University of Illinois at Urbana-Champaign School of Architecture
ARCH 572 • SPRING'11

ARCHITECTURE FOR AQUACULTURE

INVESTIGATION, DESIGN AND TECHNOLOGY OF FUTURE SYMBIOTIC FISH/ALGAE PLANTS IN SOUTH-EAST ASIA

MWF 1:00p - 5:00p in
TBH, 6 credit hours
Professor Dr. Ralph Hammann
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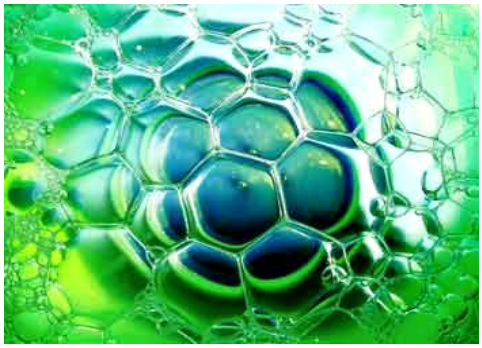


SUMMARY

The advanced studio will focus on emerging technology of large-scale symbiotic fish-algae plants and will develop—on a maritime site in South-East Asia—the following:

1. **Master Plan** for all infrastructural and program components of a symbiotic plant;
2. **Comprehensive Building Design** including the necessary building technology of an enclosed algae production facility.

Participants in this studio will have the opportunity to take part in Skype-based Q&A conversations, short-time instruction, and reviews with two of Germany's leading academics in the respective fields at the University of Giessen and the TU Darmstadt. The project teams consist of two students per team. Students will compile the final result of the studio work in a bound-book format for publication on lulu.com.

(The following text is an excerpt of the forthcoming book: Hammann, R.E. *"Creative Engineering"* (2011)

INTRODUCTION

Between 1975 and 2000, human population increased by 159%, from approximately 4 billion to 6.06 billion. Global population numbers, and rising economic prosperity in many economies, not only China, change long-established food conventions. Such shifts cause major challenges for food supply and may result in the following conditions:

- *Need for more agricultural surface area for food production*
- *Reciprocal effects related to climate change.*

Although the availability of food items on Earth has recently—on average—been improved, this does not necessarily mean that the problem of adequate food supply for approximately one billion humans is secured. In the case of China, the meat market and various livestock inventories have strongly increased to satisfy the suddenly growing demand for animal-based protein. China's protein feed import dependency rate has increased substantially.

It cannot be expected that human nutrition can be limited to an entirely vegetarian diet. Animal protein, composed of amino acids, vitamins, and unsaturated Omega-3 fatty acids, represents an essential component of a healthy diet.

Modern innovative enclosed aquaculture systems[1], in relation to land-intensive animal-based protein cultivation[2], require only 0.3 kilogram of fishmeal, 0.9 kilogram of soy, and an additional .03 kilogram of microalgae to produce 1 kilogram of

[1] Aquaculture is currently one of the fastest growing areas of food production in the U.S.

fresh fish to supply the important Omega-3 fatty acids so essential for healthy human nutrition. Enclosed cyclic aquacultures require eight times less fishmeal than traditional aquacultures. The resulting ecological and economic ramifications are significant. In addition, 10 times less soy beans are required, which has positive consequences on future land and water consumption and the general waste related to the production of food. With approximately 20% of all greenhouse gas emissions[3], human nutrition presents itself as a major contributor. Agricultural production amounts to a contribution to global carbon emissions of approximately 10–12%. Mainly the gases of methane and nitrous oxide as a by-product of livestock production are contributing factors. Plant-derived human food amounts to only a tenth of greenhouse gas emissions compared with those of non-vegetarian foods. It is noteworthy that in organic plant-related agriculture a much smaller amount of energy is required for production than in conventional, "non-green" production systems.

Algae-Fish Symbiosis

If we intend to be serious about a sustainable nutritional future for humankind, we need to consider the partial replacement of meat products with seafood. Additionally, seafood cultivation needs to shift from feeding technologies currently focused primarily on fish products, so-called by-catch (small fish), to those that provide fishmeal by algae and their by-products.

