ALPHA FARM

A Scaleable Schematic Design

Report

October 2011

MANCHESTER INTERNATIONAL FESTIVAL

This report was written and designed by Charlie Baker, John Sampson, Nick Dodd and Clara Maurel from URBED on behalf of Manchester International Festival with support from the Esmee Fairbairn Foundation

The authors wish to acknowledge the technical input into the project of Michael Shaw and Galen Fullford for Biomatrix Water, Nigel Paul and Ian Dodd at the Centre for Sustainable Agriculture, Andy Woods for the BP Institute and Helen Gribbon and Mai Ren for Buro Happold.

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EXECUTIVE SUMMARY

Manchester International Festival (MIF) has commissioned a special project for 2011's programme: a vertical farm. Committed to sustainably issues, MIF aims to explore the ways in which we can grow food to feed our ever-expanding cities – and produce that food in an urban environment.

The aim of this study is explore in greater detail a series of technical challenges identified in an initial feasibility study commissioned by Mif entitled Another day at the office, authored by Creative Concern, URBED, Capital Relations and Debbie Ellen, detailing the kind of challenges we are likely to encounter when transforming a derelict office building in Wythernhawe.

In order to test whether Alpha farm could be designed in such a way as to reduce the resource demands of the farm we have developed through this study, a scaleable schematic design for the entire building.

CHALLENGE

The vertical farm will not be sustainable if it uses more energy than conventional agriculture. The balance between what we put in and what we get out has to make sense environmentally.

Our aim is to explore how we far we can minimise the energy required for the growing systems to work. We believe we can achieve this through careful attention to lighting and heating and by selecting crops according to the available conditions. In seeking to do this we have been exploring the following issues:

Energy

- How much natural light can we capture in the building?
- How much light do we need to grow healthy and nutritious plants?
- How can we minimise the energy demands of artificial lighting?
- What temperature range do we need to maintain within the building?
- What changes do we need to make to the building to achieve this?

Nutrients and water

- What symbiotic relationships can we develop within the farm?
- How can we recycle naturally obtained nutrients within the farm?
- How much nutrient will we need and where will we source this from?
- What will the water demand be and can we meet this by capturing water within the building footprint?

Growing Systems

- What should we be growing and when?
- Which growing systems should we be using?
- Which growing systems should we locate where?

ABOUT THE TEAM

To set about exploring these questions a team of experts and designers were appointed. The team included:

URBED
URBED are Manchester based co-operative specialising in design, sustainability and community engagement. As lead designers on the team URBED were responsible for co-ordinating the team of experts that have been brought together.

Biomatrix
Are international experts in Ecological Design and Engineering Solutions for Bioremediation and Wastewater Treatment. Biomatrix provided expertise around nutrient and water flows around the building.

The Centre for Sustainable Agriculture
The Centre for Sustainable Agriculture based at Lancaster University brought international expertise on plant science with a practical focus on sustainable agriculture to the team.

BP Institute,
The BP Institute based at Cambridge University engages in 'open research' under the theme of multiphase flow and surface chemistry. The institute provided support on how we move air and moisture around the building.

Buro Happold
Buro Happold is an award winning international engineering company provided structural and environmental modeling input to the project.

Thanks
Thanks also to Coral Grainger and Debbie Ellen for their research and input that helped get the project up and growing.

A RESOURCE 'SENSIBLE' MODEL

Having completed this study we believe that by taking a comprehensive approach to the integration of nutrient, water and energy flows within the building ALPHA FARM has the potential to be developed as a resource 'sensible' model. By this we mean that the farm has the potential to grow food using less energy than conventional farming based on the input of large numbers of pesticides and fertilisers and the transport of food over large distances. Further investigation and testing is still required to test these ideas further.

NEXT STEPS

Alpha farm provides the opportunity to began to test some of the ideas put forward in this study. Through working closely with the local community in Wythernshawe the aspiration is to develop Alpha farm as a community farm, which builds a knowledge and skills base around vertical growing here in Wythernshawe.

CHALLENGE

Every day, the planet has 219,000 more people to feed. By the year 2050, it is estimated that nearly 80% of the world's population will live in urban centres. Bringing farming to the city could be a viable and innovative solution.

