# HYDRON:

## Networked Aquatic Ecosystems

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## Abstract

In order to harvest food in urban environments today, new techniques must be explored to maximize space and output. Hydroponics, a technique where plants are grown in a soilless medium, removes the need for heavy damp soil in horticulture. With this process, food can be cultivated on rooftops and even vertically, evolving urban environments by enabling growing areas never before possible. Aquaponics[1] is a method which utilizes hydroponics to produce plants and fish symbiotically. Fish and plants use each other's by-products to grow in balance, creating two food sources in one ecosystem.

These aquatic ecosystems require delicate care. Careful understanding of nutrient balance and toxin levels is very important to ensure success. Shifts in nutrient and toxin levels can happen quickly and drastically threaten healthy crops. To address this, Hydron, provides open-source affordable data collection for individuals, communities and urban farms to communicate the health of their ecosystems; creating a dialog between ecosystems and their caretakers. Once the data is collected groups of participants are able to share research. Hydron enables the participation needed to connect the efforts and findings of urban farmers across the world. Removing the barriers of entry to this field through data collection and dissemination, Hydron encourages participants to experiment, learn and adopt these increasingly necessary agricultural advancements.

As producers, individuals and communities can create their own food. By doing so, they cultivate alternative access to healthy fresh sustenance, create and support local businesses and in turn, foster sustainable urban neighborhoods and communities. Hydron provides methods for individual and collaborative learning, participation and success by enabling novice and expert urban farmers to see, understand and communicate their results with the world.

Urban farmers are a small but growing population. Their role in harvesting the world's food is revolutionizing the way we produce, distribute and even consume nourishment. Research and development at both independent and community levels is ongoing to promote and facilitate greater participation in urban cultivation. In response, Hydron provides a semi-autonomous data collection system for user education and support. Remote management of environmental data is vital to successful crop growth in urban contexts. By tracking and sharing the statistics associated within these ecosystems, Hydron seeks to support research, education and innovation in the field of urban agriculture.

## Problem

"By 2050, demographers estimate there will be an additional 3 billion people [in the world]." [2] With this steady rise in population comes the responsibility to feed them. Under current farming practices, "extra landmass as large as Brazil would have to be cultivated to feed [these additional people]"[2] In 2015 its speculated that 26 cities around the world will have a population of 10 million or more. A city of this size requires at minimum, 6000 tons of food per day.[3] Although these cities grow larger, the constituents within these cities must consume nutritious food at a constant rate in order to stay healthy.

At times,there is not adequate access to food with real nutrition, namely fresh fruits and vegetables. This is cited through the United States Department of Agriculture's *(USDA)* Farm Bill. Food Deserts are defined in

**1** Defined by The University of the Virgin Islands Agricultural Experiment Station as a recirculating system where nutrients, which are excreted directly by the fish or generated by the microbial breakdown of organic wastes, are absorbed by plants cultured hydroponically (without soil).

**2** *Skyfarming*, Chamberlain. http://nymag.com

**3** Drescher et al., *Urban Food Security*, 2-3

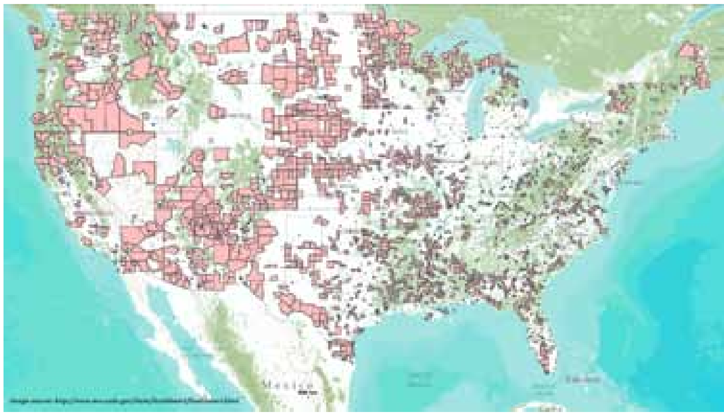

**Figure 1a - USDA Food Deset Locator Contintental United States**

**Figure 1b - USDA Food Deset Locator New York City**

the 2008 Farm Bill as an area in the United States with limited access to affordable nutritious food, particularly such an area composed of predominantly lower-income neighborhoods and communities. Looking at the USDA's Food Desert locator *(Figure 1a)* of all the lower 48 states, it is evident that there are many areas lacking access to nutritious food, at affordable prices. If we take a closer look at the data we see that the USDA deems food deserts in the New York City to be non-existent *(Figure 1b)*.

According to the New York Daily News, the USDA's map claims only 26,000 New Yorkers live in a food desert: while city officials estimate 3 million people within the New York live in food deserts.[4] This highlights the fact that there within this problem there is not support from the National Government. Solutions for this issue will not come from the top-down and therefore must come from the bottom-up. In order to begin to solve these problems the local communities who are afflicted by a lack of fresh produce must participate in creating their own sources of nutrition.

While this may seem like a simple task, many individuals and communities find it hard to participate in local cultivation. Limited access to proper areas for growing vegetables, and a lack of knowledge about urban cultivation present two large challenges, which hinder groups to begin participating. These two hurdles must be addressed in order to spark greater engagement and facilitate success.

## Design Question

Asking individuals to participate in solutions is not always successful. It is vital how we approach this particular problem to clearly understand the needs of the communities being affected. In hopes of combating Food Deserts in America we must ask ourselves - what are the systems, methods and technologies that are needed in order to empower individuals and communities to become participants in local, healthy and sustainable food production?

## Guiding Questions

Having completed an initial prototype of the project as a mini-thesis in Computation Studio in the Spring 2011 the semester before Thesis Studio 1, this course became an opportunity to step back and deeply analyze the problem, and its potential solutions. Using Professor Scott Pobiner's pre-defined course 'Modules' as a framework enabled further research and exploration around urban communities, food access and production methods. A series of questions were raised based around each module in order to shape and determine

**4** Lucadamo," 'Food desert' Status Denied to 3 million New Yorkers Without Grocery Stores", *New York Daily News.*

the logical outcomes and adoptions of the project moving forward.

**Social**
What are people's perceptions about food? Do people know where their food comes from? How involved are people in their meals production? What are paths which meals take to get to individuals? Who will need to participate in order to augment current food production? Who/What are the Stakeholders, Partners, Users and Sites needed to be involved with the project?

**Conceptual**
What are the roots of agriculture, and how do they relate to society? What is the link between culture and agriculture, where did this connect come from? What are historical instances of the use of agriculture? How have these instances shaped the landscape of society? How were the largest early civilizations/cities able to approach high output agriculture to support growing populations?

**Technical**
What are the technical hurdles associated with aquaponics, semi-autonomous and recirculating food production systems? Which techniques and methods are the most efficient for users to capitalize upon? How can we plan effective modular systems, at various scales?

**Methodological**
What are the methods others are using in approaching urban agriculture? Do the systems succeed or fail? What are the key learnings/take-aways from these methods? How can these be implemented to benefit the project?

**Evaluative**
How do we evaluate the success of the project? How can we determine the scales of success? What are the key elements needed to achieve in order to evaluate the project? Are there levels of success?

After a variety of prototyping within Thesis Studio 1, user testing and experiments within the second part Thesis, Studio 2 with Professors Scott Pobiner and Sarah Butler presented a new set of frameworks and avenues for exploration, although these questions are much broader in scope they focus on the critical nature of the project and its relation and value within culture.

**Environmental**
How can reinvigorate agriculture into our living spaces? Can urban spaces be re-imagined into high output agricultural systems? How can we promote individuals and communities to produce their own food? How can we inspire the next generation to re-implement food systems in urban spaces? What methods can we capitalize on to create robust food networks? How can we share our success and failures in local food production to support greater implementation of urban agriculture? What does the world look like when we fuse living spaces with agriculture? Can we re-imagine food distribution in the world through local food production systems?

**Societal**
Can we circumvent the preconceived notions of agriculture and farming to enable small scale local food production to happen in cities everywhere? Does agriculture have to be business? What does agriculture look like if its not a business model? How can we support communities of agricultural enthusiasts to build and maintain productive successful agricultural systems? Who benefits from growing food in local urban environ-

ments, who is harmed? How can we reconnect society to their food sources? Can society support and maintain its own access to food, specifically in areas with generally limited access to nutritious food? How can sharing success and failures of small scale local agriculture support individuals and communities in their own food production endeavors?

## Prototypes

Throughout the year long examination a series of prototypes were created in order to better understand the previously mentioned modules of Thesis Studio 1. In each module prototypes or research was initiated and led the way to fully understand an agricultural solution. In addition to module prototypes and research, was a set of exploratory prototypes in the creation of hardware elements to foster a productive ecosystem.

### Social

Starting with this module it was important to quickly acknowledge the path of people's meals, as well as their perceptions about where this food came from. In doing this, a direction was fostered, and a greater outline of participants was acknowledged.

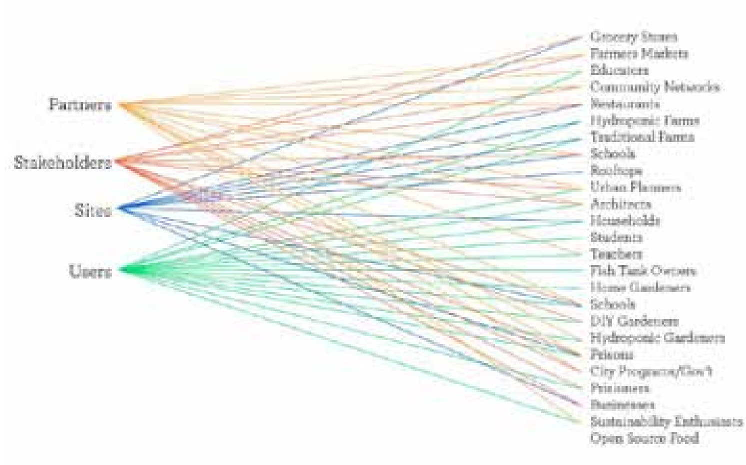


**Figure 2.a - Initial User Connections Chart**

An initial user chart was created to understand who might be involved with the process (*Figure 2.a*). With this information a simple prototype was executed on fellow graduate students. The purpose was to understand their perceptions of the 'food chain' and how their recent meals fit in.

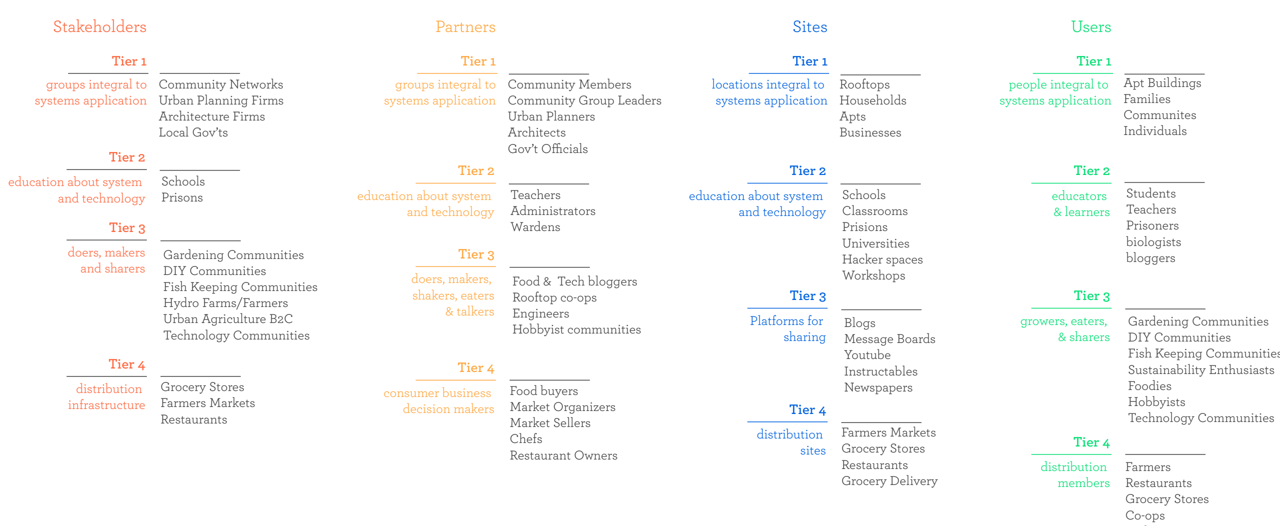


**Figure 2.b - User Identification Map**

Students were given a stack of cards with images of organizations and locations from the list (*Figure 2.a*). Participants were asked to arrange the cards according to their last meal eaten, to gauge their understanding the path that meal took to get to them. While admittedly a very menial prototype, it served a unique purpose in facilitating the creative process and brainstorming the social scenarios around food. One common thread emerged; the repetition of stores and markets. This lead to an analysis of the network we purchase food from, and how we, as consumers can potentially offset and supplement said network, as producers.

