Forecasting water demand for the City of Hamburg

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Colloquium of the EAU&3E project at ASTEE Congress in Nantes, 6 June 2013
Outline of presentation

1. Introduction – Water demand in Germany and Hamburg
2. Forecasting water demand for Hamburg – Approach and Methodology
3. The forecast model
4. Summary
Development of water demand in Germany

Development of specific water demand in Germany (households and small trade)
in liters per inhabitant and day

Source: BDEW 2011; 2010 and 2011: provisional

Decrease by 18%
Change in water delivery in Germany

Decrease of 25% (without self-supply)

1990 = Delivery total: 5.99 Mrd. m³
2008 = Delivery total: 4.49 Mrd. m³

Quelle: BDEW-Wasserstatistik
Future population development in Germany

Future population dynamics

Change of population
2005 – 2025 in %

- below -10
- -10 to -3
- -3 to 3
- 3 to 10
- 10 and more

Quelle: BBR-Bevölkerungsprognose 2005-2025/bbw
Water infrastructure – the way forward

Summary of an experts workshop at ISOE 2012

- Water network has to be restructured in the coming decades
- Future challenges can be understood in the light of transformation processes (in contrast to adaptation)
- Open question: How to involve customers in decision making?
- New tariff systems are needed (e.g. basic + consumption)
- New rules and standards have to be defined for water supply and distribution (to facilitate future developments)
- Smaller and decentralized solutions are promising options for depopulating regions
- Sustainable solutions have to be financially competitive
Water supply and population development in Hamburg

Specific water demand (total incl. commercial and industrial)

Water supply (M m³/year) and specific water demand (l/person * year)

Population

Water supply

Source: Hamburg Wasser (2012)
Changes in water demand of private households in Hamburg

Changes during the last 20 years due to water saving effects:

- Rain water reuse
- Introduction of water meters for apartments
- Water saving campaigns
- Modernisation of sanitation facilities
- (Dish) washing machines
- Change of water use behavior
Approach for water demand forecast for the City of Hamburg

Water demand $W_{\text{total}} = W_{\text{Households}} + W_{\text{Commercial}} + W_{\text{Industry}}$

$+ W_{\text{Re-distributors}} + W_{\text{Domestic requirements}}$

$+ W_{\text{Service system losses}}$

Water user groups and demand in Hamburg 2011 (total water extraction: 118 M m³)

Source: Hamburg Wasser (2012)
Methodology for water demand forecast

- Data merging on the basis of an integrated model that is characterised by high user-friendliness (MS Excel, linked sheets)
- Spatially distributed approach using a Geographic Information System (GIS), surveys and interviews
  - Analysis of water use and determining factors at address scale
  - Forecast of changes in water demand at city district scale
- A corridor of how water demand will develop in future is assessed with the help of different scenarios of alternative developments in
  - Society (population dynamics, city planning, users’ behavior)
  - Economy (number of employees in different sectors)
  - Technology (water saving in households and in commerce and industry)
  - potential impact of climate change (number of hot and dry days etc.)
Basic equation for water demand of households and economy in Hamburg

Water demand of households $$(m^3/year) = \text{Population (Number of P)} \times \text{specific Water demand (m}^3/P/year)$$

Effective coefficients $\times$ influence factors

Influence factors:
- Household size (P/H)
- Specific floor size (m\(^2\)/P)
- Garden/unsealed area (% or m\(^2\))

Others:
- Households with modern sanitation facilities (%)
- Effect of climate change

(P: Person  H: Household)

Water demand of economy $$(m^3/year) = \text{Employees (Number of E)} \times \text{specific Water demand (m}^3/E/year)$$
Data and information requirements (households)

City planning and housing programme for Hamburg

- Densification potential
- Remediation, revitalisation and conversion potential
- Inner city Habitation projects for families
- Jump over the Elbe (Extension of Inner city development)
- New housing development

Source: Behörde für Stadtentwicklung und Umwelt Hamburg 2007
Data and information requirements (households)

Spatial data of water use, population, buildings and land use
Data and information requirements (households)

Open areas (not sealed)

Open area mapping based on aerial photographs by Hamburg Wasser (2012), Google Maps (2012)
The spreadsheet model of distributed water demand for the City of Hamburg

Choice of scenario

| Scenario 1: Reference scenario                  |
| Scenario 2: Population stagnation             |
| Scenario 3: Climate change                    |
| Scenario 4: Technical innovation              |
| Scenario 5: Behavior (increasing water saving)|
| Scenario 6: Behavior (decreasing water saving)|
| Scenario X: Free scenario                     |

Multiple information output in tables for feeding GIS

Water consumption of households in Hamburg 2011
Specific WC (m³/Person/a)

