Farm City and Hortus Aquarius: A Modular and Synergetic Design Approach in Practice

Gilbert Curtessi
Maarten Feberwee

Farm City comprises a concept that can be applied for the creation of agricultural clusters with economical, ecological and social features, in order to create optimal economic and ecological performance. Several case studies have been created in the last 2 years. In this article the Farm City concept will be illustrated by 2 examples: the Rotterdam Zoo in the Netherlands and Hortus Aquarius in Oman.

Farm City is a design tool developed by Gilbert Curtessi (Happy Shrimp, Allcomm, Transmare & EnergyTransformers) and Maarten Feberwee (Ecomimics, Revaho). Curtessi's background as an entrepreneur and researcher is related to the first tropical algae and shrimp farm (known as Happy Shrimp Farm) in the Netherlands making use of residual heat. In this project a 2-km infrastructural connection with a powerplant was realized to supply residual heat for the growth of shrimp, Salicornia and micro algae. The cultivation was based on a modular system design.

Feberwee finished his master's in Industrial ecology at the TU Delft by writing a thesis on the modular concept of Farm City. Curtessi and Feberwee identified a symbiosis with each other's projects and started working on the design concept from 2012. Nowadays, the aim is to actually find stakeholders willing to design, finance and realize agro-energy cluster companies based on the Farm City principles.

Farm City is focusing on food production, in combination with education, recreation and health care. Farm City's ambition is the creation of balanced business cases. The target is to achieve a optimal level of social, economic and ecological results. Farm City applies modules according to a systematic (industrial ecology) view. Industrial ecology is the study of material and energy flows through industrial systems. Key principles are the analogy with natural ecosystems, a holistic and systematic approach and multidisciplinary collaboration. (Garner and Keoleian, 1995).

A module relates to a certain agricultural process, technology or physical space. By input-output flows of organic materials, energy and water, the modules interact with each other and with other external flows, in order to create a closed system to the greatest extent possible. This concept can serve as an example of "metropolitan agriculture" in Western Europe for other delta cities around the world.

Rotterdam; Blijdorp Zoo

The design of Farm City Blijdorp consists of a landscape park covering the existing parking area, a greenhouse and a vertical farm combined with research facilities and student housing.

The design of Farm City Blijdorp: aerial and street view. Photo: FarmCity

The proposition is based on high value products such as flowers, food, animal feed and bulk products such as biogas and fertiliser. Input of organic materials originates from the zoo and surrounding urban areas. The primary goal is to keep flows of organic materials, energy and water in the system as long as possible. Biodegradable waste from the zoo, households in the neighbourhood, private gardens, the landscape park and the vertical farm will be enough for conversion into valuable compost and energy.

The management of Blijdorp Zoo has a keen interest in sustainable development and an established Greenteam is managing and investigating possible interventions. The Zoo accommodates a large aquarium called the Oceanium. This building is located in the expansion area of the zoo, which includes a new entrance and parking area. This parking area (3.2 ha) can potentially be transformed into a multifunctional agricultural cluster. (see: www.blijdorp.nl).

In Blijdorp Zoo multiple flows are assimilated: mainly manure and various other organic materials. These flows consist of biodegradable waste (35,000 kg – 50-60 % moisture) and wood residues (10,000 kg). The restaurants release frying oil, currently used to power a ship owned by Blijdorp for the transport of salt water. The zoo requires approximately 1.2 million m^3 of gas for heating, of which the Oceanium consumes 30 %. In addition, the zoo consumes large quantities of water from different sources, which amounts to a total of 219,300 m^3 annually. Wastewater at the zoo is partly discharged to surface water (ponds etc.), partly transported through filtration beds; both salt and black water are discharged to the sewage.

The high-rise vertical farm provides energy and animal feed. The system could contribute to a drastic decrease in food miles and reduced animal feed costs. The extensive landscape park could function as a natural filtration and collection system for rainwater. A combination of a biopowered CHP (Combined Heat and Power) and biofermentation plant can convert flows of manure, black water and biodegradable waste into heat and electricity highly efficiently.

The extensive landscape park functions as a natural filtration and collection system for rainwater. As this results in a water collection unit of 3.2 ha underneath drainage, the water is not transported into the sewage system. Another advantage is the cooling effect the parking deck could provide for parked cars during periods of heat.

The next step will be a detailed design to connect these flows of water, materials and energy. Development can be enhanced by a team of available stakeholders, e.g., a real estate company, the zoo itself, universities and a parking management organisation (see figure).

Social, ecological and economic benefits for Rotterdam

- *Sustainability in agriculture; (re)circulation of energy, water and organic flows (e.g., nutrients);*
- *Establishment of parks for agriculture and cultural activities;*
- *Growth in real estate value by creating an aesthetic space over the existing parking lot;*
- *Local animal feed and food security and access to food reduces transport in a traffic dense area;*
- *Landscape park supports biodiversity and provides a habitat for plants and small animal species;*
- *Application of biological systems e.g., pollination services, water filtration, fermentation;*
- *Commercial exploitation of a large surface obtained through multiple uses of space;*
- *Introduction of a variety of vegetable and animal species.*

