CITYFOOD - Upscaled Urban Aquaponics and the Food-Water-Energy Nexus

Gösta F.M. Baganz, Manfred Schrenk, Oliver Körner, Daniela Baganz, Simon Goddek, Karel Keesman, Zorina Ziscan, Elias Baganz, Alexandra Doerberg, Hendrik Monsees, Thomas Nehls, Werner Kloas, Frank Lohrberg

(Gösta F.M. Baganz, IGB Berlin, RWTH Aachen, Germany, g.baganz@igb-berlin.de)
(Manfred Schrenk, BoKu Vienna, Austria, schrenk@corp.at)
(Oliver Körner, IGZ Großbeeren, Germany, koerner@igzev.de)
(Daniela Baganz, IGB Berlin, Germany, baganz@igb-berlin.de)
(Simon Goddek, WUR Wageningen, The Netherlands, simon.goddek@wur.nl)
(Karel Keesman, WUR Wageningen, The Netherlands, Karel.Keesman@wur.nl)
(Zorina Siscan, ASEM, Chișinău, Moldova, zorina_2005@yahoo.com)
(Elias Baganz, Berlin, Germany, elias.baganz@gmx.de)
(Alexandra Doernberg, ZALF Müncheberg, Germany, alexandra.doernberg@zalf.de)
(Hendrik Monsees, IGB Berlin, Germany, h.monsees@igb-berlin.de)
(Thomas Nehls, TU Berlin, Germany, thomas.nehls@tu-berlin.de)
(Werner Kloas, IGB Berlin, HU Berlin, Germany, werner.kloas@igb-berlin.de)
(Frank Lohrberg, RWTH Aachen, Germany, lohrberg@la.rwth-aachen.de)

1 ABSTRACT

To address the most pressing global problems of sustainable development, the UN formulated 17 goals in 2015 (UN, 2015). The current review shows that while progress has been made, efforts need to be significantly increased to achieve the sustainable development goals (SDGs) (UN, 2020) and therefore a "Decade of Action" was proclaimed to fulfil the 2030 Agenda (UN, 2021). This call by the United Nations was taken up by the German Federal Government through the revision of its sustainability strategy, which now contains six transformation areas, including the circular economy as well as sustainable agricultural and food systems (BReg, 2021).

One food production technology that belongs to these two transformation areas is aquaponics, the coupled production of fish and plants (Naegel, 1977; Baganz et al., 2021a). Given the rising importance of urban agriculture (Lohrberg et al., 2015), the project CITYFOOD posed the question of whether and to what extent it makes sense to bring aquaponics into cities (Baganz et al., 2020; Proksch & Baganz, 2020) The urban Food-Water-Energy (FWE) Nexus describes the interlinkages and interdependencies between food, water and energy in coupled systems in an urban context, whereas all three sectors have also strong impacts on climate, environment and land use (Lehmann, 2018). Within the FWE-Nexus concept, we applied a food-centric approach to reduce the complexity of the connections between these three resource sectors, taking Berlin as a case study.

Food. The starting point is Berlin's demand: with a population of about 3.75 million in 2020, approximately 21 kilotonnes (kt) of freshwater fish and fish products, 108 kt of fresh tomatoes and tomato products, and 27 kt of lettuce are needed per year to cover the demand, including the non-marketable portion, e.g. waste from fish processing. To estimate the environmental footprint, we used the results of a work conducted as part of the CITYFOOD project, which modelled aquaponic facilities with a greenhouse size of 5000 m² and year-round vegetable production for a life cycle assessment (LCA) (Körner et al., 2021). The gross area for the entire facility of about 6000 m² results from increasing the sum of the aquaculture and greenhouse net areas by 10%.

Different combinations of fish (tilapia, catfish) and plants (tomato, lettuce) were studied, resulting in four variants of aquaponic facilities that differ considerably in production parameters, e.g. fish stocking density. To enforce the aquaponic principle for the total demand of the city and balance the fish production with the vegetable production so that there is no excess production or unnecessary effluent on either side, the following proportion of preselected aquaponic combinations have been calculated: Catfish/Tomato 56%, Catfish/Lettuce 13%, Tilapia/Tomato 31%, and Tilapia/Lettuce 0%. This makes it possible to achieve the required annual yield with 370 facilities on a total area of 224 hectares (Baganz et al., 2021b).

Water. A key feature of aquaponics is the dual use of water, which is used first to raise the fish and then to irrigate and – at least in part – for plant nutrition (Kloas et al., 2015). Compared to the water footprint of the German market mix for fresh tomatoes and lettuce (LCA impact category water consumption), aquaponic production of both vegetables for Berlin would save about 2.0 billion cubic metres of water. In terms of the LCA impact category of water scarcity, about 1.4 billion cubic metres of water would be saved, especially as

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a significant proportion of the tomatoes consumed in Berlin are produced in the Spanish region of Almeria, where the rapid development of greenhouse agriculture has affected the availability of groundwater resources (Castro et al., 2019).

Energy. The LCA has shown that the energetic disadvantages of greenhouse production in Berlin, especially in winter, compared to southern European cultivation areas can be compensated by e.g. thermal coupling of rooftop aquaponics with the waste heat of a supermarket's cooling system. But even then, the energy savings from upscaled urban aquaponics are not particularly high.

Conclusion. It could be shown that aquaponics can make a relevant contribution to sustainability in Berlin. An essential prerequisite for this year-round scenario is building integration for thermal coupling needed in the cool season and the heating demand can be significantly reduced by the application of low-energy greenhouses. We identified significant aquaponic variables which influence the three sectors of the FWE nexus directly or via causal chains and which thus are useful for a designer or operator of an AP to control its environmental impacts. We further discussed the impacts of production-location, dietary shifts, and trade-offs on the FWE nexus.

Keywords: Urban Aquaponics, Food-Water-Energy Nexus, CITYFOOD, Sustainability, Berlin

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