Developing the energy saving building to more resource efficiency

Karlsruhe, 9. Mai 2014
Heidelberg – Old Town
Heidelberg Bahnstadt

Area of urban district: 116 ha
Inhabitants in future: ~ 5,000
Working places in future: ~ 7,000
All buildings according passive house standard ➔ energy demand for heating: from ~ 200 kWh/(m² a) to ≤ 15 kWh/(m² a)
Passive house standard: only the beginning . . .

Energy
- to warm rooms (passive house) \( \leq 675 \text{ kWh/(P a)} \)
- to warm water \( \sim 1200-1400 \text{ kWh/(P a)} \)
- Contained in black water (toilet)
  Nitrogen and Phosphorus: \( \text{ca. 100 kWh/(P a)} \)
  Carbon compounds (biogas): \( \text{ca. 100 kWh/(P a)} \)

Building Materials
Different kinds of solid waste
Different kinds of waste water
Passive house standard: only the beginning . . .

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Building Materials
Different kinds of solid waste
Different kinds of waste water
Waste water: an important resource

For the supply of

- thermal energy (grey water)
- process water
- chemical energy (carbon-compounds -> biogas)
- nutrients (Nitrogen, Phosphorous, Potassium)

To make available this new resource optimally, a separate treatment of different partial flows of waste water is recommended.

Separate pipe systems are necessary.
Step I: separate treatment of storm water

But pollution of stormwater by building materials possible!

Options for reuse: storage and use for
- Irrigation
- Process water in the household (e.g. toilet flushing)
- Infiltration to raise groundwater level
- Leading to surface waters to increase the
- Design urban living spaces
Pollution of stormwater and combined sewage

Regulation for roof material and house installations is necessary

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Storm water</th>
<th>Sewage</th>
</tr>
</thead>
<tbody>
<tr>
<td>COD [mg/l]</td>
<td>47 – 120</td>
<td>176 – 720</td>
</tr>
<tr>
<td>NH₄-N [mg/l]</td>
<td>0,1 – 4,0</td>
<td>0,1 – 17</td>
</tr>
<tr>
<td>PO₄-P [mg/l]</td>
<td>0,3 - 1,7</td>
<td>3,0 – 4,3</td>
</tr>
<tr>
<td>TSS [mg/l]</td>
<td>7 – 446</td>
<td>327 – 758</td>
</tr>
<tr>
<td>lead [µg/l]</td>
<td>20 – 422</td>
<td>12 – 213</td>
</tr>
<tr>
<td>copper [µg/l]</td>
<td>10 – 235</td>
<td>27 – 136</td>
</tr>
<tr>
<td>cadmium [µg/l]</td>
<td>5 – 16</td>
<td>0,7 – 4,7</td>
</tr>
<tr>
<td>zinc [µg/l]</td>
<td>610 – 6100</td>
<td>411 – 1430</td>
</tr>
</tbody>
</table>

[Fuchs 2000]
Step II: Further separation of domestic sewage

⇒ depending on
  - specific volumes
  - place of origin

⇒ depending on the content of
  - energy
  - pollutants
  - nutrients
  - germs

⇒ Grey Water from bathtub, shower, washing machine

⇒ Black Water from toilet, (kitchen)
Specific volumes and mass flows in domestic sewage

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mass Flow (kg/cap* year)</th>
<th>Grey water Specific volume (l/capita*year)</th>
<th>Black water Specific volume (l/capita*year)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>~ 30.000</td>
<td>~ 30.000</td>
<td>~ 550</td>
</tr>
</tbody>
</table>

[Otterpohl 2001]
Heat Recovery from Grey Water

Heat exchanger
Heat Recovery in a Passive House of 41 flats in Berlin

Arnimplatz
Wärmerückgewinnung auf Gebäudeebene

Grey watertreatment

Grey water heat exchanger
# Mass flows in domestic sewage

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mass Flow (kg/cap* year)</th>
<th>Grey water</th>
<th>Black water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N)</td>
<td>~ 4 - 5</td>
<td>~ 3 %</td>
<td>~ 97 %</td>
</tr>
<tr>
<td>Phosphorous (P)</td>
<td>~ 0,75</td>
<td>~ 10 %</td>
<td>~ 90 %</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>~ 1,8</td>
<td>~ 34 %</td>
<td>~ 66 %</td>
</tr>
<tr>
<td>COD</td>
<td>~ 30</td>
<td>~ 41 %</td>
<td>~ 59 %</td>
</tr>
</tbody>
</table>

Specific volume (l/capita*year):
- Grey water: ~ 30,000
- Black water: ~ 550

[Otterpohl 2001]
Decentralised waste water infrastructure – case of Lübeck

Todays waste water infrastructure

- Biowaste
- Decentralised waste water infrastructure – case of Lübeck

Combined sewer

Drainage wells

Groundwater

Black Water

Grey Water

To collection tank
To Bio tank
To sewage mains

Toilet

Toilet Valve

Jets Vacuumator®

Helmut Lehn
Step III: Separation of urine

- Highest concentration of nutrients

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Grey Water (GW)</th>
<th>Urine</th>
<th>Feces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Massflow</td>
<td>30.000 l/cap yr</td>
<td>~500 l/cap yr</td>
<td>~50 l/cap yr</td>
</tr>
<tr>
<td></td>
<td>= 1% of GW</td>
<td>= 1% of GW</td>
<td>= 1% of GW</td>
</tr>
<tr>
<td>Nitrogen (N)</td>
<td>~3 %</td>
<td>~87 %</td>
<td>~10 %</td>
</tr>
<tr>
<td>~4 – 5 kg/cap yr</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phosphorous (P)</td>
<td>~10 %</td>
<td>~50 %</td>
<td>~40 %</td>
</tr>
<tr>
<td>~0.75 kg/cap yr</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>~34 %</td>
<td>~54 %</td>
<td>~12 %</td>
</tr>
<tr>
<td>~1.8 kg/cap yr</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>COD</td>
<td>~41 %</td>
<td>~12 %</td>
<td>~47 %</td>
</tr>
</tbody>
</table>
Swedish toilets for separation of urine
German model of a no mix toilet

Toilettenschüssel (Seitenansicht)
Toilet bowl (side view)

Toilettenschüssel (Pfeil zeigt auf Urinablauf)
Toilet bowl (arrow points to urine drain)
Step III: Separation of urine

- Highest concentration of nutrients

- use in agriculture (Sweden)
  - conversion to a mineral fertilizer (GIZ, EAWAG)
  - reducing costs for de-nitrification in classical WWTP

- Separation of pharmaceuticals

But: cultural reservation, limited acceptance, technical problems
Adiabatic cooling of buildings with water

Evaporation of 1 kg water at 35 °C needs 0.67 kWh or 577 kcal

To replace classical air conditioning - by plants (transpiration of trees…)

using adiabatic house coolers

saves energy but needs more water
option: recycling of grey water
Waterflows in a resource efficient house
Waste Water Separation is…

… a promising option for new built up areas:

-> chance to leapfrog the traditional sewerage system

Therefore the energy efficient house should be further developed to the resource efficient building

necessity of different pipe systems

-> concepts for new buildings should be more flexible and upwards compatible
Hamburg: new settlement „Jenfelder Au“ for 2.000 residents under construction

Thank you very much

Helmut.Lehn@kit.edu