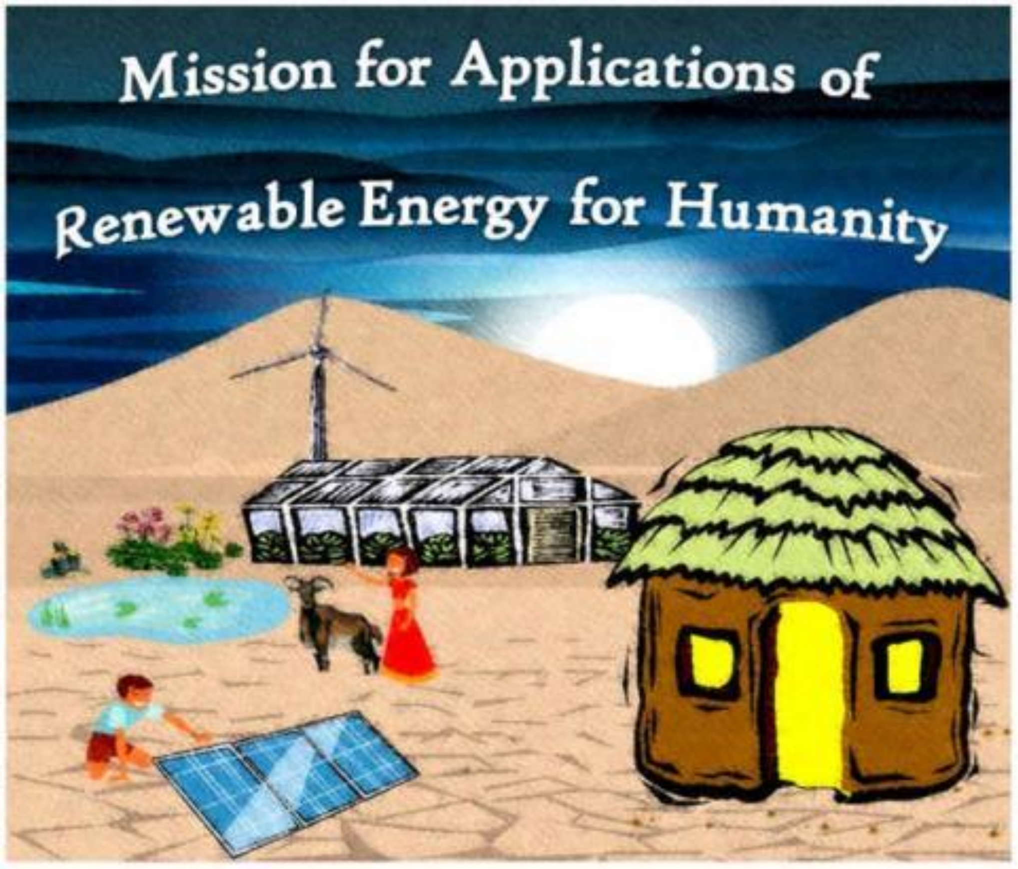


Applied Research
Sustainable Renewable System Design for Aquaponics and Hydroponics Systems

October 2013

Making sustainable technologies workable, affordable, and profitable.

Dr. Robert L. Straitt, CEM

Introduction

- People are starving in today's world, not just in foreign countries like Africa, the Middle east, in Europe, but also here in the USA, and even right here in the state of Arkansas.
- Over two billion people in our world today, do not have access to the utility electrical grids for power needs.
- Poor soil conditions and lack of access roads make agriculture extremely difficult, if not possible, in many of these areas.
- We want to find a way to counteract the problems of food shortages and lack of basic electrical power that faces so many people and families in this world.

Research Overview

- Our project in Sustainable Renewable System Design of Aquaponics and Hydroponics Systems is intended to explore both the technology and the techno-social issues of renewable energy in a setting that transcends both horizontal (geo-political) and vertical (social-economic) boundaries.