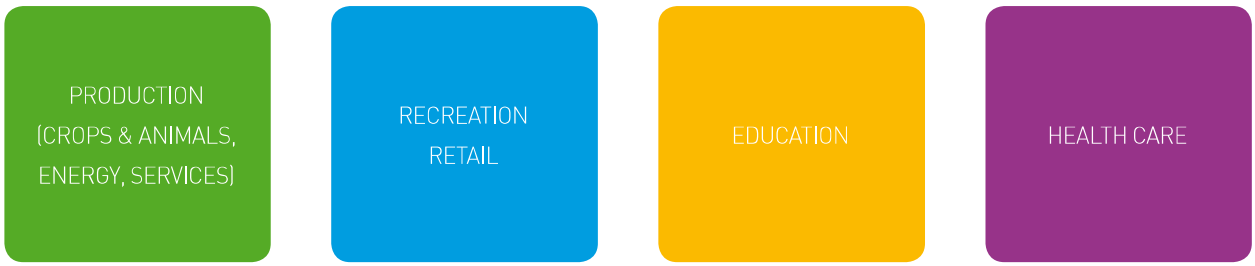
Oman; Aquapolis and the "Hortus Aquarius"

In the coming decades our world population is expected to grow rapidly. This development will lead to large amounts of sweet water being used for the production of food and drinking water, to supply households and industrial branches. A solution for water scarcity in line with the Farm City principles is the saline desert farm called Hortus Aquarius, which is currently being developed together with international stakeholders.

This project is part of the Aquapolis Centre in Oman, currently developed by Lim Shrimp. Construction of the Aquapolis Centre (2000 million tonnes shrimp production capacity) was started in 2014. The Lim Shrimp organisation is responsible for operational matters and necessary actions regarding the final business case. Analysis and discussions are currently taking place about how to integrate shrimp and vegetable production systems.

By cultivating, presenting and selling saline vegetables, consumer demand for culinary ingredients will be fulfilled within the United Arab Emirates region. Implementing a modular and phased growth in production capacity during the start-up keeps the company process controlled and reduces certain risks.

The Hortus Aquarius is unique in the sense that it simulates a semi-natural cultivation method. Curtessi initiated the design concept together with Lim Shrimp, and functions as coordinator/business development party. Feberwee, owner



Farm City combines food production with recreation, education and health care. Photo: FarmCity

of Ecomimics, "a creative process and design engineer company", assumes responsibility for a large part of the design and technical proposition of the Hortus Aquarius, together with Revaho, "a wholesale water and irrigation products company based in the Netherlands". Feberwee and Curtessi, with the input of stakeholders, are responsible for the final design, business model and investment overviews necessary for implementation. The marketing and distribution will be executed by an existing and experienced stakeholder once the product is fully developed. Initial support for the Hortus Aquarius project in Oman will be given by IMARES, part of Wageningen UR.

Social, ecological and economic benefits for Oman

The Hortus Aquarius will be a visually attractive garden where edible saline products are produced using a durable, innovative and socially responsible method of production, without interference in the natural processes. The design will be based on a modular semi-controlled infrastructure and processing of nutrient water-effluent. The crucial factor of successfully creating a Hortus Aquarius is the availability of salt and a minimum of fresh water in a controlled environment. Additional nutrients from other agricultural processes rich in Nitrogen, Phosphorus and Potassium are available as a useful nutrient flow. This is beneficial to ecological and operational results.

The Hortus Aquarius is unique in this sense: it simulates a semi-natural cultivation method. Once the germination phase has taken place for about one week (using fresh water), there are four weeks left for the product to grow towards its desired size using daylight and salty effluent. This salty effluent is collected from a central point in the Aquapolis Centre, which is part of a circular aquaculture system. Using tidal irrigation systems, the saline vegetables will be irrigated in a semi-controlled environment. After irrigation the effluent from the saline vegetable lagoons is collected in a basin and stored for further re-utilisation. The system secures year-round availability of fresh saline vegetables.

Hortus Aquarius comprises certain innovative aspects that can provide a solution for current and/or future problems:

- Modular and symbiotic system production by industrial ecology principles – the residual water from the shrimp is used for irrigation and contains a natural fertiliser for saline vegetables, reducing the use of external sources.
- The irrigation method for the saline vegetables acts as a biological filter that expands the technical and economic performance of the shrimp production system.
- Reducing waste flows – water and energy are used efficiently within both companies, reducing the waste flows and eliminating the need of extra water or another polluting energy source.
- Continuous production – the Hortus Aquarius solves the problem of seasonal availability and quality/freshness of saline vegetables.
- Provides labour opportunities.
- Natural development surrounding the Hortus Aquarius.
- Potential for market development, combining aquaculture and horticulture is both innovative and practical.

Bringing theory and practice

Currently the concept of Farm City finds itself in a stage where practical implementation of a theory is encountering design aspects. During the last decade many theories and designs were developed in the field of sustainable agriculture, industrial ecology and clustered modular agro-energy systems; now the step needs to be made to practical examples demonstrating the advantages of modular integrated agro-energy systems in our urban environment.

It is also evident that, to a large extent, location, climate and atmosphere define the modular system and its design. A desert climate in Oman is completely different than the Rotterdam climate. The input and output flows and demands differ completely. This fuels the authors' confidence and motivation to continue with their mission to develop the concept of agricultural modular designs.

Gilbert Curtessi, Maarten Feberwee
Email: g.curtessi@transmare.nl, +31 6 50615462
www.farmcity.eu

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