### HWW - Water demand forecast 2030

**English translation**

<table>
<thead>
<tr>
<th>Active Scenario:</th>
<th>Scenario 1: Reference Scenario</th>
<th>Water demand</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>[m³/a]</td>
<td>[m³/a]</td>
</tr>
<tr>
<td>City of Hamburg</td>
<td>96,477,728</td>
<td>95,364,507</td>
</tr>
<tr>
<td>Households</td>
<td>71,552,143</td>
<td>70,214,517</td>
</tr>
<tr>
<td>Industry</td>
<td>2,544,424</td>
<td>2,555,057</td>
</tr>
<tr>
<td>Commercial</td>
<td>18,506,140</td>
<td>18,768,119</td>
</tr>
<tr>
<td>Public institutions</td>
<td>2,478,579</td>
<td>2,430,378</td>
</tr>
<tr>
<td>Others</td>
<td>1,396,442</td>
<td>1,396,442</td>
</tr>
<tr>
<td>Urban hinterland municipalities</td>
<td>9,682,227</td>
<td>9,427,429</td>
</tr>
<tr>
<td>Households</td>
<td>8,005,988</td>
<td>7,752,942</td>
</tr>
<tr>
<td>Industry</td>
<td>237,265</td>
<td>223,448</td>
</tr>
<tr>
<td>Commercial</td>
<td>1,183,877</td>
<td>1,197,421</td>
</tr>
<tr>
<td>Public institutions</td>
<td>230,957</td>
<td>229,478</td>
</tr>
<tr>
<td>Others</td>
<td>24,140</td>
<td>24,140</td>
</tr>
<tr>
<td>Re-distributors</td>
<td>3,348,000</td>
<td>3,882,000</td>
</tr>
<tr>
<td><strong>Sum of total water delivery</strong></td>
<td><strong>109,507,955</strong></td>
<td><strong>108,673,937</strong></td>
</tr>
<tr>
<td>Corridor for dry and wet years (+/-)</td>
<td>5,475,398</td>
<td>5,433,697</td>
</tr>
<tr>
<td><strong>Own requirements &amp; Losses</strong></td>
<td>9,795,000</td>
<td>8,649,464</td>
</tr>
<tr>
<td><strong>Own requirements</strong></td>
<td>5,232,000</td>
<td>3,877,346</td>
</tr>
<tr>
<td><strong>Losses of pipeline network</strong></td>
<td>4,563,000</td>
<td>4,772,118</td>
</tr>
<tr>
<td><strong>Sum of raw water volume</strong></td>
<td><strong>119,302,955</strong></td>
<td><strong>117,323,401</strong></td>
</tr>
<tr>
<td><strong>Water demand without own requirements &amp; losses</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supply zone Center</td>
<td>29,786,502</td>
<td>29,529,506</td>
</tr>
<tr>
<td>Supply zone North-East</td>
<td>30,040,816</td>
<td>30,222,463</td>
</tr>
<tr>
<td>Supply zone South</td>
<td>14,127,694</td>
<td>14,152,636</td>
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<tr>
<td>Supply zone West</td>
<td>35,552,943</td>
<td>34,769,332</td>
</tr>
<tr>
<td><strong>Sum of total supply area</strong></td>
<td><strong>109,507,955</strong></td>
<td><strong>108,673,937</strong></td>
</tr>
</tbody>
</table>

#### Population

<table>
<thead>
<tr>
<th>City of Hamburg</th>
<th>[Inhabitants]</th>
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<th>[Inhabitants]</th>
<th>[Inhabitants]</th>
<th>[Inhabitants]</th>
</tr>
</thead>
<tbody>
<tr>
<td>City of Hamburg</td>
<td>1,743,627</td>
<td>1,788,436</td>
<td>1,795,641</td>
<td>1,803,996</td>
<td>1,800,117</td>
<td>1,790,171</td>
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<tr>
<td>Urban hinterland municipalities</td>
<td>182,758</td>
<td>183,829</td>
<td>184,823</td>
<td>185,817</td>
<td>182,523</td>
<td>179,229</td>
</tr>
</tbody>
</table>

#### Specific water demand

<table>
<thead>
<tr>
<th>Households in City of Hamburg</th>
<th>[m³/lnh/a]</th>
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<th>[m³/lnh/a]</th>
<th>[m³/lnh/a]</th>
<th>[m³/lnh/a]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Housesholds in urban hinterland Mun.</td>
<td>41,04</td>
<td>39,48</td>
<td>38,25</td>
<td>37,66</td>
<td>37,32</td>
<td>37,14</td>
</tr>
<tr>
<td>Total in City of Hamburg</td>
<td>55,33</td>
<td>53,62</td>
<td>52,43</td>
<td>51,98</td>
<td>51,80</td>
<td>51,84</td>
</tr>
</tbody>
</table>

Forecasting water demand for the City of Hamburg, Colloquium of the EAU&3E project, Nantes, 6 June 2013
Model output: graphics of water demand development (results of model run in 2007)

- Scenario 1: Reference scenario
- Scenario 2: Population stagnation
- Scenario 3: Climate change
- Scenario 4: Technical innovation
- Scenario 5: Behavior (increasing water saving)
- Scenario 6: Behavior (decreasing water saving)
- Scenario X: Free scenario
- Dry-year water demand, scenario 1
- Wet-year water demand, scenario 1
- Historical development

Forecasting water demand for the City of Hamburg, Colloquium of the EAU&3E project, Nantes, 6 June 2013
Summary

- Spatial analysis and spatial forecast for city districts and water supply zones → advantage for water network planning
- Relational approach (changes in future compared to today)
- Forecast model integrates data regarding socio-economy, demography and urban planning
- Scenarios allow the consideration of alternative future developments
- Approach and model development make use of the whole range of available spatial data
- Modular structure of model, adaptable to other regions
- Update of the forecast is under construction including model/data update and improvements
- Water demand for Hamburg: continually slowly decreasing along with all scenarios, despite of growing population in the next 20 years