- We are focused on research models that will produce information, on solutions that are scalable in size and adaptable to diversified climates, easily deliverable and have innovative designs that can be transitioned from the rural outback, to large commercial applications, or residential installations.

The Questions to Answer

- What could be built that would provide a way for an average person just about anywhere in the world to be able to produce food, and also would be powered by renewable energy source(s)?
- Would the supplies needed to build and operate these systems be easily available to the average person?
- Would the average inexperienced person, handy with basic tools be able to construct a system that worked?
- What would be the medium with which the plants would grow in?
- What kinds of and how much renewable energy would be able to handle a food growing operation?

A Likely Solution

Hydroponic/Aquaponic Solar Green House:

- Can be erected in virtually any climate
- Reliable, proven construction.
- Does not need to depend on fertile soil for a growing medium
- The building process is easily taught and constructed with out complicated tools.
- Hydroponics can be used in a closed loop system that will use less water than regular agriculture.

Phase I Focus Issues

1. Identify what renewable energy sources would that would be best for the climate the test bed is located in.
2. Identify what level of power could be expected from an affordably priced array of renewable energy sources.
3. Based on anticipated power generation capacity that could be provided for a rural installation what type and size of agricultural facility would be the most efficient?
4. Identify potential risks in maintaining a sustainable system in a remote community with no logistical support.

Phase I - Hydroponics (2012)

The growing of plants in a soilless medium.

Two systems are commonly used

Nutrient Film Technique (NFT)

- growing seedlings on floating rafts in non-circulating water, such as, a trough of nutrient rich water.

Continuous-flow solution culture

- circulating nutrient rich water past plants started in holes in pipes with their root system fully immersed in the water.

Phase I-Hydroponics- Key Results

1. During the concept definition activities it was determined that the first face activities would be focused primarily on qualitative rather then quantitative data collection.
2. Solar power was chosen for the renewable energy power source because of its suitability to the test site climate and analysis indicating that solar energy generation was effective in most all climates the system would be used in.
3. It was determined that ~36 watts of solar power were needed to power water pumps, oxygenators, and grow lights. A 45 watt a amorphous solar panel system array was chosen based on size, power, and costs , which provided sufficient power to run the hydroponic system.

Phase I Key Results (cont.)

4. With the ease of adding additional power module it is possible to scale up the design to provide enough produce for one or more families or a small village.
5. The largest risk to successful deployment was soon realized to be logistics of providing commercially manufactured components for the hydroponics / aquaponics, pipes, tanks, fittings, etc. to developing regions.
6. It was noted that temperature was a key parameter to monitor. Uncontrolled temperature rises could harm plant roots.

Phase II Focus Issues (2013)

Aquaponics

1. As a closed loop aquaponics system could have a higher energy demand one question was how much more power would we require to provide a proper fish habitat?
2. What type of water filtering and oxidation system could be developed from components that are generally available anywhere?
3. Type of plants would be most adaptable to this type of system, both from the perspectives of produce production and maintaining water quality.
4. Developing an approach to control water temperatures to prevent overheating of plant roots and oxygen depletion.
5. Identify any substantial differences between commercial type aquaponic systems and sustainable aquaponic systems for developing regions.

Aquaponics (2013)

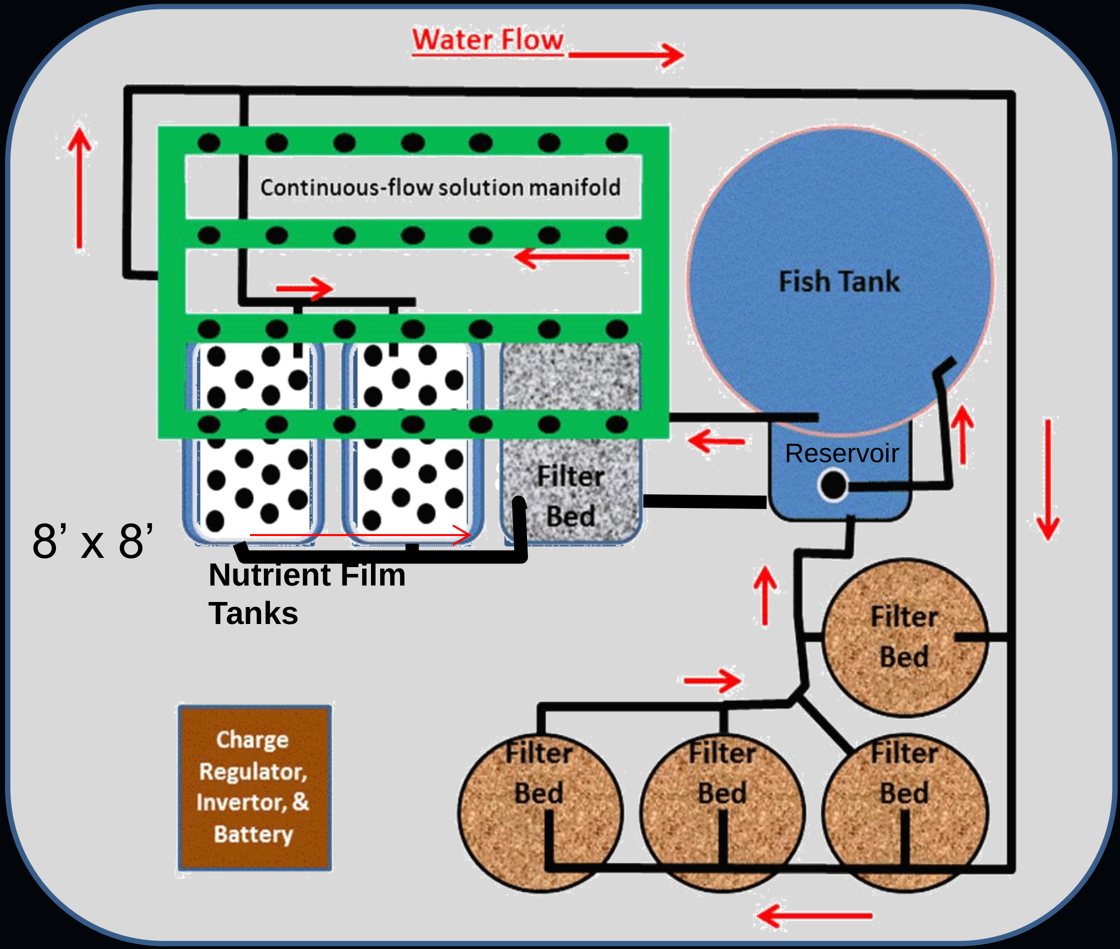
Aquaponics is the integration of raising fish and plants into a single sustainable system.

The use of natural nutrients from fish effluent (manure) can be the food stock for a variety of easy to grow and highly profitable organic foods.

Dr. Robert Straitt, CEM
Certified Energy Manager

Fish effluent has been
found to contain enough ammonia, nitrate, nitrite, phosphorus, potassium, and other secondary and micronutrients to feed a variety of hydroponics plants

Aquaponics Test Bed Configuration



- Continuous Flow manifold is elevated to level of water in fish tank.
- Nutrient film tanks are below the manifold and water flows from manifold to them and then throw filter bed
- Round filter beds set about 5" above ground level and drain from the bottom into the reservoir.
- Reservoir is below the fish tank and set on ground level.

Aquaponics Test Bed

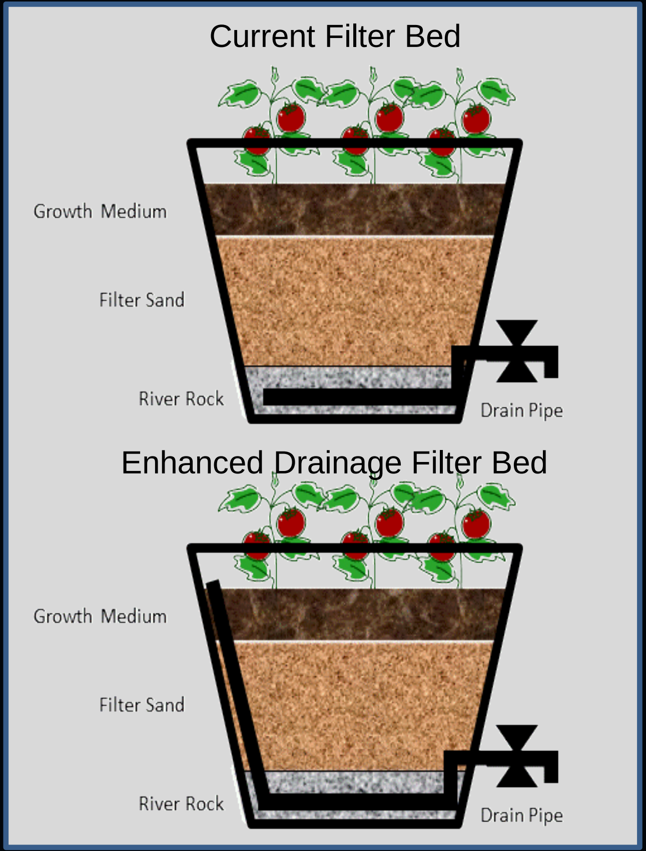
- In a developing area people will try to use whatever components they can find to help feed themselves and make a living.
- We attempted to construct our test bed from either recycled components found locally where possible or from common parts such as pipes, hoses, and wood that would be available in most places.
- Items like solar panels systems, batteries, and electric pumps would have to be imported into developing areas.

Phase ll Key Results

1. We found that a minimum of ~90 watts of solar capacity would be required to power the aquaponics as configured.
2. Adequate oxygenation is a critical a aspect of a successful aquaponics system. Our approach experimented with the following methods.
   – Water cascade method-all drainage water was allowed to free fall in pipes and splash in filter beds to self-oxygenate
   – Solar powered water spray-a small solar powered pump was used to create a spray in the fish tank to oxygenate the water
   – Oxygenation pumps were used to experiment with increasing oxidation level in the fish tank and hydroponic pant growing areas

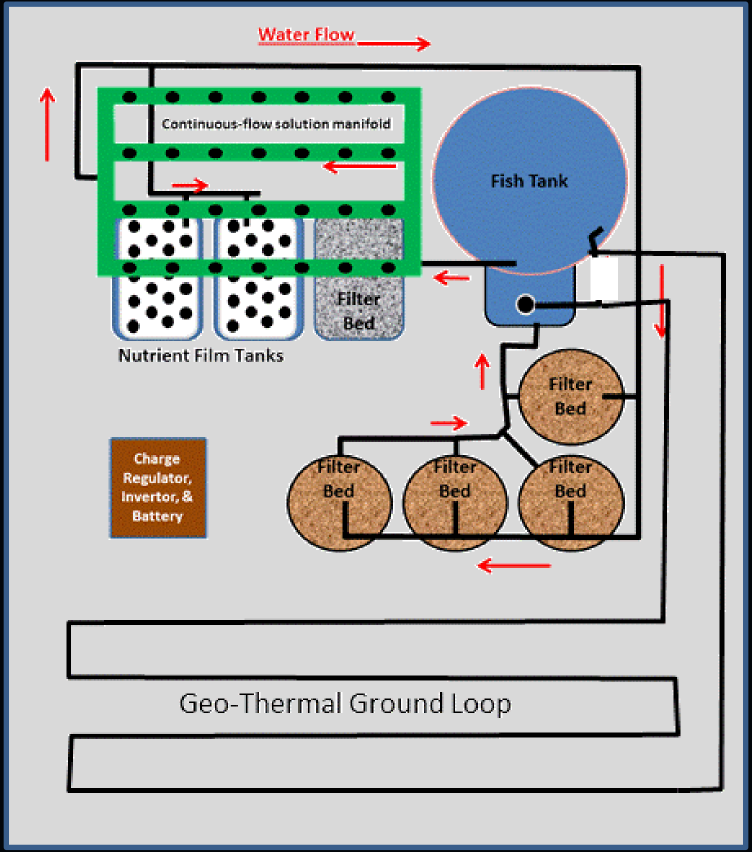
Phase II Key Results (cont.)

3. Use of artificial lighting powered by solar energy provided a significant improvement to plant growth rate and overall plant health.
4. Filter beds can become over-saturated with water at various times and must be designed to be able to effectively drain without allowing excessive amounts of unfiltered water back into fish tanks.
5. Composted bark mulch was used as a top layer growth medium in the filter to represent a degraded soil condition that may be found in harsh environments. Even though it tended to discolor the water the fish continued to thrive and algae growth was minimal.



Phase II Key Results (cont.)

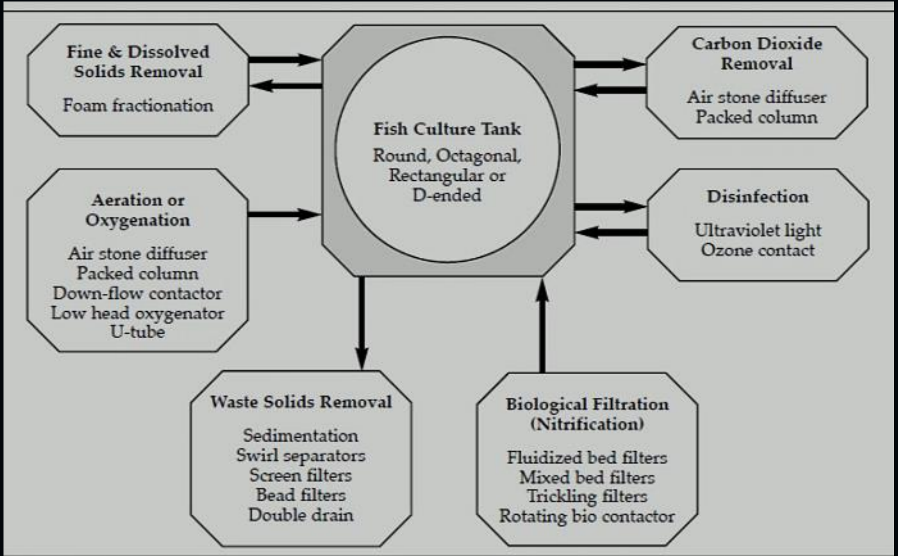
6. We found that a minimum of ~90 watts of solar capacity would be required to power the aquaponics as configured.
7. Oxygenation is a critical
8. It was noted that temperature was a key parameter to monitor. Uncontrolled temperature rises could harm plant roots.
9. A Geo-Thermal cooling/heating component was added to the configuration to regulate the water temperature in the fish tank and hydroponic tanks.



Phase II Key Results (cont.)

10. After doing intensive research into commercial scale hydroponics systems it became obvious that both the energy demands and the logistical support demands of aquaponics systems configure in this manner would fall well outside the parameters of sustainable renewable energy aquaponics for deployment at the family level in developing regions. A better model is needed to meet the techno-social demands of the end users.

(It is recognized that renewable energy can support commercial system but not for this particular end user group)



Required unit processes and some typical components used in recirculating aquaculture production systems.

Mission for Applications of Renewable Energy for Humanity

Sustainable Aquaponic and Hydroponic Systems

Phase II Key Results (cont.)

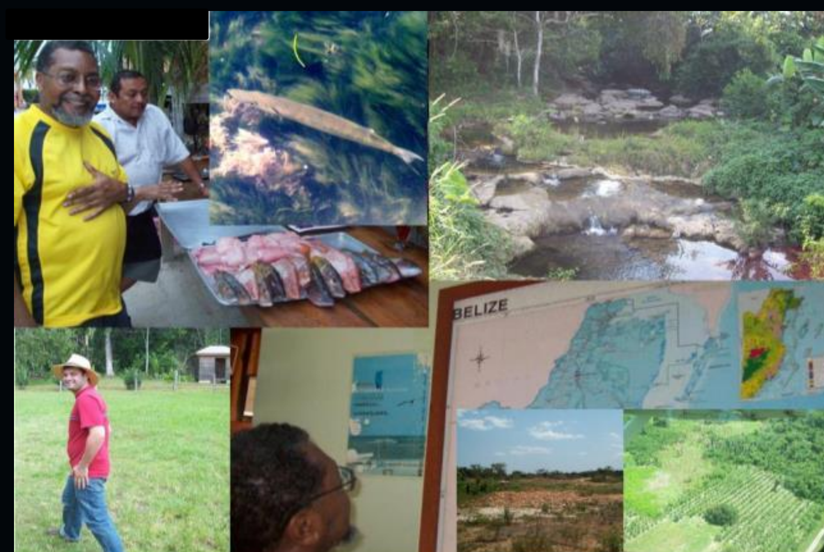
10. (cont.) Commercial Aquaponics Research & Training

Jacob Holloway, M.S.
Certified Aquaponics Technician
MAREH

University of the Virgin Islands, Aquaponics Research Center

Phase II Design for Sustainability & Supportability

11. Research into the techno-social aspects of small scale sustainable agriculture indicated that a sustainable design must be focused around the concepts of supportability as defined by the logistical infrastructure capability local to where the system will be deployed.



Above: MAREH's Walter Ellis and Dr. Robert Straitt review a model of small scale sustainable agriculture, to better understand the conditions that renewable energy would have to support and operate in.

Left: MAREH's Walter Ellis and Jacob Holloway in Belize collecting data for developing a sustainable renewable energy system model that can be deployed in developing regions to aid local populations.

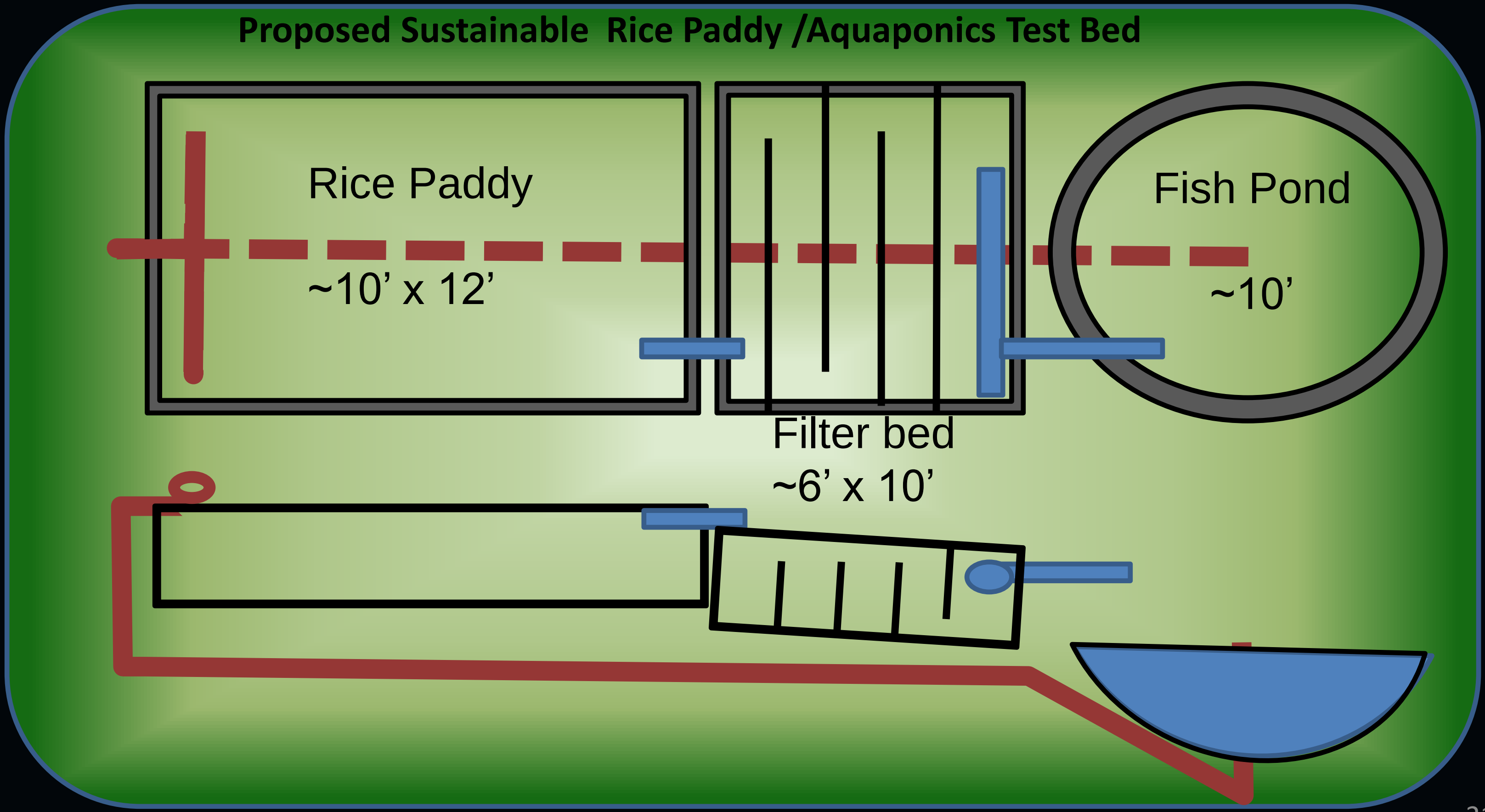
Phase III (2014)

Sustainable Aquaponics Test Bed

Objectives:

1. Understand the practical and environmental aspects of closed loop sustainable aquaponics powered by renewable energy.
2. Create a working model of a low-cost, supportable and sustainable food and energy production system that can be easily installed and maintained by unskilled/semi-skilled workers in developing areas.
3. Collect data on water quality of growing area run-off water and fish pond/collection basin water to help define the best methodologies for keeping plant nutrients and soils in the plant growing areas, removing effluent and other undesired materials from fish growing habitats, while minimizing the need for continually adding fresh water from wells and other sources to the system.

Phase III (2014) Sustainable Aquaponics Test Bed (cont.)



Phase III (2014)

Sustainable Aquaponics Test Bed (cont.)

Model of a rice field, and drainage area, with an in ground fish pond/water runoff collection basin.

1. Designed around structural components that are readily available in the local markets:
   - Sides/frame can be from boards, logs, rocks, dirt mounds.
   - Water retaining liner can be plastic or other impervious material such as local clays, or even cement.

Phase III (2014)
Sustainable Aquaponics Test Bed (cont.)

3. Configured to minimize need for renewable energy.
4. Designed to conserve water to minimize need for chemicals, curtail soil erosion, and reduce nutrient run-off into waterways.
5. Will be instrumented to collect information on water flow, nutrient leaching into runoff areas, and drain water erosion loading including; dissolved load, suspended load, and bed load, as well as water temperature of the pond and root systems will be monitored.

Conclusion

- Multi-year/multi-phase project to understand not only the renewable energy technology but also the techno-social issues in successfully integrating renewable energy generation on a broad scale across developing regions, has completed phase II objective and is moving on to phase III.
- Researchers are actively participating in understanding the social/cultural and have acquired significant qualitative experience and understanding of the sustainability processes that are used in a variety of agricultural settings, that effect the initial success and the continued sustainability of renewable energy systems in rural developing region.
- Enough qualitative data has been collected to design, build, and evaluate a instrumented test bed, which will mimic in scale an easily implemented and maintainable renewable energy powered aquaponics system for families and communities in rural developing regions around the globe.

For more information on this project or other applications of renewable energy for humanitarian, educational, residential, or commercial project please contact:

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