With Alpha Farm we plan to explore how to retro-fit redundant, empty city buildings to grow food – using pioneering new technologies such as aquaponics, hydroponics and aeroponics to turn a disused, eight storey office block in Wythen-shawe into a productive food hub.

What we learn in this building could revolutionise the way the world's population could be fed. We will be learning as we go, seeing which farming methods work the best, what crops can be grown and how to get the community involved.

Launching at MIF 2011 and culminating at MIF 2013, this project is deliberately experimental. Exactly where it will take us is the really exciting bit…

WHAT DO WE NEED?

	Population	Cropland need (global ha/cap)
UK	Over 60 million	70 million
England	Over 50 million	60 million
Greater Manchester	2.5 million	2.85 million
Manchester	500,000	570,000

- ***Safe and equitable water supply***
- ***Food safety and security***
- ***Engagement of society in sustainable lifestyles***
- ***Reduced dependence on fossil fuels***

WHAT ARE THE ISSUES?

- Feeding a **world population** of 6.8 billion people requires a land area the size of South America. By 2050 this population will have increased to 9.5 billion people.
- **World food prices** have risen dramatically as pressure on land, water and fossil fuel reserves has increased.
- Worldwide, **10 of the hottest years on record** have occurred since 1990 and this has affected global food production.
- **Pesticides and fertilisers** are responsible for the pollution of water courses and long-term decline in soil fertility.
- Since 1980, worldwide **oil consumption** has exceeded discovered reserves
- Nearly **40% of the Earth's land mass** is already used for agriculture.
- A typical supermarket trolley of food is quoted to have **travelled a distance** of 3,000 km.
- On average we throw away **one third of the food** that what we buy, and shops also dump food for its appearance past and sell by date.

CONCEPT

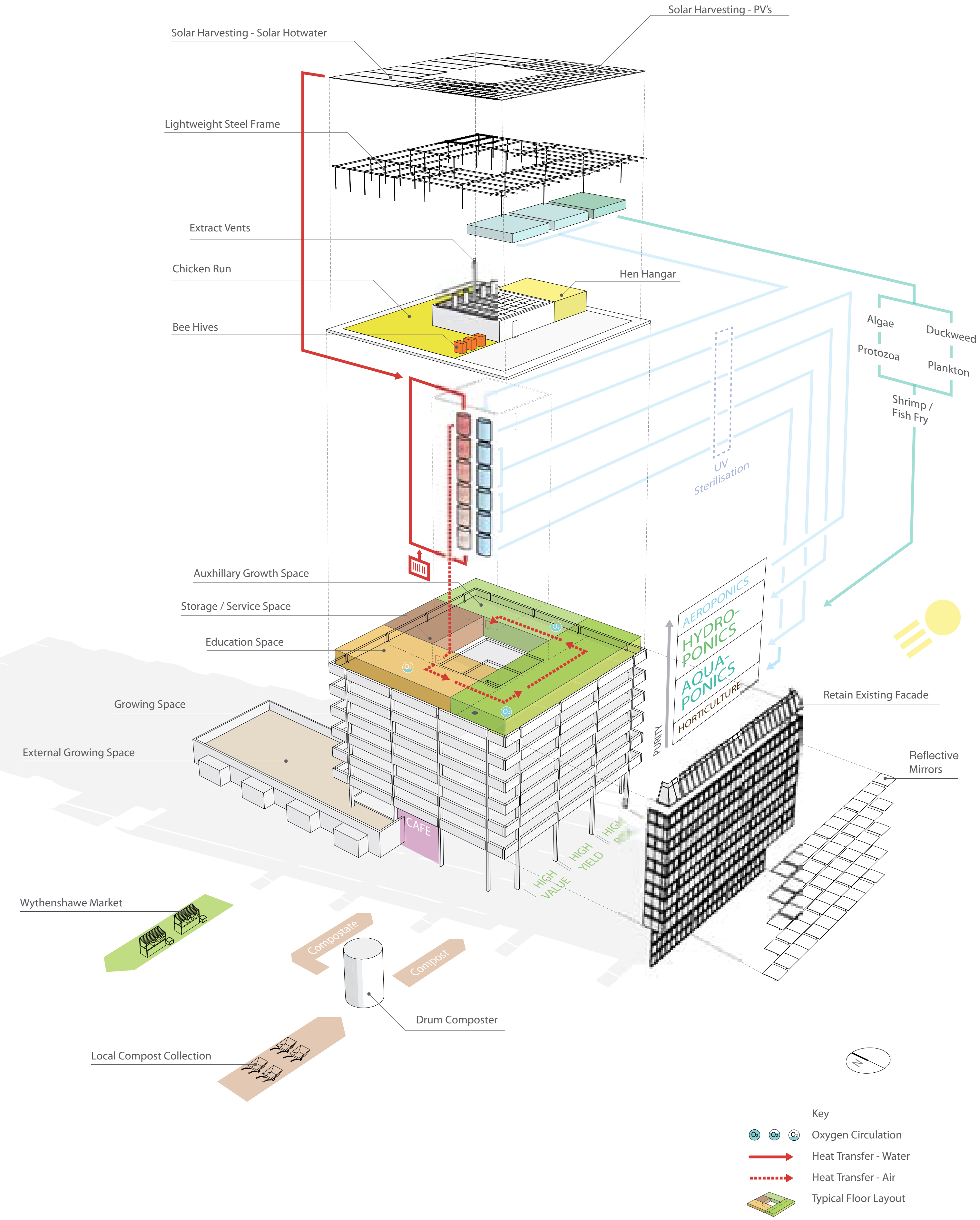
POTENTIAL BENEFITS OF VERTICAL FARMING IN A CITY:

Benefits for the community:

- *Control of food safety and security*
- *Extension of growing seasons*
- *Distribution of fresh local food*
- *Creation of local jobs*
- *Protection from weather-related crop failure*

Benefits for the environment:

- *Reduction in land use*
- *Reuse of abandoned buildings*
- *Recycling of organics waste*
- *Saving water*
- *Reduction in use of fertilisers and pesticides*
- *Prevention of agricultural run-off*



THE STORY SO FAR

What we can learn from precedents:

The Harvest Green Vertical Farm
– Vancouver, 2009 – Romses Architects

A dynamic design including a large farmer's market supermarket, agricultural research and education, and residential and hospitality areas.
http://webecoist.com/2010/01/13/3d-farming-26-vertical-farms-and-green-skyscrapers/10-harvest-urban-vertical-farm/

Center for Urban Agriculture Concept
– Seattle, 2007 – By Mithun

An off-grid design project integrating housing and farming in downtown Seattle.

http://webecoist.com/2010/01/13/3d-farming-26-vertical-farms-and-green-skyscrapers/21-seattle-off-grid-vertical-farm/

UTOPIAN CONCEPTS

The Living Tower
– Paris, 2006 – SOA Architects

A building combining offices and residential spaces with green-houses on inclined floors to allow for natural irrigation.

http://www.ateliersoa.fr/verticalfarm_en/urban_farm.htm

Forwarding Dallas
– Dallas, 2009 – Atelier Data & MOOV

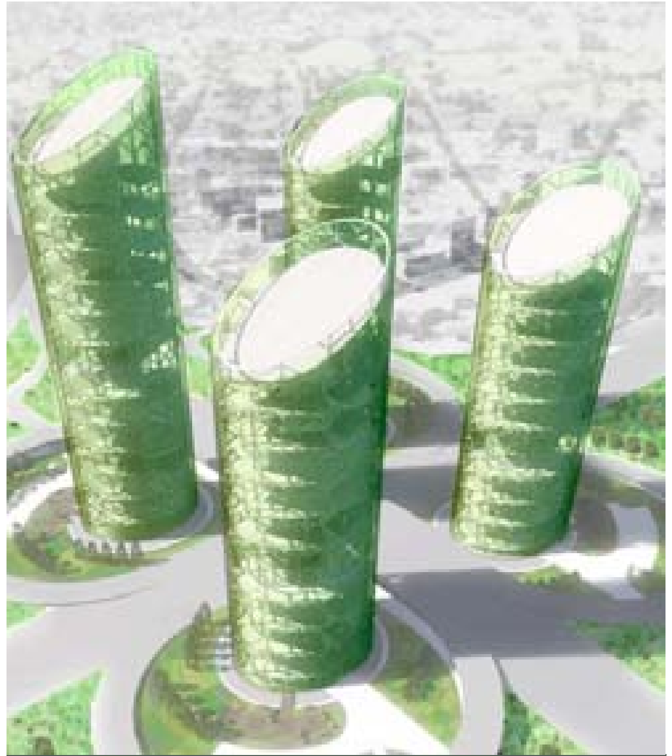
A series of valleys and hilltops designed to run 'off the grid' in Dallas

http://webecoist.com/2010/01/13/3d-farming-26-vertical-farms-and-green-skyscrapers/1-revision-dallas-green-city-design/

