100% Renewable Energy Scenario for Frankfurt am Main

Gerhard Stryi-Hipp
Coordinator »Smart Energy Cities«
Head of Energy Policy
Fraunhofer Institute for Solar Energy Systems ISE

Future of Cities Forum 2015
World Future Council
Beijing/Tianjin, China, 14/15 Sept 2015
Fraunhofer Institute for Solar Energy Systems ISE

Largest solar research institute in Europe
Director: Prof. Eicke R. Weber
1250 employees (incl. 300 PhD and diploma students)

12 Business Areas
- Silicon Photovoltaics
- III-V and Concentrator Photovoltaics
- Dye, Organic and Novel Solar Cells
- Photovoltaic Modules and Power Platns
- Solar Thermal Technology
- Energy Efficient Buildings
- Storage Technologies
- Hydrogen and Fuel Cell Technology
- Energy Efficient Power Electronics
- Zero-Emission Mobility
- System Integration and Grids incl. »Smart Energy Cities« concepts
- Energy System Analysis
TARGET: Challenges to identify an optimized sustainable energy system of a city or region

Decentralization: mainly local generation to be adapted to local load profiles

⇒ Individual solution necessary for each city and region

Transformation period: 20 to 40 years needed to implement a sustainable energy system, short term solutions can be counterproductive long term

⇒ Short term measures must be in line with long term goals

Complexity: fluctuating generation, storage, demand-side management, combined heat and power, power to heat, power to gas, electric mobility,....

⇒ Temporal dynamic and interdependencies of energy sectors must be taken into account
PROCESS: Transformation strategy

1. Decision on ENERGY TARGETS

2. DATA gathering
   - Demand profiles
   - Supply potential
   - Current and forecasts

3. Simulation of ENERGY SYSTEM SCENARIOS
   - Possible solutions

4. Assessment of ENERGY SYSTEM SCENARIOS

5. Decision on a TARGET ENERGY SYSTEM

6. Development of the ENERGY ROADMAP
   - Implementation plan

7. Monitoring concept development
   - Process and targets

8. Decision on the ENERGY MASTER PLAN

IMPLEMENTATION
- Few lighthouse projects
- Many small projects
- Regular monitoring

Actions by local government: 

Actions by research partner/consultant: 

© Fraunhofer ISE 2015
Local / Regional Energy System based on 100% Renewable Energies

Region
- Wind
- PV
- Hydro
- Solar heat
- Geo thermal
- Bio gas
- Wood

City
- Import/Export
- Electricity grid
- Electricity storage short time
- Heat storage seasonal
- Heat network
- Gas network
- Wood trading
- Gas storage seasonal
- Wood
- Generator

Distributor / Grid operator
- CHP
- HP el
- PtH
- HP gas
- Elyz
- Meth

Consumer
- St
- SH
- Demand type i
- Generation type j
- Location k

Source: Fraunhofer ISE

Heat generators with * are alternative (one generator per building), others are optional.

HP el/gas = Heat pump electric / gas driven, CHP = Combined heat and power, WS = Wood stove, St = storage, SH = Solar heat, Elyz = Elektrolyzer, Meth = Methanation.
Way of proceeding
to develop the roadmap towards a sustainable urban energy system

Characteristics of sustainable urban and regional energy systems:

- High **efficiency**
- High share of **fluctuating** generation
- **Decentral** generation
- High interdependency of electricity, heating, cooling and mobility sectors
- Use of thermal and electrical **stores**

⇒ Temporal highly resolved modelling is needed to find the most cost-effective target energy system

Way of proceeding:

1) **Modelling** target energy system 2050
2) **Roadmap** development by backwarding
New modelling tool

to find the most economic sustainable energy system

Fraunhofer ISE developed the modeling tool »KomMod« to calculate optimized target energy systems for cities and regions

- Temporal highly resolved simulation of electricity, heat/cold, transport

Questions answered:

- Cost-effective design of the energy system to achieve high share on renewable energy sources
- Possible energy system structures
- Necessary capacities on generation, grid and storage
- Necessary energy import/export to the city/region
- Investment and operation costs

Example: Electricity supply and demand of one week in spring
How the city of Frankfurt/Main could be supplied by 95% renewable energy from the region by 2050

The city of Frankfurt/Main aims to be supplied by 100% renewable energy sources (RES) from the region by 2050.