In the end, a more robust participant outline was created *(Figure 2.b)* as well as an understanding of the social connections that happen around food. The examination of this prototype then fostered research into neighborhoods and food culture in New York, and led to the acknowledgement and integration of the Food Desert as an agricultural issue. A document was created to show the juxtaposition of what communities as consumers vs. producers would look like, and how small New York shops, namely bodegas can serve as a community pillar for fresh food and vegetables *(Figure 2.c)*.

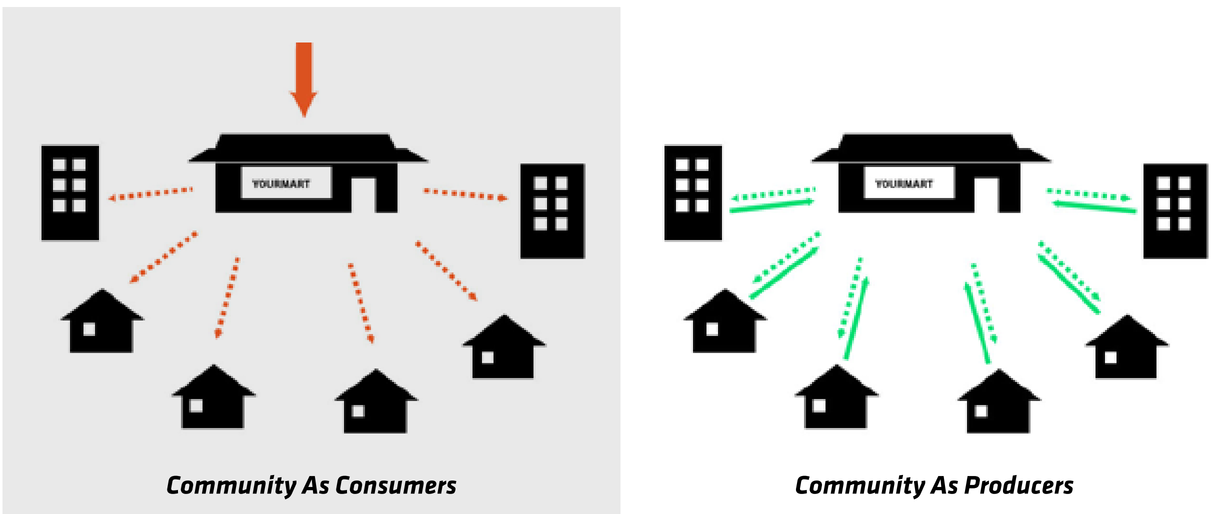

**Figure 2.c - Community Roles Diagram**

**Conceptual**
In order to examine the conceptual nature of Hydron a research prototype was created as a way to understand agricultures role and benefits in society. Five different scenarios throughout history were examined for their unique contributions related to agriculture and its way of creating, facilitating, or empowering a community of people.

A document was created outlining each identified advancement. For each item, the Mechanism, Means, Method, Task and Benefit were recorded and began to shape the key areas in which the project would need to be grounded *(Figure 3.a)*.

In the end, this prototype leads to the understanding of three main conceptual areas, in which the project must focus as an agricultural advancement. These three areas - the Aesthetic, the Cultural and the Technological emerged to showcase a balanced focus for the work. The Aesthetic is the opportunity to create beautiful spaces within with agricultural techniques, as seen in the Gardens of Babylon. The Cultural, is prevalent in each section *(Figure 3.b)*. It is highlighted in the need for people to be involved through labor, distribution and planning. Last is the Technical; in this sphere there was a realization that the dual production of Aztec

Chinampas is actually a technical advancement. This distinction lead to the integration of the modern dual production method of aquaponics.

| *AGRICULTURAL TECHNOLOGY* | *MECHANISM* | *MEANS* | *METHOD* | *TASK* | *BENEFIT* |
|---|---|---|---|---|---|
| **Sumerian Agriculture** | Systematically Planting Crops | Individuals Tasked With Care and Maintenance | Implementing Farms and Distribution | Care, Maintenance, Distribution and Billing | People can eat Without producing Or hunting |
| **Egyptian Irrigation** | Moving Water to arid Land | Creation of Dams and Canals | Planned systems of Water and land | Digging, Engineering, Planning and Maintenance | Non-fertile areas Can produce food |
| **Mayan/Aztec Chinampas** | Lakes as crop fields | Creation of floating Beds for planting crops | Mud, Williow trees, Combine to retain land And absorb lake nutrients | Digging, Engineering, Planning and Maintenance | Produce vegetables And proteins Simultaneously |
| **Babylon Hanging Gardens** | Brick, pumps and Asphalt building Housing plants | Structure/Building As a garden/oasis | A system of pumps to Move water into growing Beds for plants | Care, Engineering, Planning and Maintenance | Beauty and Enjoyment |
| **Victory Gardens Movement** | Call to arms to plant Gardens in public and Private spaces | 1920's media, newspapers, Movies, posters and radio Broadcasts as War propaganda | Empowerment of families, And communities to Become food producers | Creating culture of Creators to supplement War-time food stocks | Self dependent Communities, Local commerce, Feeding armies |

These findings helped to conceptually frame the project's major needs in order to design an agricultural advancement, similar to five key adaptations outlined (*Figure 3.a*). The results also helped to identify areas of further growth specifically as related to the technical requirements of the project, which became the next section of focus.

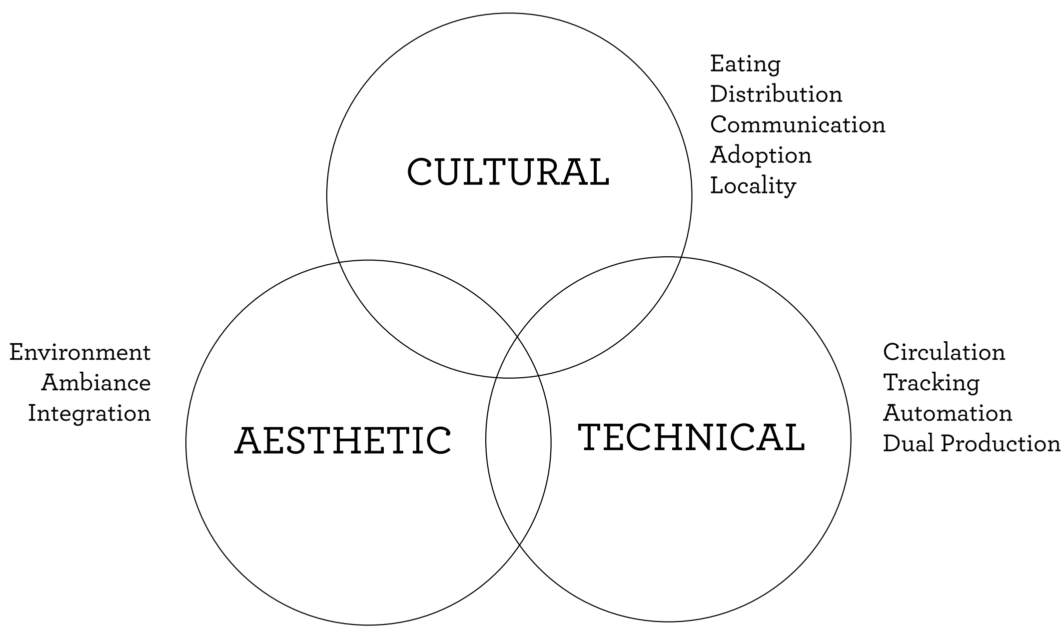


**Figure 3.b - Conceptual Vienne Diagram**

## Technical

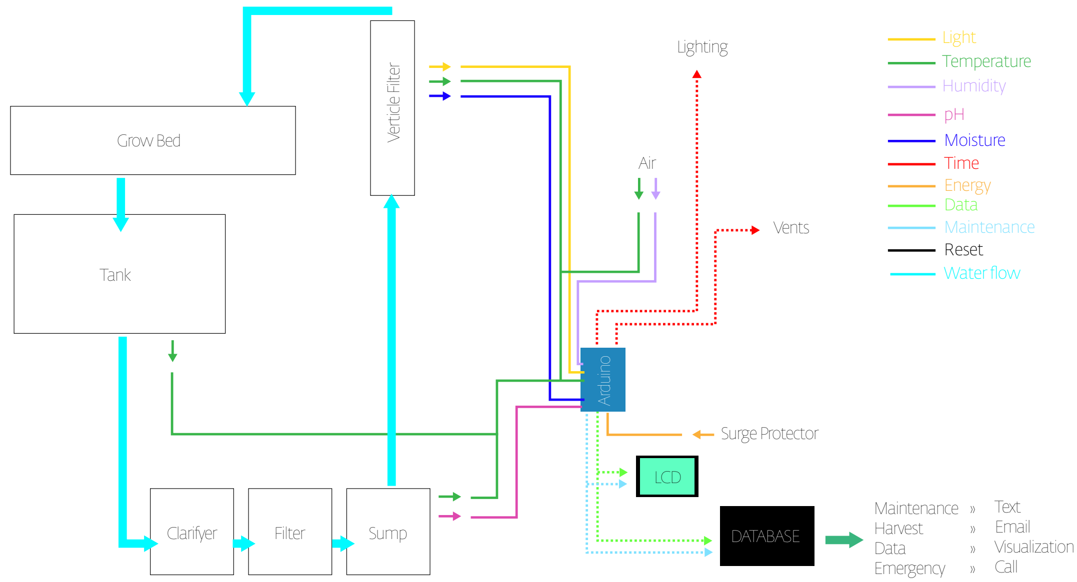


**Figure 4.a - Technical System Document**

Entering the technical module the project had a framing from the conceptual examination. Which brought to light the true value of a dual producing, integrated environment, with cultural support. The technical module provided the opportunity to understand how these 'concepts' could be implemented into working solutions.

In order to approach this module in digestible manner, the technical module was divided into three key areas to examine, Scalability, Modularity and Affordability. Scalability became apparent for users to be able to manage a system of any size using the tools provided. Whatever the implementation a user needs the same system of control over this technology to manage it. Modularity arose as a need for individuals and communities to implement things within their unique spaces. Finally, Affordability was identified through a need for individuals to be able to build, pay for and impliment these systems, without insane costs. All of these areas were identified by building upon previous examinations, from the social and conceptual modules.

In the hope to create a scalable and manageable system, a series of sensors and controls (Figure 4.a) were proposed to support users in their aquaculture endeavor.  According to the F1-Recirculating System by Family Farms, this type of aquaponics unit is capable of producing a pound of fish and a pound of fresh vegetables for each gallon of clean water used. This proved the promise of dual farming, outlined in the conceptual modules, as a key method for solving the problems of Food Deserts. This method provides the ability to grow both

| Data | | Use |
|---|---|---|
| Light | » | Health, Harvest & Lighting Control |
| Temperature | » | Health & Vent Control |
| Humidity | » | Health & Vent Control |
| pH | » | Health, Harvest |
| Energy | » | Efficiency |
| Moisture | » | Health, Harvest & Valve Control |
| Time | » | Harvest & Valve Control |

**Figure 4.b - Data Value Chart**

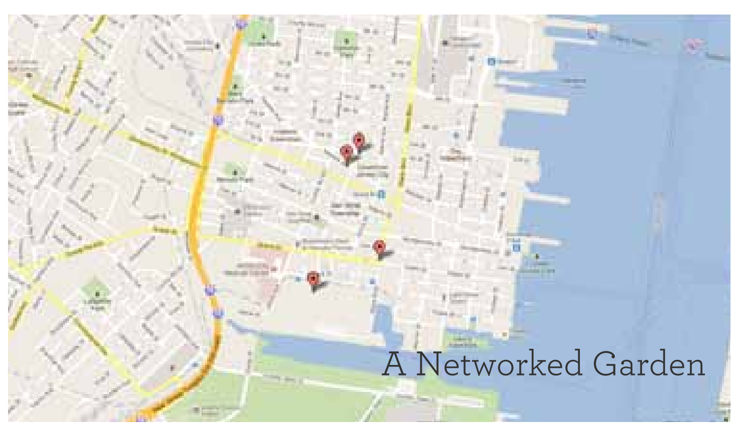


**Figure 4.c - Networked Gardens**

fresh vegetables and healthy proteins, creating a well-rounded meal. In order to justify the use of sensors and their needs, a document was created outlining their role within the proposed system (Figure 4.b).

In thinking about the Scalable nature of a system of this time, it is important to acknowledge the internet, and the potential to connect to others. By enabling connected systems users can impliment at scales which are appropriate and document those successes for others. Once networked, these gardens possess the ability to then become hubs for a farmer or gardener to visit (in physical space) only as needed. A system of alerts and real time information to users micromanages and supports the tasks necessary for care taking; making system maintenance theoretically easier. If the sensor network can a greater ease of use, than an individual or community can capitalize on a variety of locations for their garden in localized space (Figure 4.c) as a way to stagger crop harvests and take advantage of limited urban spaces.

The last aspect of the technical module, was the element of affordability. This became its own section of the prototypes, seen in the Filtration section as its prototypes spanned the majority of the projects time period and provided a great deal of growth and learning. A variety of experiments in the components needed to build cost effective aquaponics ecosystems for production were conducted. This technical examination found that there are ways which filtration and water flow can be built without the need to purchase expensive patented solutions. In designing affordable components, users have greater accessibility for adoption of the system as well as a greater benefit in the ratio of costs to production.

**Methodological**

The methodological module provided the opportunity to examine successful projects, in order to understand the methodologies they implemented. During this time period a variety of precedent projects were researched. Three projects were highlighted as key precedents to Hydron. The rationale for their role as a precedent was articulated and then each project was examined by a framework, in order to best understand its approach and results.

Each precedent was outlined by its Approach, Medium, Planning and Result. The three projects analyzed were Fritz Haeg's Edible Estates, Britta Riley's Window Farms, and Ken Rinaldo and Amy Youngs', Farm Fountain. These projects showcased themselves as the most relevant to Hydron, and their successes, war-

| *PROJECT TITLE* | *APPROACH* | *MEDIUM* | *PLANNING* | *RESULT* |
|---|---|---|---|---|
| **Edible Estates Frizt Haeg** | Converting Lawns/public spaces into Edible Crop gardens. Crowd Sourced for Lawns to gain recognition | Land and Edible Plants | Acquiring sites, plant selection and layout | Becomes a 'show' and an exhibit. Creates buzz which generates interest |
| **Window Farms Britta Riley** | Converting Windows into Hydroponic gardens | recycled materials, nutrients, pumps | Make it yourself or purchase pre-made. Schematics, how-tos, community forums . | Community of window farmers is growing across the country |
| **Farm Fountain Ken Rinaldo & Amy Youngs** | Using Urban space for aquaponic garden as installation | plants, fish, recycled materials, bacteria, lights | Location, plant selection, fish selection, light identification | exhibition installation, diy system, no community |

**Figure 5.a - Precedent Analysis**

ranted further analysis (Figure 5.a). In the end, this task facilitated a keen understanding of the competition's strengths and weaknesses, as well as avenues for adoption and an outline of what makes successful projects in Urban Agriculture.

The exercise highlighted the need for community involvement, through the methodology of both Edible Estates and Window Farms, and their success being related directly to fostering communities of people. Farm Fountains inability to foster a community highlighted a disconnect and a potential area of growth for them. Overall the methods for success were noted and are key to set the methodology for which Hydron must observe. At the same time this analysis facilitated the projects analysis into the Evaluative Module.

**Filtration**

This section serves to acknowledge the filtration specific needs of this project. Specifically it is important to note the integral needs to develop filtration for small scale aquaculture, using only accessible inexpensive materials as highlighted by the affordable section of the Technical Module.

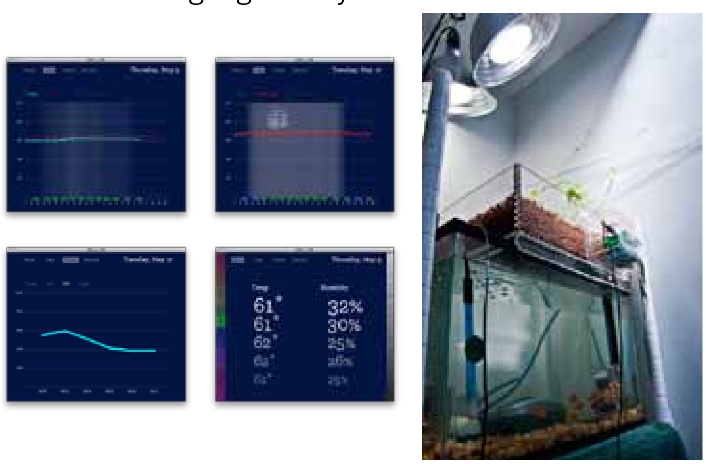

**Figure 6.a - Prototype v00.0**

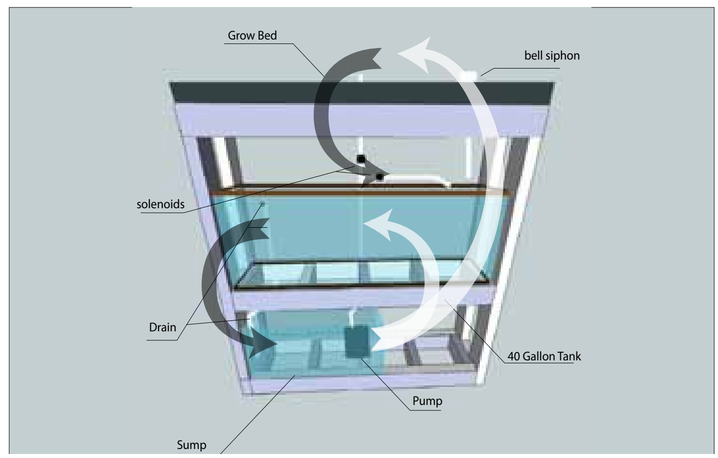


**Figure 6.b - Prototype v00.1**

The initial prototype(*v00.0*) was created based off the fore mentioned mini-thesis project from the semester prior, Spring 2011(*Figure 6.a*). This prototype, a 10 gallon tank with a plant filter, used a method of aquaponics known as an ebb and flow[5] system. Entering fall semester, it became apparent through research that the larger an aquaculture system, the more stable and dependable it becomes - this is common knowledge in the fish rearing and aquaculture communities. Additionally the first prototype showed a need for more water clarification, filtration, and oxygenation in order to provide a healthier aquatic environment for fish.

A more technically enhanced prototype(*v00.1*) of the initial ebb and flow system created was proposed to cycle watering and create constant flow of water for aquatic life (*Figure 6.b*). In order to execute the prototype two pieces of hardware needed to be created, a control using solenoids to regulate flow to location, and a sump/filter(*Figure 6.c & 6.d*). This filter used a bio filter[6] of sponges along with a substrate filter of rocks. Additionally the stand (Figure 6.b) was created to house the unit. (Note: The evaluation of this prototype will be addressed within the evaluative section below.)

The next prototype(*v00.2*) focuses on a realization that alternative technical solutions to cleaning and flowing water can also be solved within the scientific methods of Aquaculture. Rather than continuing to pursue a means of continuous water flow, through added electricity and programmed intelligence devised an alter-

**5** A hydroponic method where the plant grow-bed fills with water, until it reaches a cut off point of a syphon. Once the syphon is engaged all the water is pulled out of the grow bed. This cycle runs multiple times an hour keeping the plants roots saturated.

**6** The area within a aquatic ecosystem where good bacteria grows. This bacteria feeds on harmful ammonia, created via fish waste, and created nitrites and nitrates, or plant food. This byproduct is then safely removed from the system by fertilizing the plants.

Figure 6.c - Prototype v00.1 Sump

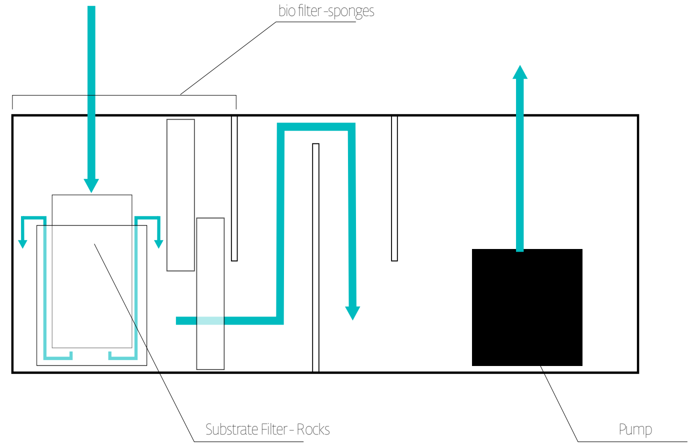


Figure 6.d - Prototype v00.1 Sump Flow

native solution to the ebb and flow method was concepted(*Figure 6.e*). Creating a continuous flow system, rather than ebb and flow presented the opportunity for cleaner water and better nutrient absorbtion for plants. In order execute this model a new type of filtration was required. Including a new functional requirement known as a Clarifier[7] (*Figure 6.f*). In addition to this system, a vertical grow bed[8] and a raft bed[9] (*Figure 6.g*), were added to the growing environment for the plants.

The filter examinations provided a means to understand better control of the science behind aquaponics. Rather than continually focusing on technology as a digital or electronic based result, it is important to acknowledge that technology can take the form of new scientific methods. In this case the prospective avenues show promise to lower energy costs and provide better nutrient absorption.

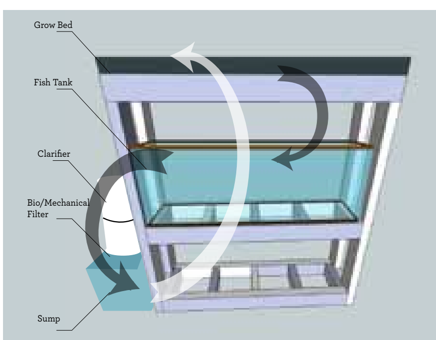


Figure 6.e - Prototype v00.2

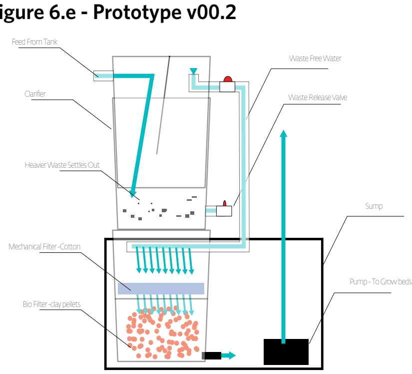


Figure 6.f - Prototype v00.2 Sump/Clarifier Flow

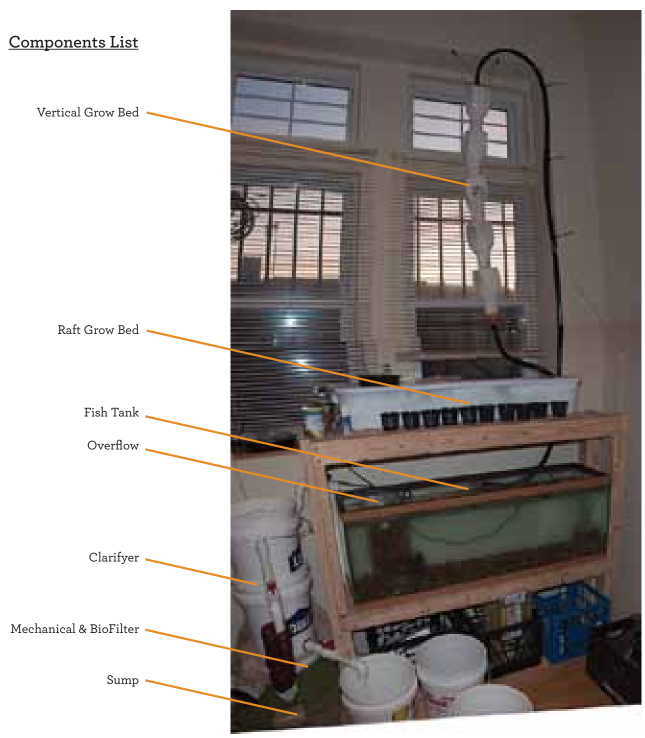


Figure 6.g - Prototype v00.2 component break down

**7** A piece of hardware which takes in water from a fish tank, the water is forced downward gently. The liquid is then forced to slowly rise in order to exit the device. During this process solids are settled out from the water, removing suspended solids, which cloud the water.
**8** A hydroponic technique of growing plants vertically to save space. The plants are provided nutrient rich water to their roots, while in a soilless substrate container suspended in air.
**9** A hydroponic technique where a plants roots sit directly in nutrient rich water that provides the roots nutrient rich water, using this method water must be extremely clean, continually moving and have a high oxygen content in order to maximize root intake and minimize root rot.

**Evaluative**
Approaching the Evaluative module last allowed for reflection upon the entire semester, as well as an analysis of the work completed to date. This facilitated reflection upon all the previous modules, including the filtration specific module. Additionally this section allowed for the integrated design principles as a guiding structure to gauge success, and evaluation of the project. Finally this section fostered the establishment of a method for every eco-system built, to begin to understand their differences, strengths and weaknesses with acknowledgement to the projects evaluative framework. Past prototypes were then applied against this evaluation guide, as a means to determine success and future direction.

Using the module framework provided within Professor Scott Pobiner's Thesis Studio proved quite useful. The constraints gave guidance to the process and in turn helped to provide direction and clarity. In approaching the evaluation of the work completed during the Fall Thesis Section, it became important to find other frameworks to support the project. Realizing that the project's main goals were to support sustainable economies and communities, it became evident that the Five Principles of Ecological Design by Sim Van der Ryn and Stuart Cowen[10] would provide strong framing for the examination and its potential success.

*The Principles of Ecological Design:*

1. *Solutions grow from place*
2. *Ecological accounting informs design*
3. *Design with nature*
4. *Everyone is a designer*
5. *Make nature visible*

Any prototypes or projects attempting to solve the Food Desert problem within New York, must fit within this framework to be deemed successful. Acknowledging this, the evaluative method was created to analyze past and future prototypes; leveraging two overarching classifications for the evaluation of prototypes. The first area is the environment a constructed system lives in; referencing the second Ecological Design Principle - we must be aware of the environment we design within and its effects. Each system must perform in unique areas, and accounting for fish and plant species correlates directly to the external environments in which these lifeforms thrive. The environment with which the Hydron system lives in is then analyzed by three sections; the micro, macro and social. The second area for evaluation is the prototype domains; it is important to recognize that there are a variety of domains merging within this project. By stating the purpose and use of each domain for each prototype it is clear to see what is overlapping, and then make distinctions as to what is successful and unsuccessful(*Figure 7.a*).

In looking at the document it is easy to see that the environment for each prototype is currently unchanging. This is due to the fact that new space has yet to be allocated, until now. This will be re-discussed within the Next Steps section. The prototype v00.0(*Figure 6.a*) failed to meet certain principles of the framework. Firstly the prototype had no social interaction, a processing sketch without any outside access to data. In addition the placement of the system provided a lack of light, which in turn prompted limited growth. Prototype v00.1(*Figure 6.b*) also had a had downfalls when examined through the lense of the framework which are important to point out. In this prototype, organizational flaws and a push for the use of technology caused a drastic and dangerous prototype. Leaking water caught above solenoids prompted circuit malfunction. The prototype was eventually scrapped for an alternative direction in which filtration hardware could replace

**11** Edwards, Andres R. 2006. The Sustainability Revolution: Portrait of a Paradigm Shift. Philadelphia, Pa: New Society. 103-104

| *PROTOTYPE VERSION* | *ENVIRONMENT* | | | *DOMAIN* | | | |
|---|---|---|---|---|---|---|---|
| | *MACRO* | *MICRO* | *SOCIAL* | *AQUACULTURE* | *HYDROCULTURE* | *HARDWARE* | *INTERACTION* |
| **v00.0** | North Eastern United States | Apartment | No Social Interaction | 10 Feeder Fish, Need more circulation & suspended matter removal | Minial plant growth, Needs more light and Grow Bedspace | Custom Ebb&Flow System with air pump | Flawed./ Non-existant |
| **v00.1** | North Eastern United States | Apartment | thesis.piuggi.com | Cannot support fish life | Cannot support plant life | Dangerous electrical components mixing with water. | Flawed./ Non-existant |
| **v00.2** | North Eastern United States | Apartment Temperature Instability | Data Visualization | Blue Gill fish, using clarifier | Vertical and raft grow beds to be provided natural and artificial lighting | Raft, Clarifier, BioFilter, Mechanical Filter, LED Light systems | Data Feedback |

**Figure 7.a - Prototype Analysis Chart**

electrical hardware.

Prototype v00.2 (*Figure 6.g*) is a work in progress, while a new attempt at clarifiers is being rectified the system is running without it. A sudden drop in temperatures recently frosted an infant crop, rendering the plants dead. In evaluation of Prototype v00.2 the opportunity to analyze work in progress as well as evaluate the evaluation tool itself comes to light. In mapping out the projects (*Figure 7.a*) the chart visualizes the additions to prototypes. With v00.2 we can see how the micro environment of this current set-up is unstable. This is potentially related to the time of year (winter), an important item to note for future progress. Additionally with this version, an attempt to push an open data visualization as a means of providing data feedback to users is underway. This demonstrates how the document for evaluation becomes a tool to facilitate project growth. Note the two prototypes with sub-par results, by illustrating this pattern a change in prototyping can be made. In doing so progress can be noted, in the lineage of the prototyping process. The current clarifier and vertical filters in this space have been providing leaks, which may indicate that a shift back to an ebb and flow basin for this space may be necessary, due to the space constraints. Two small low powered LED grow lights have just been donated to the project, and will currently be under testing to sprout new crops, and then supplement the natural light for the budding ecosystem.

The evaluation document serves to showcase glaring flaws and potential directions for prototypes. As future prototypes are built they will be designed using successful elements while avoiding past pitfalls. This also provides opportunity for reflection and analysis by evaluating the components and advancements of the prototypes. Categorizing the sections serves as a checklist for each sequential examination. In doing so a greater understanding of choices, decisions and outcomes is fostered, as well as a concise metric for evaluation.

**A Tale of Two Semesters**

In closing, the prototyping which occurred Fall 2011 in Thesis Studio 1 proved quite fruitful. Although there were not a great deal of successes. The failures that happened created strong learning points and fostered better, more ecological advancements on the road to synthesizing the solution. The Modules provided a strong initial framework to explore the design question, and in turn the prototypes shed light on questions proposed. After completing the modules a more defined vision of the project and its proposal emerged.

After the break between semesters, January 2012 was the chance to get working and building again. Before work began it was important to identify a path to follow in order to best facilitate engagement and success in small scale urban aquaponics. Past field research with community groups and individuals had presented information that caretakers found ability to understand accurately what was happening to their farms and gardens, was of value to them but generally out of their budget. The focus of this semester became about the hardware and software connecting and migrating the data from small urban aquaponics systems to the communities who are hoping to cultivate them.

**Physical Hardware**

Moving forward, an initial hardware prototype was created to track the ecosystem built during Fall 2011 Thesis Studio. The prototype tracked temperature, within the air, grow bed and fish tank, humidity, pH, and light controlled by an Arduino and connected to an ethernet jack.

Like all first hardware prototypes it was rudimentary, but worked. The circuitry was not pretty and the containers were not large enough to house the entire system. The prototype addressed concerns of varying scales. The problems which arose were: how to build low-level prototypes that were self contained and waterproofed while still allowing for modularity and additional parts to be integrated into the system; how to reduce wires and give sensors priority space necessary, (.ie light sensor must be placed in non obstructed space); how to reduce cost and increase sensor accuracy.

**Figure 8.a - Prototype v00.4**

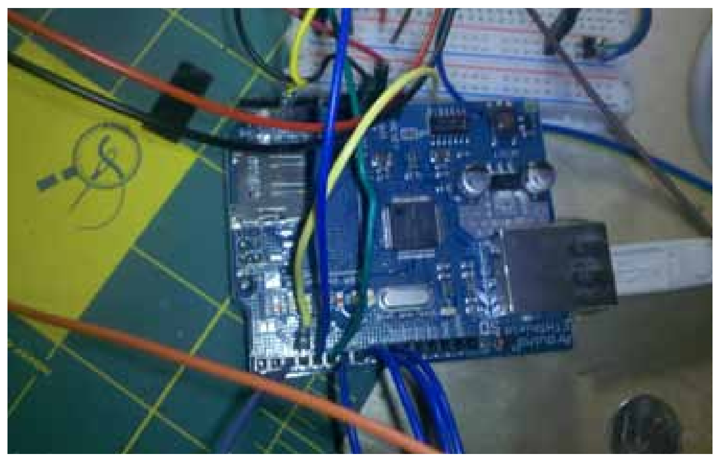

**Figure 8.b - Prototype v00.4**

The unit also provided a means to begin to examine the data itself and how individuals and communities may begin to interface with the data. Additionally this endeavor provided the examination look and feel[12] of the artifact and how it will exist in the lives of individuals and communities of the project.

**Web Interfaces**

After completing the hardware to sense the environment it became important to store that data. It was time to put it someplace where, people could see it and share it. Where else should it go but the internet? This prototype became an examination and implementation of getting the units data to the web. To do this there were three areas this prototype addressed: receiving and storing data; retrieving and visualizing that data.

In order to effectively manage data on the internet a database was used. In order to best outfit which type of database to use a list of needs was complied as a way to best understand how the storage would be used. The application being prototyped would need to simultaneously receive and send data from various

**12** "What Do Prototypes Prototype", Hounde and Hill, p. 2


**Figure 9.a - Prototype v00.5 - Website Home Concept Mock-up**

**Figure 9.b - Prototype v00.5 - Website System Dashboard Implimentation**

addressable loggers; quickly sort datatypes and return values in custom parings with ease; output data in a usable format for others to collect. Using these as a base point for data storage MongoDB was chosen to handle data. MongoDB stores data as JSON meaning that the data can be sent directly from the database as a bundle in a standard format that all programming languages can quickly and efficiently parse. The benefit is compact data structures which are just as efficient in storaging data as in parsing and distributing data.

In order to connect the hardware to the database, an intermediary script was used. The script was written in a manner that allows for any and all data types to be sent to it and stored within the database; meaning that the interface does not expect or limit what data types or naming conventions the hardware or user can send; the data simply passes the data directly into storage. This key feature allows the developer the ability to write data types into the hardware and not have to update any code or select any options on the server or on a web interface.

The next aspect of this prototype was to explore retrieval and visualization. In order to understand the scope of the site and the functionality that it would need to entail a user flow was created. This facilitated which pages would direct the user and how the user navigates and connects to all the pages. With this document the next facet of visualization could be approached, and for the purposes of this prototype the two main pages created were the System Dashboard, and Datatype view. The database dictated that data would be

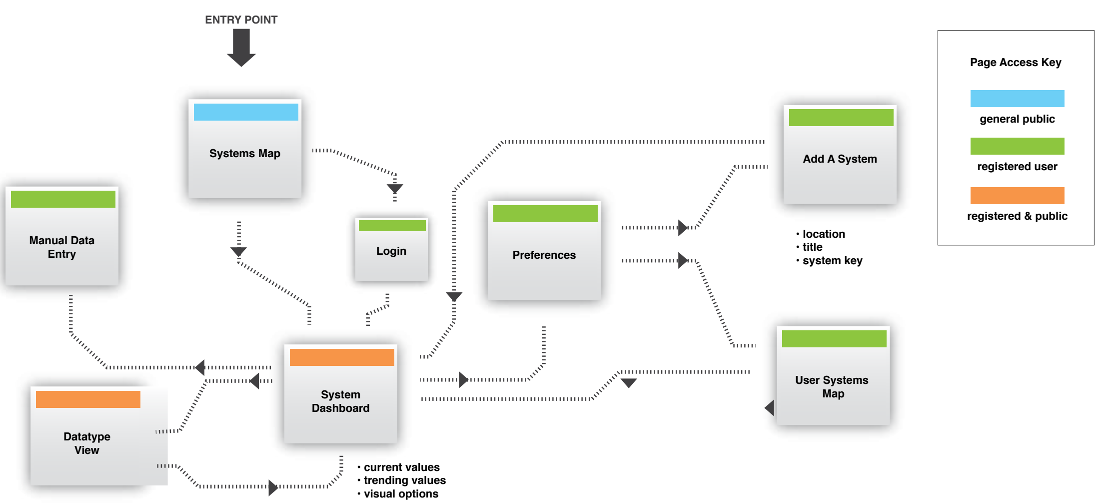


**Figure 9.c - Prototype v00.5 Website User Flow Diagram**

sent and received via JSON, which made javascript and ajax of great use to both import and visualize the information coming in. Javascript enabled the use of HTML5's <canvas> tag as a means of creating and rendering dynamic data visulaizations based on users requests. This prototype served as an implementation how the system would work and connect. Its real purpose was to enable greater feedback and dialog from the community as a means to test what functionality a participant would need and want.

In this regard the prototype was quite successful. It enabled many individuals such as novice and professional urban farmers, DIY makers, and amateurs to engage with the data and begin to contextualize what they needed from an interface which showcases the health of recirculating ecosystems. Unanimously, testers asked the same questions: how can I compare multiple data types; what does this data mean; where are the important overlaps between the data; how can I view and compare different time scales; when will this be ready for me to use?

All these valuable questions and feedback facilitated the understanding that the scope and scale of creating an interface for data collection is enormous, an undertaking the size of its own Thesis project. This particular prototype provided the rationale and insight to see the scope and scale of the project and its creation, and help to create realistic goals about outcome of the project through the end of the thesis process, and which elements would begin after.

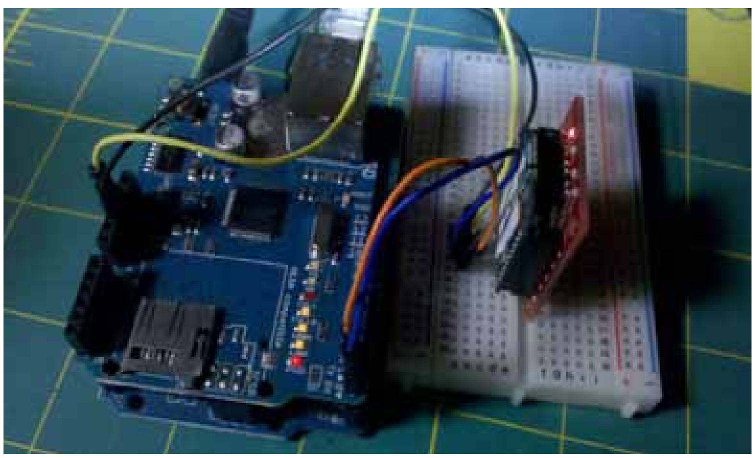

**Figure 10.a - Prototype v00.6**

**Figure 10.b - Prototype v00.6**

### Wireless Transmitters

Moving back to the initial hardware outlined in the Physical Hardware section, new ways of building the hardware and connecting the internet were questioned. In order to facilitate this thought process the project was situated in the context of developing a consumer based product. In doing this it outlined some ways in which data could be collected and connected and how consumers would use the product. Keeping in mind the frustration of wires from the last prototype Radio Frequency(RF) Modules were looked at as a way to wirelessly distribute the hardware.

Although RF Modules can be expensive they present many opportunities in the ways we can connect components and distribute information. When ecosystems span a variety of sizes and layouts the ability to send accurate data without running long wires creates more embedded components and data collection. In low voltage sensor data is easily lost over long wires when sensor signal is limited low power. This prototype began to explore RF through the use of a Bay station which could receive and track data from various components and disseminate them to the internet script which stores the information. In addressing the compact and waterproof nature of the unit an Arduino, EthernetShield and RF Module were fully embedded into a waterproof

Sensor Kit Types

| Wired Ethernet Units | | Wiredless RF Units | | | | |
|---|---|---|---|---|---|---|
| **The Basic** | **The Intro** | **The Novice** | **The Novice Kit** | **The Pro** | **The Pro Kit** | **Wireless Bay Station** |
| Wired Agricultural Sensor Unit | Wired Agricultural Sensor Unit | Wireless Agricultural Sensor Unit | Wireless Agricultural Sensor Unit with bay station | Wireless Agricultural Sensor Unit | Wireless Agricultural Sensor Unit with bay station | Connect Multiple Sensor Units to the site |
| Light | Light | Light | Light | Light | Light | xbee series 2 |
| Temperature | Temperature | Temperature | Temperature | Temperature | Temperature | Arduino Ethernet |
| pH | pH | pH | pH | pH | pH | |
| Humidity | Humidity | Humidity | Humidity | Humidity | Humidity | $90 |
| | ORP (oxygen reduction potential) | ORP (oxygen reduction potential) | ORP (oxygen reduction potential) | ORP (oxygen reduction potential) | ORP (oxygen reduction potential) | |
| $170 | CO2 | CO2 | CO2 | CO2 | CO2 | |
| | | | | Air Quality | Air Quality | |
| | $270 | $310 | $400 | Dissolved Oxygen | Dissolved Oxygen | |
| | | | | Electrical Conductivity | Electrical Conductivity | |
| | | | | $640 | $700 | |

**Figure 10.c - Unit Costs Breakdown**

container; allowing data to be sent long distances to an ethernet port.

Once this technology had been identified and prototyped it was important to begin to shape the costs of the system with and without this technology, as a means to situate what the costs and options would be for a fleet of systems using wired and wireless technologies to collect and disseminate data for aquaponic systems.

**WindowFarms Add-on**

In March 2012 Pachube (pronouced patch-bay) was looking for ways to increase use and access to their "web-base service built to manage the world's real-time data, [which gives] people the power to share collaborate and make use of information generated from the world around them."[13] They contacted me to build a prototype for a hardware add-on to the WindowFarms(previously identified as a core precedent to this thesis endeavor). From its inception the WindowFarm project has grown into a large community of urban farmers using and iterating on methods created by Britta and her team to create a hydroponic drip systems in their apartments. To Pachube, this group presented a large community of individuals they would hope to migrate over to their services as a means of sharing the data associated with their hydroponic systems.

The two groups presented unique opportunities, the already active community for testing, and the data management interface and system.  The previous round of prototyping highlighted the true scale of creating and managing a data interface system; working with Pachube presented a means to facilitate data storage and visualization without the need to develop large scale databases or entire front end websites. Pachube offers the ability to pull data from it, and if a custom skin were to be developed it could be done by

**Figure 10.b - Prototype v00.7**

**13** "About Us," Pachube. http://www.pachube.com/about_us. Accessed March 28, 2012.


**Figure 10.c - Prototype v00.7 Implimentation D12 Lab**

requesting the data off of Pachube. Having an established community to test with, enables new users and types of users to become exposed to the prototyping process and enables individuals with fresh eyes to critically question the interface and interaction presented by the project.

The hardware prototype created for demographic sampled tracks electrical conductivity, total dissolved solids, salinity, pH, temperature of water and air, CO2, light, root moisture and nutrient level. The combination of these values allows users to understand the success and health of their home hydroponic systems as well as troubleshoot what types of problems may be arising as the system grows. This particular prototype connects directly to Wifi routers to update data; rather than using a bay station this is a more efficient means and has provided a new avenue toward making the system smaller, cheaper and easier to use. The initial round of this prototype has been finished and installed. Further iterations will be coming based off of user feedback.

Next steps for this prototype will be to use smaller parts. Currently the prototype runs off a larger microprocessor because earlier iterations failed due to what appeared to be memory allocation issues. While this prototype was very benefitial it also presented a great deal of challenges which, took over 2 months to develop due to a unqiue error.

This prototype worked with a series of high resolution digital sensors. These sensors, which connected to the to a microcontroller through a communication type known as uART. In the development of the prototype core functionality within Arduino, the open-source microcontroller used to control the hardware system, was found to be unreliable. The innate Serial function was corrupted by a bug between the various channels of communication happening concurrently.

Various iterations of this hardware were built out on three different Arduino boards, the Duemilanove, the UNO,  and then finally the Mega, the largest and most expensive option, however the board with the most computational power. Even with this large upgrade the Serial errors persisted, to no avail. However the Mega did provide noticable improvement.

Moving forward with the project the hardware will be implimented into the WindowFarm workspace for user testing and modifications. Additionally avenues such as sensor development and a higher power of computation must be explored. The next and more likely steps will be to begin building prototypes with the same microcontrollers which run our smart phones. Enabling use of a full Linux based system on a computer the size of an Arduino.

**Aquaponics as Industrial Design**
When thinking about ways to engage people in food production within an urban environment, the methods and locations that people use for production is an important factor to examine. This was something executed in a variety of ways in Computation Studio Spring 2011 and Thesis Studio Fall 2011, however each of these prototypes provided unsatisfactory results towards creating elegant solutions for small scale urban aquaponics.

Entering Thesis Studio 2 it was quickly accessed that open hardware would take up the entirety of the time, the aesthetics and integration of a home sized aquaponics system. As this realization was made timely communication was received via email.

*"Hello Chris!*
*My name is Judit Boros, I am a visiting student from Milan and I will spend the next semester at Parsons, in the Transdisciplinary course, working on my thesis.*

*I used to work on hydroponic systems..with plants and fish - I was doing it for my bachelor's diploma (made a small prototype for it) and now I am planning to go on with it in this topic."* [14]

With her background in industrial design, Judit presented many new and interesting avenues to implementations and environments where this piece could live. The collaboration began with the realization that the scope of work possible for one person in the allotted time for this project was unattainable. However having a reference point to the industrial design and home integration of small scale aquaponics systems is vital to adoption of these technologies. If people cannot purchase or build their own systems, there is no purpose for the data collection and dissemination. Judit's research will go a long way towards creating integrated home production systems, and her findings will be implemented collaboratively to create a running system at Par-

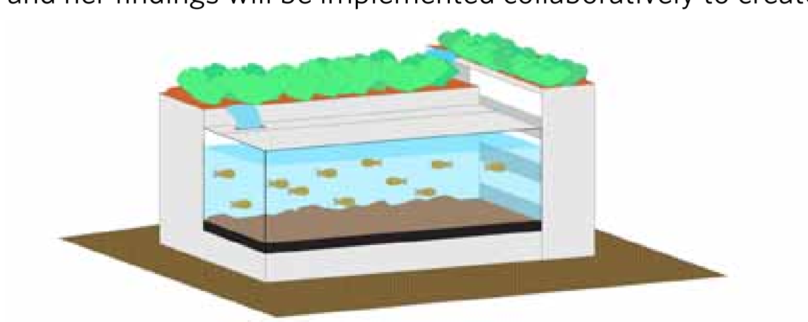

**Figure 11.a - Prototype v00.8 Concept Sketch**

**14** Judit Borros, e-mail message to author, February 5, 2012.

sons.

**Installation as Prototype**
The installation served to explore two other facets of the Hydron project. One, the aesthetic nature of what a system small scale aquaponic system could be; Two, develop a new round of hardware with which to analyze the system. The discussions, sketches and iterations over the course of the semester with Judit Borros helped to produce and define the final installation; A small fully recirculating semi-autonomous system, which featured tomatoes, lettuce, peppers, strawberries, basil and mint. Additionally a native fresh water fish species, Bluegill were used which enabled an overall lower pH for the system. Typically in Aquaponic systems Tilapia,

Figure 12.a - Implimentation Prototype v00.8

an african fish, are used. Plants which generally enjoy a pH slightly below 7 in hydroponic systems are forced to thrive with Tilapia which enjoys a higher pH (7.2-7.6). This Tilapia plants and fish are fighting eachother for an ideal pH. Conversely this prototype served to counteract the typical imbalance through use Bluegill to strengthen the symbiosis.

The system was provided limited space by the MFADT Thesis Installation Representatives. This was a beautiful constraint, many times in city dwellings, in particular apartments, limited space exists for horticulture. The allocated space mimiced the constraints presented by our direct urban environment and coaligned with the goal of the prototype: to create a usable system, which would facilitate the Parsons community, gallery visitors, and street bypassers to experience what small scale aquaponics could look like in their homes. (*Figure 12.a*)

This installation also featured another hardware prototype. This version facilitated newer additions to sensing, such as Oxygen Reduction Potential (ORP) as well as an LCD interface to the current processes. This refined unit was built off the Windowfarms prototype, and retained many of the major software/hardware bugs, however it was a great opportunity to examine how the hardware would sit within a refined home system. This hardware prototype pushed even further how this system might actually look as a home product.

**Figure 12.b - Hardware Unit Prototype v00.8**

In the end this prototype was extremely valuable in realizing the potential and inherit beauty that these eco-systems provide us. With its direct ability to connect with a larger audience it provided feedback and inquiry from many respondents. In addition this prototype's collaboration showcased the inherit value which designers and technologists provide in this field.

**Bushwick Campus Greenhouse**

The Bushwick Campus is a High School in Brooklyn's Bushwick neighborhood. The campus is home to four separate schools, Academy of Urban Planning, Academy of Environmental Leadership, Brooklyn School for Math and Research, and Bushwick School for Social Justice. These highly focused and unique schools provide students the ability to focus their studies and work hard to bring outside collaborators to teach students about the variety of subjects these distinct school work towards.

In December 2011, EcoStation:NY and Boswyck Farms successfully funded a kick-starter to build a greenhouse at the campus. The purpose of this greenhouse is to provide students a space to learn about traditional growing methods as well as hydroponic, and aquaponic methods of food production. The goal was to create a space "for scientific exploration and innovated curriculum development."[15]

I connected with Boswyck Farms January of 2012 about their greenhouse project, and the hydroponic systems it housed. A collaboration was struck between us and we began to develop the open hardware toolkit as an after school initiative for robotics students engaged in the Brooklyn School for Math and Research. The purpose of this internship is to teach students about hydroponics and aquaponics through the integration of open source technologies. Students will be given a platform to understand what data collection is and how important it is to food production systems of these types. The high school students will follow work towards building a networked open source sensing unit for the hydroponic and aquaponic systems to disseminate data about the Bushwick Campus Greenhouse to the general public, via the internet. The students will utilize

**15** "Bushwick Campus Greenhouse," Kickstarter.com. Accessed March 28, 2012
http://www.kickstarter.com/projects/1806127628/bushwick-campus-greenhouse

software and hardware developments made throughout the year, as a means to better understand the role and potential of technology in agriculture.

Concluding a year of prototyping only shows how much there is still left to do. The challenges and undertakings which this project presents are massive and the scope of work has been enormous. The collaborations and connections which have been fostered during this time have showed the large amount of people interested in and working on urban agriculture. In each regard the need for data collection and dissemination among their respective communities was a vital role in the systems they create, maintain and distribute. Further prototypes must be developed to better identify and smooth out hardware components, automation and data

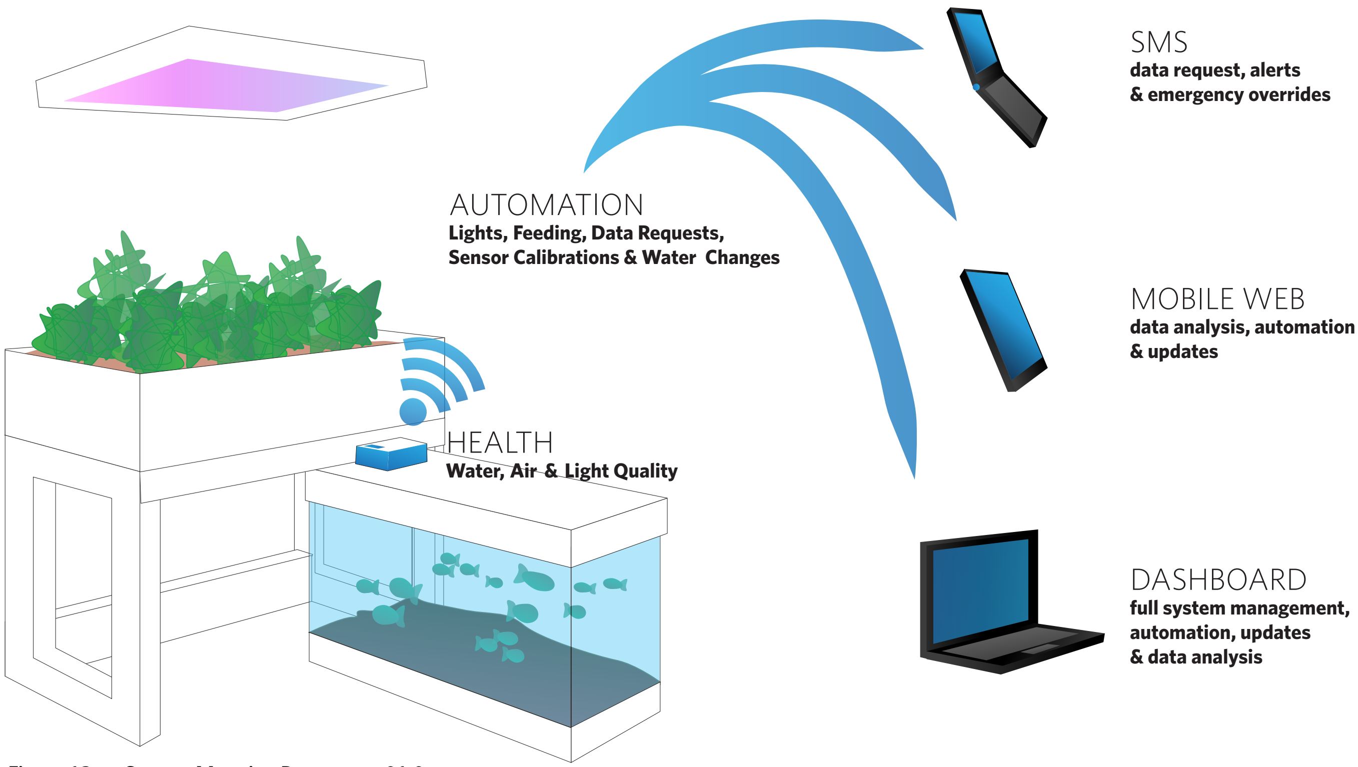


**Figure 13.a - System Mapping Prototype v01.0**

integration. By providing integration with individuals daily lives in more seamless and fluid way Hydron will be able to provide the utmost of service to ecosystem caretakers in need of support and knowledge.*(Figure 13.a)*

## User Research

It is very clear for me to see the many individuals that have been involved or associated with this project since its conception. Each person has played a different role within the urban agriculture movement and as such, has played a different part over the past year shaping the project. Starting the Fall semester off prototyping with the social module really helped to facilitate a survey of the current shape of the industry and all the players that were involved. Using that base point I was able to then systematically approach individuals from each sector and begin to either collaborate or gain insight from them. This section will pay homage to these individuals and their key perceptions which helped guide and sythesize the Hydron project.

This document serves as the map of the collaborations and interviews carried out over the course of the year.

Although it cannot show the various levels of interaction within this community that have taken place between myself and the city of New York, it is a reflection of the responses garnered from this research endeav-

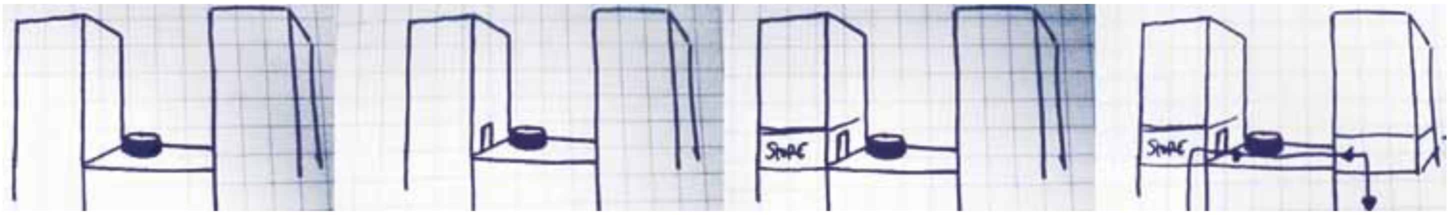

**Figure 14.a - Victoria Marshall's Sketch**

or.  Many of the interviews and collaborations that have occurred helped to shape this document and better identify the key players in the emerging community; in addition to the best ways to serve and empower this growing community of participants.

The first round of interviews were completed in the Fall of 2011 with three individuals; the Urban Planning Director at Parsons, Victoria Marshall, the Community and Outreach Director at Connecticut's Association for Community Action(CAFCA), Derek Haviland, and a documentary film maker, Michelle Calabro whose Seeds to Soil videos examine an urban community and their relationships with agriculture.

Victoria Marshall provided a unique look at how urban planning and maximizing use rooftop space can provide opportunities. She introduced the idea of how roof-top systems can provide alternate access to outdoor space, while integrating into a food system. She presented the question, can promotion of outdoor growing systems augment how we use and give access space on roof-tops? She did this all on paper with a unique set of sketches (*Figure 14.a*).

Her insights showed the value of circumventing traditional uses of urban space. Once you opened the doors to roof-top space, urban planners and development groups would have a potential part in changing the urban infrastructure, and help provide unique and beautiful sites in which this agriculture could take place.

Derek Haviland provided another unique perspective on urban agriculture, as the Community and Outreach Director at a state run government organization, At CAFCA Derek researches community and partnership opportunities for low income areas within Connecticut to create local solutions to their various problems. Havliand was recently in charge of examining food systems, in order to provide these areas with better access to fresh healthy food. He highlighted the importance of the relationship between communities, governments and businesses in low income neighborhoods. Haviland discusses how they are all key groups in providing fresh produce to the areas in need.

> *"Federal Grant funding is the only way I see [local sustainable food production] happening on large scale... Commercial enterprises need subsidies or tax breaks in order to set up a system for low income communities. Low income areas are still going to use EBT or food stamps to purchase this food, instead they would be able to purchase fresh organic vegetables rather than junk at a bodega."*

What this means is that even though a system or business could be created to provide fresh food to a dire community living in a Food Desert, that system or business would need to rely on the pre-set infrastructure of payments and support that is within the neighborhood. Without such a backbone, a venture could quite easily fail. This conversation highlighted that Governments are in fact a key stakeholder, they facilitate the distribution of goods to the community stores and sanction the various methods of payment needed for business in urban agriculture to survive and thrive. This interview was a key point in understanding the interaction between Government and Community groups, after which it was clear that discussions with community group members must take place.

Documentary film maker Michelle Calabro contributed a means to understand the community members better. She provided an interesting look at the community and its perceptions of Urban Agriculture. Her most recent documentary completed Fall 2011 was a series of short films about a Harlem Community and its members. When asked what the title of the work was Calabro said, "There's no official title." The series of short films interviews people who were associated with the project Seeds to Soil by Michelle Jackson and Lien Tran. The videos were shown at an event in October 2011 called "Creatively Harlem". Calabro has been filming the community members since June about their use and access to agriculture. Michelle Calabro outlined her unique perspective about working with real communities and offered valuable advice on how to talk with the community and get them to connect the work being created.

> *"Residents are hesitant, you have to listen to them and make the right choices. So many times people come from outside the community to help them and they actually end up making things worse when they leave."*

This highlighted the fact that when working with a community it needs to be about that community. By relying on already established community groups who have credibility within the neighborhoods in need will facilitate better connections between potential users and future partnerships.

These initial interview provided a base understanding of who the players in the field of urban agriculture are and which groups are actually important to the project's completion and success. In building upon the interview with Michelle Calabro, it was vital to speak with the other participants in her project. An interview was organized with Calabro's calibrator, Michelle Jackson.

In addition to participating in Seeds to Soil, Michelle Jackson is an avid community gardener in her Harlem neighborhood. For the past 8 years she has participated in the communal growing space at the Harlem Center for Healthy Living. As a representative of the community garden Jackson discussed many of the initiatives they were working towards, providing many unique insights about the role this garden played in the greater neighborhood.

> *"Collectively our members are interested in food access and social justice, through their own sources of food. They want to learn about new ways to create their own food sources and break their dependence on stores that don't provide adequately for the community."*

When asked if she thought her community would be interested in collecting and disseminated the data from their garden Jackson immediately replied yes. She outlined the notion that while they are looking for new ways of creating their food, they are also looking for new ways to teach the community and neighborhood about ways to succeed at growing their own food. The interview helped document the true need that communities living in New York faced, and ways in which individuals were collectively participating in ways facilitate change within their neighborhoods.

In a different type of community group is Steve Kreuser, of the newly formed hacker space Hack Manhattan. Steve and his community members are interested in starting a community garden on their roof space. In an email thread Steve outlined some very key ideas about what Hack Manhattan was looking for and some problems they had run into.

> *"I am more interested in more 'traditional' forms of gardening. If given the keys to the roof and told to go wild, I would work towards building an aesthetically pleasing, semi private place for members to escape to from time to time... However, I realize that growing a garden on the roof presents some very unique challenges, and as a result I am very interested in experimenting with hydroponics as well as living walls. (aquaponics is also something I have been researching recently, but I am not sure how feasible that is to do on a roof)"* [16]

Discussions with Steve outlined the lack of knowledge circulating around urban agriculture and the methods and spaces which can be used for production. Furthermore it illuminated a potential preconceived notion that hydroponics and aquaponics are not 'aesthetically pleasing' avenues of integration into a space. The value of these discussions was to understand the current perceptions of the various agricultural methods and the struggles community groups starting out face when attempting to create their own avenues of food production.

In November 2011 I was giving a talk about the potentials of data tracking and small scale aquaponics at the New York Internet of Things Meetup. The discussion was well received and at the end of the talk, the floor was opened for questions. One member from the crowd spoke up, asking if I would come to set up a system at his house, after the talk. Through a set of communications with Jacob Cohen a set of hurdles was discovered.

> *"I'm currently looking to solve a couple issues:*
> *1. How to keep the plants alive during the winter*
> *2. How to collect and broadcast data from the plants*
> *3. How to grow food in the space even during the winter"*[17]

The communications reaffirmed the lack of knowledge about urban agriculture and the means and methods to production. Additionally it showcased an interest in collecting and disseminating the data to better understand what was happening within the system. While it did re-affirm many of the points it also shed light on this interest of data collection in urban agricultural environments.

These communications and interviews in Fall 2011, greatly helped to shape the project and its outcome. In talking with individuals connected with and interested in urban agriculture the needs and roles of communities, governments and individuals was fully understood and in turn synthesized into a tangible and realistic product. Taking this valuable information into the Spring 2012 semester allowed for new views and contacts to be made. This section will outline the collaborators and influencers of the Thesis Studio 2 without these partnerships the project would never have been possible.

As stated in the aforementioned prototype section of the paper during the Thesis Studio 2 a collaboration with Pachube and WindowFarms was created in an effort to build an add-on to the WindowFarms project which would deliver data to Pachube. Working with these two organizations facilitated an view of user groups in a slightly different but more robust context. Three key players from these organizations helped to shape

**16** Steven Kreuser, e-mail message to author, October 31, 2011.
**17** Jacob Cohen, e-mail message to author, November 11, 2011.

that view; Ed Borden, Senior Manager and Platform Evanglist, Pachube; Usman Haque, Founder, Pachube; Britta Reilly, Founder, Windowfarms.

In a discussion with Ed Borden, March 13, 2012, in regards to the project and its potential in the marketplace. Ed provided a strong vantage point to something that he Usman, and Britta all understand, community building.

> *"Its not about the sensor system, gardens or hydroponics - what you need to be thinking about is using these tools as a mechanism for creating a community. The business challenge here is building and leveraging a community of people who engage with the product."*

Borden loves talking about Open Source Hardware (OSHW). OSHW is currently a proposed set of principles for providing a definition for engineers, designer and artists to make and share their hardware; enabling others to participate with, modify and redistribute what others have made and released. Taking inspiration from the Open Source Software movement OSHW seeks to facilitate a greater participation through transparency of process and methods.[18] Ed discusses the true value of open hardware in an article published on the Pachube blog.

> *"There's an opportunity here to blow away the old model with something completely new -- a different way to think about where the value is in a piece of hardware. Think about open source platforms instead as something that can be inexpensively/quickly leveraged to gain an audience, build a community, and drive engagement online..."*[19]

Ed is not the only one of this group who believes that community building is the result to successful projects. In her TEDx talk, "A garden in my apartment" Britta Riley discusses her idea of Research & Develop It Yourself (R&DIY), similar to R&D however rather than operating behind the closed doors of a large corporation this Research and Development happens openly within a participating community.[20] This is the method she has used to build her WindowFarms. Through 12 community iterations her team was able to put together a crowd-sourced project, which raised $250,000 on Kickstarter. This product launch is directly related to the various iterations and additions that happened within this community simultaneously. Riley's team was there to put together documentation and bring the community and dialog together. It is a powerful showcase of what can be done by leveraging communities, and how true Ed Borden's thoughts about community are. "So, when we talk about value chains, business models, and monetization... Our focus needs to be on how we can leverage open hardware to build these communities -- the rest inevitably follows." [19]

Usman Haques additions to the project take form in two areas. The first is the creation and implementation of Pachube, allowing for the project development to focus strictly on the hardware components. The other main and guiding aspect has been as an evangelist for the community. Usman has continually challenged me to think in depthly about parts and costs of the system. Forcing the justification of various hardware components. This exercise enabled a better device to be created with more realistic adoption patterns. Without this grand insight the project could have very easily taken a turn in the wrong direction.  Ultimately the ethernet solution that Usman seeks is the most cost effective and scalable, however the dynamic user experiences

**18** "OSHW", Freedomdefined.org/OSHW, accessed November 4 2011.
**19** "The Value of Open Hardware in in the Empowerment of Communities," Pachube Blog. Accessed March 13, 2012. http://blog.pachube.com/2011/09/value-of-open-hardware-is-in.html
**20** Riley, Britta. "Britta Riley: A garden in my apartment" Filmed May 2011. TED video, 7:53. Posted November 2011. http://www.ted.com/talks/britta_riley_a_garden_in_my_apartment.html

presented in Radio Frequency and Wifi communication present in my mind the potential for a smoother engagment with the hardware and interface.

The last extremely important collaborator within this undertaking has been Lee Mandell, Chief Hydroponicist at Boswyck Farms. Lee is an urban farming expert, and his organization Boswyck Farms seeks to deploy the valuable information about how to cultivate in urban environments to communities throughout Brooklyn, New York. Lee has become a key user tester in the process as his needs and goals are directly correlated to the project's. The various farming sites which are spread across the city need daily care and maintenance. Automated data collection and dissemination allows Lee to take a hands off approach to data samples and logging. Giving him the ability to survey his systems simultaneously and prevent catastrophic losses by understanding, in real time, what the true environment of the plants is. Through close collaboration and feedback Lee has provided various guidance in the form of what the data means and the importance of sharing it. He has been continually enthralled with the idea of providing his expert information to the world. Through data dissemination, Lee believes others can understand the blueprints of producing hydroponics and aquaponics systems. Additionally, Bosywck sees data collection and sensing as a way to ensure that volunteers and participants in these fragile farms truly understand what they are working on.

The various insights and collaborations that have come forth through experts in their respective field have truly helped facilitate better understandings of the current marketplace, and the role in which communities play within this project. By garnering conversations and feedback from these experts this project has been able to establish real use cases and recognize the benefits of community outreach and communal R&D as a means to develop a product.

## Use Cases

Three use cases have been developed based off the research and interaction with communities, experts and novices. The use cases serve to personify the key participants of Hydron and the benefits the project presents.

**Professional Urban Farmer**
As an urban aqua or hydroponic farmer, I am not afforded the space of a traditional farmer. With a dozen systems spread around the borough, daily maintenance is burdensome and tedious from multiple locations a day. Hydron Modules are installed in each of my 'fields' providing real-time scientific-grade crop data, allowing me to deal with emergencies, remotely manage the ecosystem, and tailor growth plans based on environment trends.

**Community / School**
We are interested in learning to grow our own crops for our community. We have/will be building an aquaponic/hydroponic system where multiple people will be involved with care and maintenance, many of whom will be learning/volunteering. With real-time accurate environmental information we can better understand and react to what is occurring. This helps us understand if certain people need re-training or are neglecting systems, before crop loss occurs. We love sharing our information with the greater community to inspire them to participate or start their own endeavors.

**Individual/Family**
I love having fresh vegetables in my home aqua or hydroponic system. Sometimes I need reminders about what my crops like – from nutrients to light and carbon dioxide. Having my gardens data gives me access tailor nutrient plans for my crops, and learn to maximize my yields. Being able to see what the experts are doing

with their farms provides me the confidence to succeed and at the same time I hope that others will benefit from my results and be inspired by my success.

## Solution

The solution to the Food Deserts in America is clear, to provide better access to fresh and affordable food sources. The difficulty of this is how to facilitate this access, and what ways large scale systems can be implemented to enable neighborhoods and individuals afflicted by this lack of nutritious food to become participants in a community of change. Looking at some initial research from the User Module of Thesis Studio 1, augmenting the consumer versus producer model has the potential of drastically changing the relationships of community members and the stores and markets which serve them. As producers these communities actively participate in the retention and growth of nutritious and affordable foods. In striving to attain this model methods for individual and community research, exploration and engagement within self-perpetuating, sustainable ecosystems must be designed as a foundation to empower neighborhoods to cultivate healthy self-sufficient local economies.

There are three key elements in attaining and implementing this solution: 1. Users must be provided with the ability to create and manage their own productive ecosystems via an interface to support and guide users with data feedback; 2. Aesthetic solutions must be designed in order to effectively integrate ecosystems into everyday spaces, as a means of promotion, awareness and adoption; 3. Facilitate user implementations at scales which can be supported by resources available to participants, as well as ensuing a viable cost to produce ratio. With these three steps individuals and communities will be able to participate in local agriculture, providing affordable healthy food to the surrounding residents in their urban environments.

Through the various discussions relating to urban agriculture which have occurred throughout this Thesis project there has been one main theme, people who participate in this field need support. Even experts in their respective fields need better ways to understand and manage the unique farms which they care for. To that extent, novices entering into this field need even more of a network of support to ensure success and growth. By providing this, we can collectively enable a community of urban cultivators; by applying Britta Reilly's R&DIY methodology we are able to build a web of co-creators actively participating in the growth and success of this project.

A platform for individuals to collect and disseminate data enables a virtual network of participants, each creating their own blueprints for success based upon their unique crops and system types. When this data is stored and tracked we provide both experts and novices the means to understand and disseminate their success.

> *"If knowledge from a distance is the goal of telerobotic devices, then epistemic immediacy should be the goal of interface design. This may be achieved by interfaces that allow the user to 'cope skillfully' in the remote environment - to interact instinctively and unreflectively with distant objects, rather than treating them as theoretical entities to be inferred from evidence on a video screen."*[21]

As Ken Goldberg, astutely points out creating robust interfaces for individuals to cope in the remote environ-

**21** Goldberg, *The Robot in the Garden*, 22.

ment is key. Through telepresence we can create meaningful and robust interactions with ecosystems far removed from individuals subverting agriculture into a virtual community allowing knowledge to be freely transferred and built upon.

Through data collection and open hardware we are able to create strong bonds between participants and provide a virtual community of support through which people can teach eachother how to best grow crops. Using the identified Use Case Scenarios we can see a recirculating ecosystem of engaged members, where research and methods are challenged and tested.  In this environment what emerges is successful models and blueprints for crops and systems. The continual refinement by envigorated eyes enables greater iteration strengthening the ways in which the community can build and impliment aquaculture. *(Figure 15.a)*

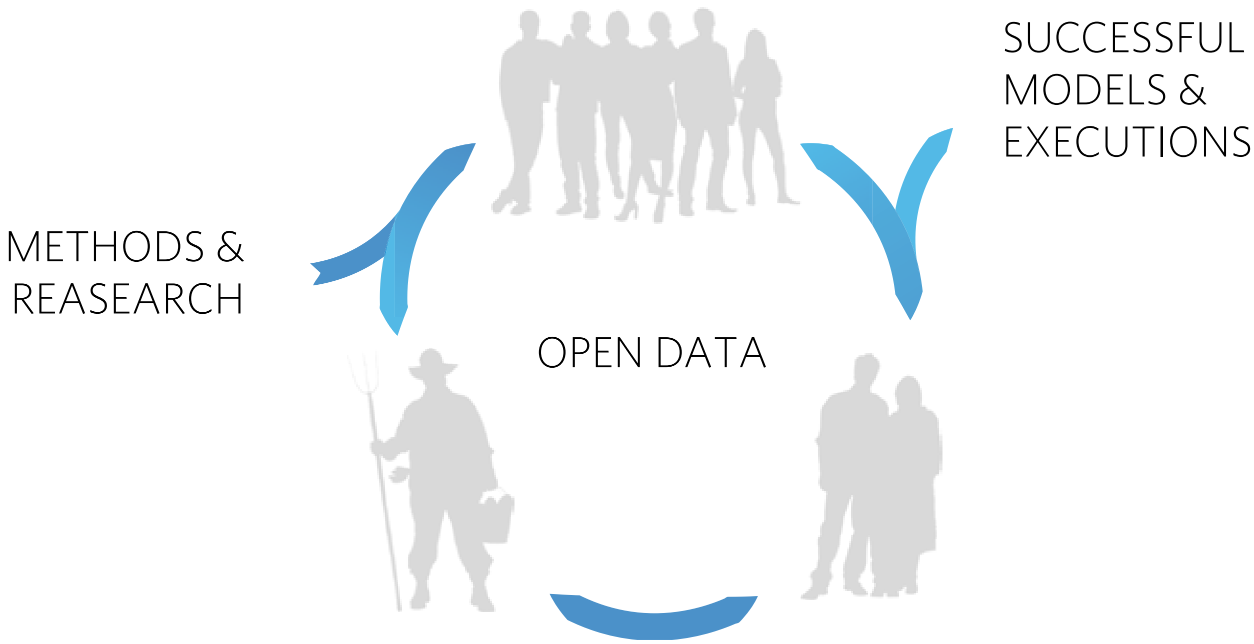


**Figure 15.a - A Virtual Community of Urban Farmers, Community Groups & Individuals**

These blueprints provide a lower entry point to engaging with aquatic ecosystems. They enable interested parties to overcome many of the hurdles that the field of Urban Agriculture presents. Learning from the failings and successes of others in addition to a system of automation shrinks the tasks involved with particpation. According to Yochai Benkler in The Wealth of Networks "a successful large-scale peer-production project must... have a predominate portion of its modules be relatively finegrained."[22] By following this mindset we are able to facilitate greater participation and in turn success.

In order to promote the integration of small scale aquaponics systems they must fluidly exist within our current environments. Be it rooftops, small apartments, backyards or any other unique location, these systems must seamlessly meld with their micro environment to adapt to the expectations of gardeners or onlookers. The aesthetic design of such a system is just as important as the eco-system and interactive design of the entity. By providing tools and system designs which are aesthetically pleasing participants can be inspired to produce food in locations never before imagined, and a community of individuals building within their own

**22** Benkler, *The Wealth of Networks,* 101.

unique space provides a great opportunity for iteration. With so many potential and unique constraints a virtual community would greatly benefit from the tips and tricks to building their ideal systems.

While prototyping and designing solutions, it is important to acknowledge the necessity of various scales. The principles of Ecological Design tell us that solutions come from place, and in using this framework it is important to focus current prototypes within the New York City environment. With that understanding these solutions must still recognize the need to be transferable to other regions around the world. Instantiating this will allow for greater adaption and implementation as well as a better pool of collaborators. It is narrow sighted to posit that the best solutions to urban agriculture will come from the United States however badly we need them. By enabling a diverse set of co-collaborators we create an even more diverse set of iterations and thus solutions.

Hydron servers to create fluid and effective integration and communication between production ecosystems and the caretakers who must be aware of their current status. The end goal of this endeavor is that the methods, for individual and community research, exploration and engagement as related to high production agricultural systems remains open, affordable and adoptable. By maintaining Hydron under open-source guidelines, users have the opportunity to participate without enormous overhead, while simultaneously iterating and researching new and better implementations. Creating nodes of support and blueprints for success positions the platform in a way that individuals and communities can easily begin to experiment, learn and adopt these previously foreign technological advancements; successfully adapting their local environments into sustainable food sources.

## Glossary

**Aeroponics**
A hydroponic system which uses misters to spray nutrient filled water onto roots

**Ammonia**
A toxic chemical created when fish waste builds up in a tank water without good bacteria

**Agriculture**
The active production of useful plants or animals in ecosystems that have been created by people.

**Arduino**
Low powered open source hardware microcontroller

**Aquaponics**
A Combination of hydroponics and aquaculture where waste from the fish is the only nutrient the plants need to grow

**Aquaculture**
A method for farming fish in a commercial way to provide large quantities of fish to a given market

**Bio Filter**
A natural filtration method for fish tanks where in the nitrogen cycle takes place in order to keep water clean and healthy for aquatic life

**Culture**
Development or improvement of the mind by education or training

**Drip Systems**
A hydroponic system which continually drips water onto media to keep roots with nutrients and moisture

**Ebb and Flow Systems**
A style of hydroponic growing where in a grow bed is filled and drained continually to water plants and keep roots moist

**Food Desert**
Described by the 2008 Farm Bill as,  an area in the United States with limited access to affordable and nutritious food, particularly such an area composed of predominantly lower-income neighborhoods and communities.

**Hydroponics**
Growing plants in soil less media, and providing nutrient rich water to fertilize plants.

**JSON**
Javascript Object Notation a data storage type that allows for cross platform reading and distribution

**Nitrates**
Nitrogen based molecules which are created by Nitrosomas bacteria, the second step in the nitrogen cycle

**Nitrites**
Nitrogen based molecules which are created by Nitrosomas bacteria, the first step in the nitrogen cycle.

**Nitrogen Cycle**
The conversion of Ammonia into Nitrites and then Nitrates in order to remove them from the water for healthy fish.

**Urban Agriculture**
According to A.W. Drescher, Urban Agriculture refers not only to food crops and fruit trees grown in cities but encompasses animals... The urban farming system is a composition of many different activities like gardening, staple food production, gathering, hunting... combined with food production.

**UART**
Stands for Universal Asynchronous Reciever/Transmitter it is a form of serial communication between computation devices where the devices can have continual communication.

**Vertical Gardening**
A technique of rasing plants on a wall or surface and pumping water with nutrients to them, to maximize space.

**Victory Gardens**
A movement during World War I and II to promote local agriculture to support a large mass of troops needing to be fed over seas.

## Biliography


Axel W. Drescher, Petra Jacobi & Joerg Amend. “Urban Food Security: Urban agriculture, a response to crisis?” *Urban Agriculture Magazine 1 No. 1 (July, 2000)*

Benkler, Ken. *The Wealth of Networks: How Social Production Transforms Markets and Freedom. (*New Haven, Conn: Yale University Press, 2006), 99-101

Borden, Ed. “The Value of Open Hardware in in the Empowerment of Communities,” *Pachube (blog)*, September 15, 2012. http://blog.pachube.com/2011/09/value-of-open-hardware-is-in.html

Chamberlin, Lisa. *“Skyfarming,” New York Magazine*, April 2, 2007, Accessed March 2010, http://nymag.com/

Diver, Steve and Lee Rinehart. *Aquaponics - Integration of Hydroponics with Aquaculture*. National Sustainable Agriculture Information Service, 2010.

Edwards, Andres R., *The Sustainability Revolution: Portrait of a Paradigm Shift.*
(Philadelphia, Pa: New Society, 2006), 103-104

Evans, Alex. “Global Food Crisis: Counting the Real Cost of Biofuels”, The Guardian, May 31, 2011, http://www.guardian.co.uk

“Food Desert Locator Documentation,” USDA Economic Research Service, accessed Oct 9, 2011

Goldberg, Ken. *The robot in the garden: telerobotics and telepistemology in the age of the Internet.*
*(*Cambridge, Mass: MIT Press, 2000)

Gollin, Douglas, Parente, Stephen and Rogerson, Richard. “The Role of Agriculture in Development.” The American Economic Review, Vol. 92, No. 2 (2002): 160-164.

Hamilton, H.C and W. Falconer, trans. The Geography of Strabo (London: John Childs and Son, Printers 1857), 144 -145.

Houde, S., and Hill, C., “What Do Prototypes Prototype?” In *Handbook of Human-Computer Interaction (2nd Ed.)*, edited by Helander, Martin, Thomas K. Landauer, and Prasad V. Prabhu, 367-380. New York: Elsevier Science B. V, 1997.

Levine, Donald (ed) ‘Simmel: On individuality and social forms’ Chicago University Press, 1971. p6.

Lucadamo, Kathleen. “ ‘Food Desert’ Status Denied to 3 million New Yorkers Without Grocery Stores”, *New York Daily News*, August 14, 2011, accessed September 28, 2011, http://articles.nydailynews.com

McLaren, Christine. “Food justice: 3 million New Yorkers live in a food desert. Do you?” Lab Log, BMW Guggenheim Lab, September 23, 2011, http://blog.bmwguggenheimlab.org

Norman, Donald A. Things that make us smart: defending human attributes in the age of the machine. Reading, Mass. [u.a.]: Perseus Books, 1993.

*Open Source Hardware Definition*, accessed November 26, 2011. http://freedomdefined.org/OSHW

Rakocy, James “The Status Of Aquaponics, Part 1,” Aquaculture Magazine; Jul/Aug99, Vol. 25 Issue 4, 83.

Rakocy, James, Bailey, Donald S., Shultz, R. Charlie and Thoman, Eric S, *“Update on Tilapia and Vegetable Production in the UVI Aquaponic System.”* University of the Virgin Islands Agricultural Experiment Station, 2003.

Riley, Britta. “Window Farms.” NYU, Masters Thesis. http://www.windowfarms.org/

Riley, Britta. *“Britta Riley: A garden in my apartment,”* Filmed May 2011. TED video, 7:53. Posted November 2011. h ttp://www.ted.com/talks/britta_riley_a_garden_in_my_apartment.html

Rinaldo, Ken & Youngs, Amy. “Farm Fountain.” http://www.farmfountain.com/

Yee, Doris. “Keiki Gardens.” Parsons the New School of Design, Masters Thesis.