series for any region, provided that the input time series is provided for an overlapping geographic coverage.

Diversity in terms of peak load, profiles and sub-regional total demand, which was not possible with econometric methods.

Correlation factors >90% and relative errors for total demand below 20%.

In the near future: comparison of performance with other disaggregation methods.
Summary and next steps

In the general case:

GitHub tools:
- tum-ens/renewable-timeseries
- tum-ens/generate-models/
- generate_load_timeseries

DIVIDE

- Resolution of input data

CONQUER

- High resolution
- Desired resolution

Desired resolution

Kais Siala, M. Sc. (TUM) | Chair of Renewable and Sustainable Energy Systems
Back up