Fraunhofer ISE was asked to investigate, if this is possible and if yes, how.

The energy system (electricity, heating, cooling, local mobility) of Frankfurt/Main was captured, assumptions were made for energy demand and energy scenarios simulated for the target year 2050.

Results

100% RES supply is possible, if the RES potential of the region is used.

95% regional RES is much more economic, due to a lower storage capacity needed.

ENERGY STRATEGY

1. Significant increase of efficiency (in generation, CHP, demand)
2. Maximal use of local renewable energy sources
3. Energy cooperation with region
4. Smart technologies: smart grid, storage, electric vehicles,...
Times series of Frankfurt/Main 2050 modeling results for a typical week in spring and in autumn

1 week in spring

1 week in autumn

Heat supply

Electricity supply
Structure of the energy system Frankfurt/M 2050
Based on 95% renewable energy sources regionally generated

Result of a temporal highly resolved simulation (hourly basis). RES Potentials: All RE and waste potential of the city, 50% of the potential of the region and 11.6% of the potential of the federal state of Hessen from Wind und Biomass (= share of Frankfurt citizens of Hessen)
Frankfurt/M. 2050: 95 % RE from the region
Installed capacities of the energy sources

<table>
<thead>
<tr>
<th>Energy source</th>
<th>Electr.</th>
<th>Heat</th>
<th>Installed Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biogas CHP</td>
<td>4%</td>
<td>4%</td>
<td>81 MW&lt;sub&gt;el&lt;/sub&gt; / 72 MW&lt;sub&gt;th&lt;/sub&gt;</td>
</tr>
<tr>
<td>Solid biomass CHP</td>
<td>10%</td>
<td>9%</td>
<td>124 MW&lt;sub&gt;el&lt;/sub&gt; / 99 MW&lt;sub&gt;th&lt;/sub&gt;</td>
</tr>
<tr>
<td>Solid biomass boiler</td>
<td>-</td>
<td>11%</td>
<td>271 MW&lt;sub&gt;th&lt;/sub&gt;</td>
</tr>
<tr>
<td>Sewage gas CHP</td>
<td>&lt;1%</td>
<td>1%</td>
<td>15 MW&lt;sub&gt;el&lt;/sub&gt; / 19 MW&lt;sub&gt;th&lt;/sub&gt;</td>
</tr>
<tr>
<td>Waste incineration CHP</td>
<td>9%</td>
<td>31%</td>
<td>131 MW&lt;sub&gt;el&lt;/sub&gt; / 392 MW&lt;sub&gt;th&lt;/sub&gt;</td>
</tr>
<tr>
<td>Photovoltaic</td>
<td>32%</td>
<td>-</td>
<td>2003 MWp</td>
</tr>
<tr>
<td>Wind power</td>
<td>34%</td>
<td>-</td>
<td>1624 MW</td>
</tr>
<tr>
<td>Hydro power</td>
<td>&lt;1%</td>
<td>-</td>
<td>6 MW</td>
</tr>
<tr>
<td>Solar heat generation</td>
<td>-</td>
<td>22%</td>
<td>1470 MW</td>
</tr>
<tr>
<td>Heat pumps</td>
<td>-</td>
<td>21%</td>
<td>378 MW</td>
</tr>
<tr>
<td>Import in city area</td>
<td>10%</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Electrical / thermal storage</td>
<td></td>
<td></td>
<td>2036 MW&lt;sub&gt;el&lt;/sub&gt; / 2594 MW&lt;sub&gt;th&lt;/sub&gt;</td>
</tr>
<tr>
<td>Electricity generation costs</td>
<td>12,0 €ct/kWh</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

[CHP = Combined Heat and Power]
Conclusions

- A sustainable energy system is a key pillar of a Smart Cities
- An effective transformation of an urban energy system needs **systematic planning & implemention**
- **New modelling tools** can identify the most cost effective target energy system to achieve the energy target of a city
- **Frankfurt/Main** can meet its energy demand with 95% renewable energy sources from the region, shown by temporal highly resolved modeling
Thank you very much for your attention!

Fraunhofer-Institut für Solare Energiesysteme ISE

Gerhard Stryi-Hipp

gerhard.stryi-hipp@ise.fraunhofer.de

www.ise.fraunhofer.de