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

Syllabus

MWF 1:00p - 5:00p
Location: TBD
6 credit hours

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

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 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

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\(^1\) Aquaculture is currently one of the fastest growing areas of food production in the U.S.

\(^2\) 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
dioxide supply, and pH level. The dried algae plant material will be used as algae feed for large-scale aquaculture. 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 typography. 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 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.

**PROGRAM**

<table>
<thead>
<tr>
<th>Gross site area:</th>
<th>27,604.00 m²</th>
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</thead>
<tbody>
<tr>
<td>Useable area: 65%</td>
<td>17,942.60 m²</td>
</tr>
<tr>
<td>Roads, Parking, Storage, Sewage Treatment Plant and Landscaping</td>
<td>9,661.40 m²</td>
</tr>
</tbody>
</table>

A: FISH HALLS (incl. storage, processing, auxiliary) (4): 8,560.00 m²
B: ALGAE PLANT (incl. storage, processing, auxiliary) (2): 3,250.00 m²
C: BIOMASS PLANT (1): 1,700.00 m²
D: ADMINISTRATION CENTER (1)
E: POWER PLANT (Type: Combined Heat-Power Plant CHP)(1): 1,632.60 m²
F: BIOGAS PLANT and FERMENTER (1): 1,000.00 m²

TOTAL Gross Square meters “Buildings” 17,942.60 m²

**SEMESTER OBJECTIVES AND OUTCOME**

This is a semester-long project. It is organized into **two phases**.

**Phase 1** *(Group Project, and Team Project, 2 persons)* will consist of an
  1. in-depth analysis of the program, Research of Literature, Bibliography;
  2. the construction of a site model;
  3. theoretical studies of algae and fish farms already in existence and the related technology for their operation;
  4. Master Plan for the facility, showing location for fish halls, algae farms, infrastructure, office and laboratory building, and all necessary access roads for truck, car, waste removal and delivery traffic, including parking.

**Phase 2** *(Team Project, 2 persons)* will explore
  1. the building design, including the features for energy generation such as photovoltaic and solar thermal systems,
  2. the assembly and materials of an advanced building envelope and roof structure for
     a) either the fish halls
     b) or algae farm installation
3. The selection of materials, i.e. glass types and metal construction of the enclosure, systems of external solar shading and internal glare protection as well as the integration of such systems into the structural and active and passive systems concept of the building will be required. One overall building model and one large physical model of the building’s chosen facade section are required.

**Pedagogical Objectives**

Upon successful completion of the studio laboratory course, students will be able to:

- Analyze requirements and select solutions for current state-of-the art industrial scale organizational schemes.
- Assess, select, and coordinate building envelope systems, structural and material assemblies with the chosen building design in coordination with selected building systems for a modern industrial building;
- Select, configure, and detail building materials and assemblies, mainly in the area of the building envelope to satisfy the requirements of complex building programs with an emphasis on energy consumption and conservation, and active and passive building systems;
- Be able to communicate effectively the essentials of the project program and selected design by a variety of means, including scaled physical models at various scales, drawings, sketches, and computer generated representation techniques;
- Be able to design, calculate and configure in metric scales (SI units.)

**Completion requirements:**

- Completion of assigned exercises;
- Periodic progress review;
- Mid-term and final semester presentations;
- Comprehensive demonstration of competence by inclusion of complex variables in project design with documentation through sketches, drawings, models, photos, and computer renderings.

**Semester Body of Work:**

1. **Phase 1** (Group project, two students)
   Topographic Model Scale 1:500, metric.

**Master Plan design (Group project)** The phase of initial design is also the moment to analyze climate data as a base for the selection of future building systems selection. Here the following parameters of the site will be of importance:

   a) Number and yearly distribution of hours/days of sunshine;
   b) Amount and distribution of rainfall;
   c) Temperature and humidity distribution, daily maxima, yearly/monthly average, diurnal swings etc.;
   d) Soil conditions (in order to evaluate feasibility for geothermal applications), water table, flood plain existence;
e) Wind; direction, intensity, percentage of occurrence.

   Recommended software: ClimateConsultant incl. Weather file for Seoul.

2. **Phase 2** (Team project):
   Building design of large span industrial structures, Façade concentration

**Studio Project Requirements**

**Phase 1:**

a) **Topographic model**, Scale 1:500
b) **Climate and country analysis**, Case study
c) **Design of Master Plan. Due:** (Mid-term).

Review spaces: TBD

**Final Deliverables Phase 1 for Midterm, incl. above:**

a) Site analysis documents (Culture, climate, suburban fabric conditions, traffic)
b) Site plan 1:500, metric (all buildings, infrastructure, access roads, parking, landscaping)
c) Site model 1:500, metric
d) Site sections (2) East-West, North-South 1:500
e) Site elevations (2) 1:500, metric

**Phase 2:** In-depth investigation: Architectural Design/Structure/Enclosure/Energy for Final Review

Incl. all items of Phase 1.

a) **Description of concept** (500 words)
b) Site plan (1), incl. roof view, landscaping, roads, parking etc. 1:500 metric (This will be an updated version of site plan of Phase 1).
c) Floor plan (1), complete facility (1:200)
d) Floor plan(s) of the selected facility (either Fish halls, or algae plant) 1:100
e) Elevations (2) of the selected facility, 1:200
f) Sections (2) of the selected facility, 1:200
g) Four (4) exterior renderings depicting clearly façade design incl. shading, façade materials, shading, structure etc.
h) Four (4) interior renderings depicting clearly structure of roof, basins, wall treatment, colors, technical infrastructure, building systems and infrastructure.
i) Cross-sectional model of the selected facility (1:100, material: acrylic white and/or clear only)
j) **Book chapter entry into hardcopy book. (Details will be provided in class)**

   Presentations in reviews in Arch 572/E3 are electronic. Details about presentations will be discussed to a later stage. However, selected projects will need to be prepared as hardcopies for Earl Price and/or Chicago prize submissions, as well as for archival and accreditation purposes.

   **Note:** The project will be developed and design in SI (Metric) units.

3. **Text**
Recommended and essential for the design process are the following books related to project specificities:

- “Technology of Ecological Building”, Daniels, K. Birkhaeuser
- “20°/40° Latitude: Sustainable Building Design in Tropical and Subtropical Regions” Hindrich, Daniels (Eds.)

Recommended and essential for the design process are the following books related to building and envelope topics:

- “Intelligent Glass Facades”, A. Compagno, Artemis 1995

Recommended architectural journal for the course is:

- DETAIL magazine

which is available in the library. Students are encouraged to make extensive use of Ricker Library’s resources, including the Avery Index to Architectural Periodicals, accessible from the Ricker Library’s website: www.library.uiuc.edu/arx/

Recommended as a “Rule-of-Thumb” reference guide for the sizing of structural members and mechanical systems in the initial design phase is: