Chair of Urban Water Systems Engineering
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NEXUS CITY

Operationalizing the urban Water-Energy-Food Nexus for climate change adaptation in Munich, Germany

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Objectives of WEF Nexus project

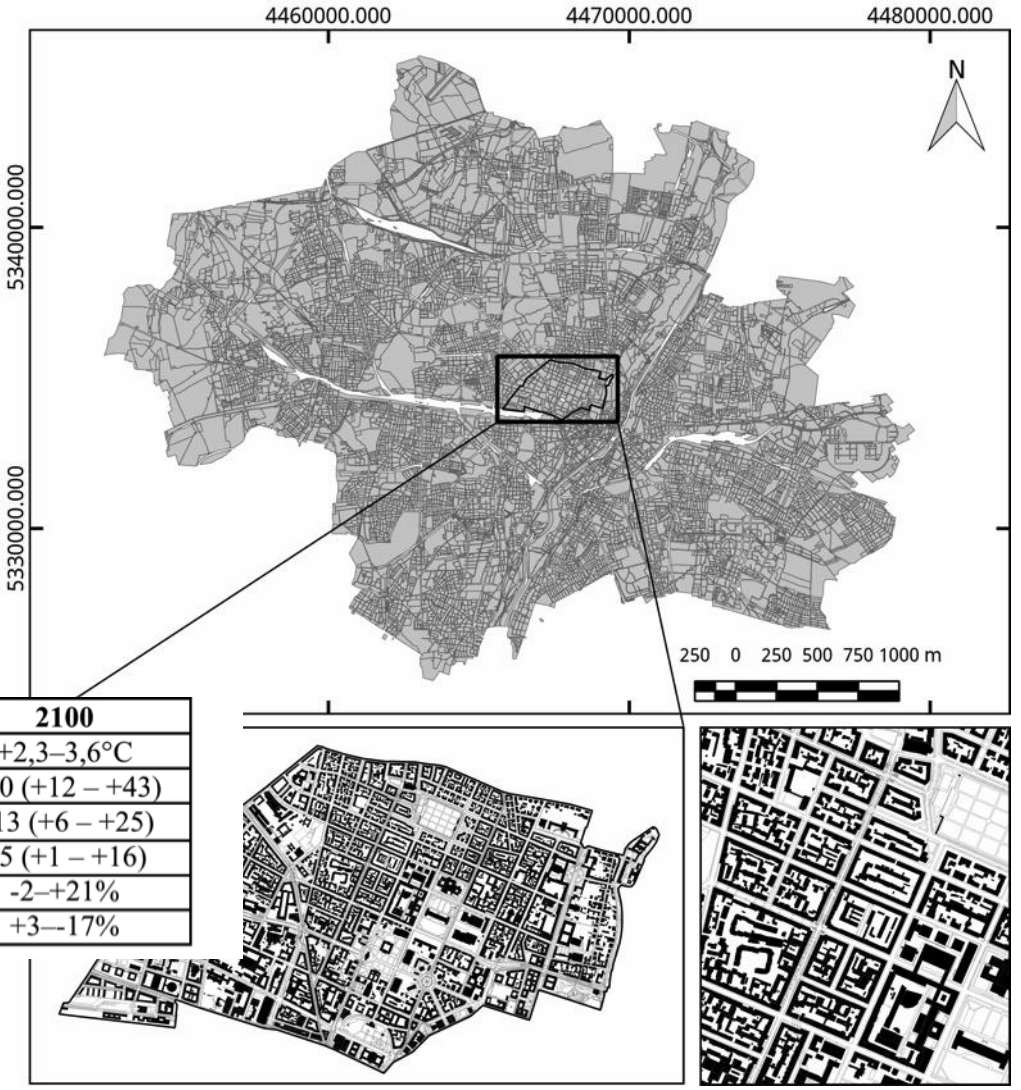
- On-going Water-Energy-Food (WEF) Nexus project at TUM since 2011, funded by European Commission, German Research Foundation (DFG), TUM Global Incentive Fund, Bavarian State Ministry of Environment and Consumer Protection, in partnership with **Water Future Programme** of Future Earth.

- **Background**: Cities need to **exploit synergies** between climate change mitigation and adaptation approaches to take climate action effectively. Water reclamation and reuse is a key synergy opportunity for this.
- Few operationalized examples of WEF Nexus at the **neighbourhood scale**, e.g. Hamburger Water Cycle: more **pilot projects needed**, e.g. in Bavaria.

- **Aim**: apply WEF Nexus concept to a case study neighbourhood of Munich.
- **Hypothesis**: the more green the better – for now. Although research suggests that smaller well-planned interventions can achieve significant effect (Zölch et al., 2016). However, for paradigm shift, “Green City Vision” needed.

Climate change impacts in Munich

- Munich one of densest cities in Germany in terms of urban fabric.
- Maxvorstadt neighbourhood of **urban block type** is particularly dense.
- **Heat island effect**: especially young children and the elderly already face serious health risks.
- Total pop.: ca. 50,000 (City of Munich, 2014).



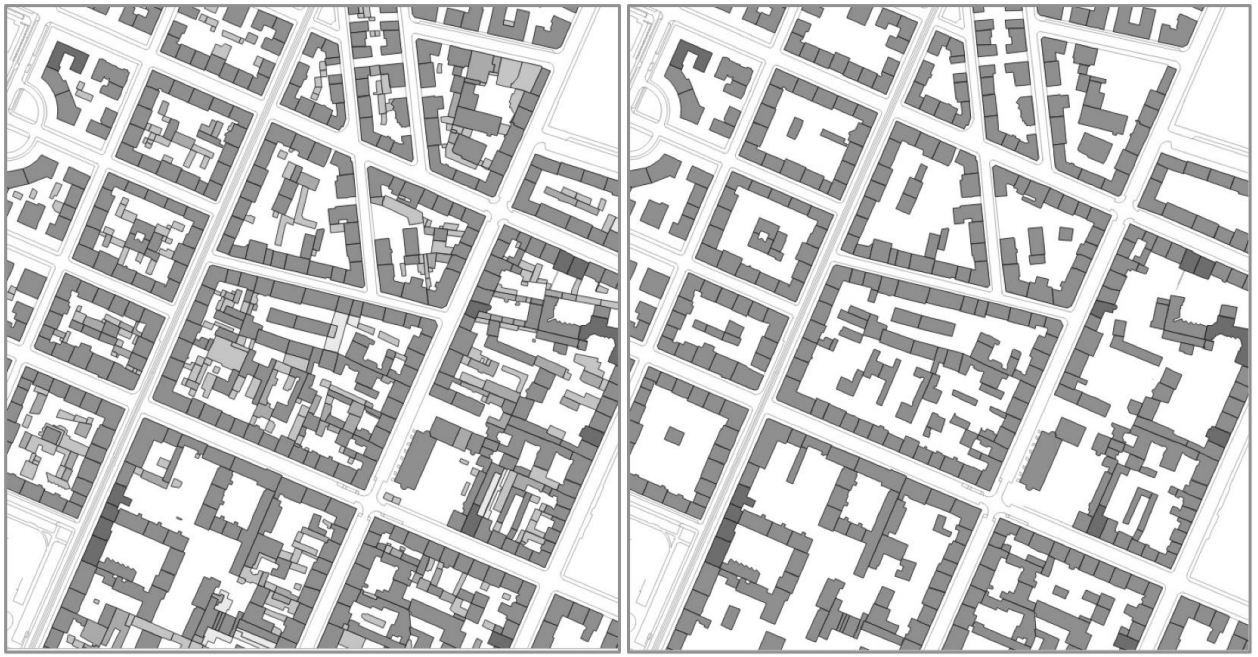
Climate variables	2050	2100
Average temperature	+0,9–+1,7°C	+2,3–3,6°C
Summer days (max. temp. > 25° C)	+9 (+4 – +19)	+30 (+12 – +43)
Heat days (max. temp. > 30° C)	+2 (+1–+9)	+13 (+6 – +25)
Tropical nights	+1 (+0–+5)	+5 (+1 – +16)
Average precipitation winter half-year	-1–+11%	-2–+21%
Average precipitation summer half-year	-7–+5%	+3–-17%

Climate change projections for Bavaria. Source: Bayerische Klimaanpassungsstrategie, StMUV, 2016

“What if” scenario

- Currently, the area inside Maxvorstadt blocks is 60 % covered by buildings (many are garages) and 20 % covered by sealed surfaces, mainly car parks. **Green area is only 20 %**.
- Assuming the trend that car use will decrease radically in Munich due to air pollution, much sealed area could in theory become available for **intensive greening to cool the micro-climate**.

Land use type	Area (ha)	Percentage (%)
Maxvorstadt district	430	100
Blocks urban fabric type	195	45
Roads / pavements	108	25
Green area, parks and water surfaces	29	7
Museums, universities etc.	98	23
Maxvorstadt blocks	195	100
Buildings	117	60
Parking lots / sealed surfaces	36	19
Green area	42	21



Implications for WEF Nexus

- Max. horizontal + vertical area used for **urban agriculture**, for simplicity, although of course other functions (playgrounds, paths, sealed surfaces with benches etc.) and issues like sunlight need to be considered.