Algae as the promising human food energy supplier for the future have the following remarkable advantages:

- High biomass yield
- Capacity to capture carbon-dioxide
- High lipids concentration
- High protein concentration
- Omega-3 fatty acid concentration
- Capability to produce hydrogen
- CO_2 connection capacity
- High bio diversity.

Algae are best produced in a "factory" environment where not only clean, controlled conditions can be assured, but where the plant is exposed to the most favorable temperature range, carbon dioxide supply, and pH level. The dried algae plant material will be used as algae feed for large-scale aqua cultures. The farming of fish is the most common form of aquaculture. It involves raising fish commercially in tanks, ponds, or ocean enclosures. Fish species raised by fish farms include salmon, bigeye tuna, carp, tilapia, catfish, and cod.

In 2004, the total world production of fisheries was 140,500,000 tons, of which aquaculture contributed 45,500,000 tons or about 32%.The growth rate of worldwide aquaculture has been sustained and rapid, averaging about 8 percent per annum for over thirty years, while the take from wild fisheries has been essentially flat for the last decade. The aquaculture market reached $86 billion in 2009. Aquaculture is an especially important economic activity in China. Between 1980 and 1997, the Chinese Bureau of Fisheries reports, aquaculture harvests grew at an annual rate of 16.7 percent, jumping from 1,900,000 tons to nearly 23,000,000 tons. In 2005, China accounted for 70% of world production. In order of magnitude, the major producers are China—their reported output is double that of the rest of the world combined (although some scientists raise doubts about the numbers being published)—followed by India, Vietnam, Thailand, Indonesia, Bangladesh, and Japan.

Architecture for Algae-Fish Symbiotic Plants (AFSPs)

Future symbiotic microalgae-aquaculture facilities, or AFSP, will be an opportunity—and necessity—to develop an entirely new architectural expression, a new building typology. Since both radial or linear layouts of the microalgae tank arrangements can be conceived, only limited by the characteristics of the selected site, the architecture of such plants will have the opportunity to work with the two most common—and most powerful—geometrical shapes in architectural design: the circle and the axis (or datum line.) Large radial arrangements for the algae farms could resemble those systems used for irrigation called "center-pivot or circle irrigation," which are prominent sites in an arid or semi-arid landscape when seen from

[2] The Amazon lost some 10,000 square miles of forest cover in the year 2009 alone—40 percent more than the year before. In Brazil, soybeans are claiming increasingly bigger swaths of rainforest to make way for plantations, adding to the inroads by ranching.

[3] In Europe

an aircraft. Since AFSP aquafarms may be located near, or within, bodies of water such as coastal or inland lake areas (saltwater or freshwater fish), the plant facilities also will be transitional structures bridging a gap between two physical site conditions, such as the shore or land, and that of water.

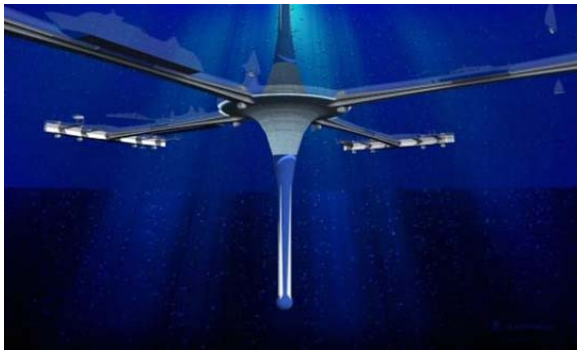
Depending on the following parameters of the selected technology and the desired fish production, the architecture of the future AFSP will be determined as follows:

A: Microalgae Production

in the following geometrical configurations:

- Linear
- Circular
- Spiral-vertical, or
- Plates

B: Fish Production



- Mariculture (fish production in sheltered coastal waters, also for marine crustaceans (shrimp) or mollusks (oysters)
- Sweet water farms (inland, near lakes, or independent.)

Additional components of a master plan for such large facilities will be plants for sewage treatment and removal of other pollutants.