03. Definition

Circularity and the Food-Energy-Water Nexus

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Food, energy, and water security are inextricably linked and are all essential for human health, well-being, livelihoods, activities, and prosperity. They are also critical to reducing poverty, improving living standards, and ensuring sustainable development around the world. Up until recently, food, energy, and water have been considered as separate entities, which has led, in some instances, to an unbalanced system, whereby access to one or more of these resources has been dramatically reduced. This approach has manifested in management structures and policies, which have further exacerbated the rift between available and unavailable resources in specific climates or regions. Now, food, energy, and water are being considered as part of a systems-thinking approach, which explores the interconnectedness of these resources and acknowledges the far-reaching impacts of individual actions. The connections between food, water, and energy are numerous, complex, and sometimes nuanced. Collectively, food, water, energy, and the relationships between them create the food-energy-water nexus; sometimes referred to as FEW nexus or WEF nexus. The food-energy-water nexus is a conceptual approach to resource governance, which aims to map and analyse the complex relationships between natural environments, resource availability, and human activity. The food-energy-water nexus does not only depict these interrelationships, but it also helps identify synergies and bottlenecks within this complex system as well as serving as a basis to predict, mitigate, and manage stresses and conflicts to ensure resilience, equilibrium, and availability.

Interrelationships

Here is a simple diagram that represents some of the simplified relationships between food, water, and energy. Whilst this diagram does not represent all the interactions, it does, however, give an indication of how this conceptual approach is applied. For example, if we look at the smallest loops, we can see that water is necessary for agriculture, yet agriculture can adversely affect water quality if herbicides, pesticides, and fertilisers are allowed to leach into waterways. In order to provide the water for agriculture, energy is required to treat the water and distribute it to where it is needed. Reciprocally, water is also required for cooling and to transport energy in thermal energy production such as coil- or gas-fired power stations, in addition to playing a key role in hydroelectric power generation. If we look towards renewable energy, water is also required in the manufacturing processes of these technologies in addition to the transportation of heat within neighbourhood heat grids, for example. If we now look at the larger loops, we can see that energy is required for agriculture to help transport the necessary resources to the farms, to powering the machinery on site, to transport the crops once harvested, and to store these foods in cooled or chilled environments. Finally, food can also be used for energy when considering the production of biofuels.

Stresses

Currently, global resources are under pressure due to population growth, urbanisation, economic development, changing diets, technological advancement, and climate change. By 2050, it is expected that food production will need to increase *[Food production increase: by up to 70% by between 2017 and 2050 (Hunter et al., 2017)]* even though land availability continues to decrease and climate change results in decreasing yields. It is also expected that water use will increase *[Water use increase: between 20% and 30% between 2016 and 2050 (Burek et al., 2016) 60% in agriculture (Alexandratos et al., 2012)]*. and that energy use will rise as well *[Energy use increase: between 123% and 150% (World Energy Council, 2010)]*. Stresses on either food, water, or energy can lead to significantly reduced availability of the other two resources. An example of this is the drought of 2012 in India, which led to the largest blackouts in history. The failure of the electricity grid in three regions of India was driven by an increased need to draw water up from beneath the surface from greater and greater depths to irrigate crops. The energy demands from agriculture were so significant that it led to 620 million people being left without power. Another example with further reaching implications occurred in 2008. At this time major land use changes were made to boost the production of biofuels. This, in turn, resulted in a decrease in food production, which was a contributing factor to the 2008 food crisis. This crisis not only greatly increased the price of foods by up to 75 percent, but it also led to civil unrest and political instability in some cases.

Using the nexus

At the macro and meso scales, the food-energy-water nexus requires vast datasets and complex analysis to understand the unique synergies, stresses, and consequences of a climate or region. Historic events can be analysed to better determine the causes and effects of certain nexus events to uncover deep relationships between resource availability, climatic events, and human decisions. These events, alongside real time resource availability, climate, and weather data can be fed into spatial computing models, which can be used to help manage the relationships within the nexus as well as predict future events to assist in their mitigation. As designers, we are able to affect the nexus at the micro scale when we consider urban resource flows. This can fit within a circular approach whereby the need for food, energy, and water resources are minimised where possible, through efficient use and the reduction of waste. We can also ensure that any waste flows that do occur are captured and fed back into productive systems to reduce demands elsewhere. This could include the use of food waste to produce food once again through composting or to produce biogas through anaerobic digestion. Rainwater from rooftops and greywater can be treated to irrigate crops in, or adjacent to, cities or simply used to flush toilets or wash clothes. Nutrients can be extracted from black water to help grow food as well. Renewable energy can be generated in or close to cities to reduce the need to import energy even further. The thermal renovation of buildings can reduce energy demands as a whole. Waste heat from other processes can also be captured and used for space heating elsewhere. Utilising waste flows as inputs to other systems also greatly reduces the energy needed to transport and process waste.

Ultimately, the success or failure of the food-energy-water nexus in any context is based upon human decisions in the presence of differing climates, climatic events, weather systems, and resource availability. At the macro and meso scales, it is important to focus on creating decision-support systems and at the micro scales it is important to consider how the need for food, energy, and water can be minimised and how loops can be closed to maximise the impact of waste flows to reduce the need for these resources as a whole.