How can urban water infrastructures contribute to a sustainable urban metabolism?

Dr. Eve Menger-Krug (Fraunhofer ISI, Karlsruhe), Trust Conference in Mühlheim, April 2015
How can urban water infrastructures contribute to a sustainable urban metabolism?

- **Spotlight on selected results of TWIST++** (please refer to [www.twistplusplus.de](http://www.twistplusplus.de) for a overview of project results)
- Urban water chain: Extended energy balance and metabolism analysis
- Urban water chain in context of the urban metabolism: the big 4 of urban flows
- Presentation of a concept for water reuse in urban areas developed in TWIST++
Example: Electricity consumption and generation along the Urban Water Chain in kWh per person and year, ca. 50% of German population (advanced conventional).

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- Calculations:
  - brutt: 75 kWh/p*a
  - subtracting 21 kWh/p*a for incineration gives:
  - nett: 54 kWh/p*a
Energy Balance: Urban perspective

- **Per Person:**
  Electricity Use of Water Infrastructures
  << Electricity Use in Households

- **City Perspektive:**
  Electricity Use strongly clustered
**Substance Flow Analysis**

**CO₂-Emissionens (renewable) vs. Energy Recovery [kWh/p*a]**

SFA shows the pathway of the Elements Carbon C, Nitrogen N and Phosphorus P in the processes Wastewater and Sludge Management and the Emissions to the different environmental compartments.

Influent

- C 100%
- N 100%
- P 100%

Load AD

- C 65%
- N 48%
- P 99%

Backload sludge water

- C 6%
- N 22%
- P 9%

Sludge

- C 29%
- N 19%
- P 90%

Solid / Ashes

- C 34%
- N 54%

- C 5%
- N 20%
- P 9%

- C 29%
- N 7%
- C 29%
- N 19%
- P 90%
## Extended Energy Balance

### Material Resources per Person and Year

<table>
<thead>
<tr>
<th>Element</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>14 kg</td>
</tr>
<tr>
<td>N</td>
<td>4 kg</td>
</tr>
<tr>
<td>P</td>
<td>0.7 kg</td>
</tr>
</tbody>
</table>

### Chemical Energy

- C: 17.9 kWh/kg
- N: 16.4 kWh/kg
- P: 7.9 kWh/kg

### Grey Energy

- Large Potential for Heat Recovery

### Thermal Energy

- Primary energy: 700 kWh/p*a
- Exergy (greywater): 200 kWh/p*a
- Exergy (mixed): 35 kWh/p*a

### Pollutant Problem

- C: 15% recovered, 250 kWh/p*a
- N: 4%
- P: 20% recovered, 65 kWh/p*a

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Urban Metabolism

Semi-hypothetical model city: Household consumption of one person per year

Input of Electricity, Heat (Gas), Water, Food, Detergents, Pathways to air, wastewater, and organic waste
Urban Metabolism

Relevance of urban water chain for urban Metabolism today

- Very high relevance: Water Use (Tap) Flow dynamics Water Quality (Urban Stream Problem)
- High relevance: Total Energy Consumption (clustered)
- Very high relevance: Emissions to Water (Eutrophication)
- Very high relevance: Emissions to Water (Soil, Air)

Tomorrow

- Very high potential: contribution to natural water cycle
- Very high potential: for Renewable Energy Production
- Very high potential: for Nutrient Reuse
- Very high potential: for Emission Reduction
So far, our Water Infrastructures worked well, why should we change them.

Your Thinking!

The World is changing. We need infrastructures that support a sustainable metabolism for the green cities of tomorrow.

Your Cities!

... then
i.W.E.T (innovative Water Energy Transistion - working title)

- From this holistic perspective on the big 4 of urban flows, we developed a concept for water reuse
- outside the box of traditional grey infrastructure approach
- based on a hybrid system including technical modules and eco-engineered urban landscapes
- providing service water in buildings and “fertigation” water for gardens

- Thinking outside the box has advantages:
  - supports natural water balance (- run off, + evapotranspiration)
  - optimizes energy balance
  - protects from eutrophication, and reuses nutrients for bioenergy production
  - eliminates and buffers pollutants
  - and provides water for urban landscapes and their ecosystem services
Heat Recovery

Treat-
men-

Storage

Hygien-
isa-

Service Water (Toilets, Cleaning)

→ Reuse in Building

Greywater * Bath, shower

Filter

Heat Recovery

R

Tap Water

Reuse in Building

Sewer

Back Wash

Sludge

Excess water
Evapotranspiration for urban climate
Nutrient reuse
Barrier for Eutrophication

Habitat for Biodiversity
Carbon Sequestration
Barrier for Pollutants

Bioenergy (Wood Pellets)
Water for Open Reuse
Integrated Water Storage

Stressed „conv.“ trees and hedges
Fertilizer (N and P)
Agricultural Land

Elimination of CNP at MWWTP
Anti-Depressants
Greywater+ Gardens

- Water loving plants for garden design
- Robust system with low maintenance

- Turn over lower than for Energy Alley
- Cascade use of water and Multi Barrier Approach

- Plant selection
- Seasonality

Iris versicolor  Lythrum salicaria  Hemerocallis minor  Ajuga reptans

http://www.lwg.bayern.de/landespflege/landschaftspflege/14087/linkurl_0_6.pdf
Rain Gardens: Sustainable Landscaping for a Beautiful Yard and a Healthy World

davesgarden.com
perennialconnection.org
Heat Recovery from Greywater

Energy Alley Water Treatment for Open Reuse + Bioenergy

Water Reuse from Greywater and Rain

Greywater+ Gardens, Balconies, Facades and Roofs for Aesthetics
Visible Colourful Infrastructures for Reuse in Water-Sensible Cities

- Beauty, Awareness, Water Culture
- Ecosystem Services
- Water + Energy Efficient, Flexibel

Reuse Cascade: Multi Barrier System

- Open Reuse
  - Lawn, Food
- Grey-water Gardens
- Water storage

Reuse of water in urban landscape
- Energy Alleys
  - Clean Water + Bioenergy
- Lawn, Food

Reuse of water in house

Invisible Infrastructures for disposal → No ESS

Transport

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Transition Pathways

- Example: Town of Luenen
- i.WET for greywater and rainwater
- Introduce with building renovation
- -50% volume in sewer → mitigation by flushing sewer with surplus water from energy alley
- Vacuum for blackwater
- Introduce with sewer renovation
- Co Substrate for Digestion
- Flexible Transition Pathway
Thank You for Your Attention

Thanks to BMBF and all TWIST++ Partners