- WHO recommendation for a healthy diet: 400 g of fruit and vegetables per person*day.

- Potential crop yield in Maxvorstadt could supply **66 % of demand for fruits** and **246 % of demand for vegetables** of the local population.

Crop type	Area (ha)	Potential yield (t/ha)	Potential yield (t)
Vegetables			
White cabbage	92	91,6	8,427
Fruit			
Apples	50	39,4	1,970
Grapes	26	11,4	296

Implications for WEF Nexus

- Average **freshwater consumption** in Munich: 128 litres per person*day, of which 35 litres for toilet flushing (SWM, 2015). Current demand in Maxvorstadt blocks is 6 million l/day. Ca. 600 million l/year used for flushing toilets.

- Reclaimed water could be used for **urban agriculture irrigation**.

- Using all roofs steeper than 15° were used for **rainwater harvesting** could yield ca. 780 million l/year: **sufficient for toilet flushing**, could reduce freshwater demand by 26 %, with energy implications.

- In the Hamburg Water Cycle (population ca. 2000), blackwater with sludge from greywater and organic waste is used to generate 340,000 m^3/year of biogas yielding 370 kWh/person*year of electricity and 778 kWh/person*year of thermal energy (Schönfelder et al., 2013). With a similar process for **energy production**, biogas production in Maxvorstadt blocks could come to ca. 8 Mio. m^3/year, could in theory meet 20 % of local household electricity demand.

Discussion: back to reality

- **The centralized sewerage system of Munich needs large-scale renovation**: cost of redevelopment of a particular 1.6 km section estimated at 26.5 million Euros (SZ, 2014) and the system is 2,500 km long. It is expensive, even if this section is not the norm.

- However, Munich is in a water-rich region and freshwater provision is virtually energy-free due to topography: there may be **lack of incentive** for this type of WEF Nexus operationalization:

- **Water**: Rainwater delivery facilities to substitute toilet flushing: savings by not paying for drinking water would be less than 4 Mio Euros per year. Rainwater treatment, conveyance, pumping energy etc. also need to be considered.
- **Energy**: May be difficult to convince households to invest as would require a dedicated dual distribution system, which would be very expensive and difficult to implement and would entail various risks.
- **Food**: to cool the microclimate, green does not need to be food.

Conclusion

- **Transitioning to an alternative system in Munich is not very attractive economically**:
  - Redesign of such large-scale existing infrastructure and planning conventions would require a considerable amount of time.
  - It would have to be proven that in particular energy savings would be more than marginal.
  - In an existing neighbourhood like Maxvorstadt, cost outweighs benefits by a huge extent.

- Nonetheless, the fact that the centralized sewerage system is in need of expensive large-scale renovation is a "**window of opportunity**" to think about other technological solutions to effect a **paradigm shift**.
- Today, decentralized water reclamation and recycling is not very economical if considered a timeframe of 20 years (Sedlak, 2015). Yet, what if it is 100 years and considering the cost of providing freshwater to cities like Sao Paolo?
- In the US, the cost of restoring existing water systems is est. 1 Trillion $ in the next 25 years (AWWA, 2012).

Key aspects for further WEF Nexus work

- **Data needs**: there is much existing data about conventional large-scale systems on energy efficiency, but hardly any such data exists to be able to compare smaller scale options.
- **Key indicators** need to be developed, along the **key questions**:

Key question	Key indicators
1. Which resources predominantly trigger supply needs/abilities?	Climate; geographical and regional differences; water, energy and food demand; supply and availability; history and trends; ethics/religion; etc.
2. What are the components of the existing water management system?	Relative location of water supply sources, topography, distribution and storage system, sewerage system, existing legislation and by-laws, existing infrastructures and construction features, etc.
3. How acceptable is a different system to the local community?	Awareness; socio-economic indicators on income, education, health; etc.
4. How can a modified or new system be administered?	Existing institutions, legal and regulatory framework, policies, budget, etc.
5. What would be the necessary material and financial investment?	Financing, cost-benefit analysis, existing resources e.g. for construction, etc.

- A key question that may be formulated for the future development of Munich: **is it sustainable to maintain the existing infrastructure**? Which type of infrastructure may be suitable for new parts of Munich now being planned?

Thank you for your attention!

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