Dragonfly Vertical Farm
– NYC Roosevelt Island, 2009 –Vincent Callebaut

A bionic two crystalline wings tower concept for New York

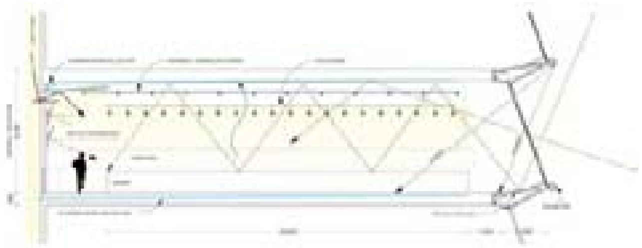
http://vincent.callebaut.org/page1-img-dragonfly.html

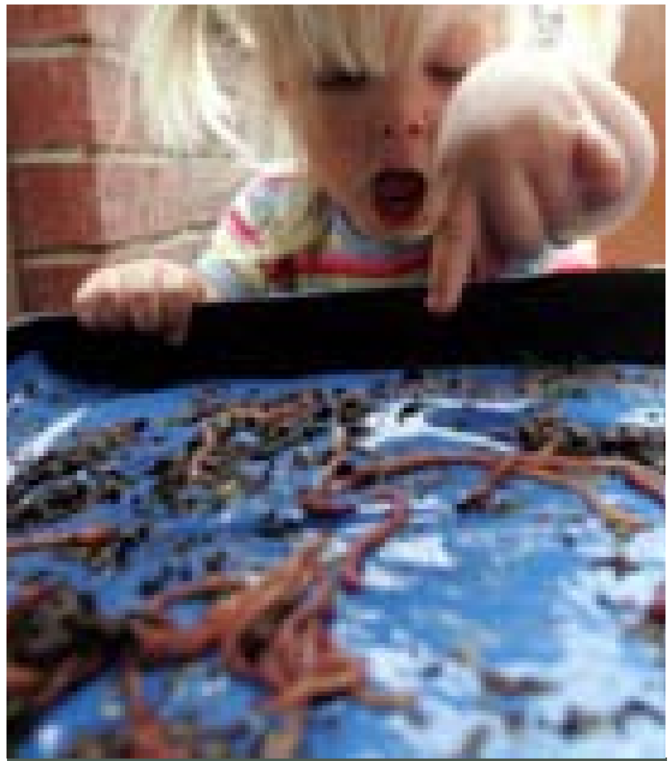


EVF: Experimental Vertical Farm
– Santiago, 2009 – Claudio Palavecino Llanos

Vertical farms could be designed to exploit underused urban sites

http://www.presidentsmedals.com/Project_Details.aspx?id=2432&dop=True&year=2009





Light: VF - Type O.2
– Australia, Olivier Foster

Light penetration in each floor of the farm

http://verticalfarmingaustralia.blogspot.com/2009/01/vertical-farm-type-o.html

Verticrop
– a Valcent product used in Paignton Zoo, UK

Animals at Paignton Zoo eat plants grown in the zoo with less water and less energy.

http://www.valcent.eu/

Combining aqua/horticulture: The ABLE project
– Wakefield

A closed loop: the plants feed off the fish waste and filter the water, and their waste is composted in a wormery from where worms are then fed to the fish.

http://www.theableproject.org.uk

Sewage/waste reuse: The Living Skyscraper
– Chicago, Blake Kurasek

Intern black water collected, treated and used as fertiliser

http://www.jessesuchoffdesign.com/the-living-skyscraper-farm-ing/vertical-farm/8602885

COMPONENTS OF THE FARM

The Plant – Chicago, 2010 – Chicago Sustainable Manufacturing Center / Illinois Institute of Technology

Volunteers are rehabilitating a former meat processing plant into the first vertical farm in Chicago.

http://www.plantchicago.com/?page_id=2

The FARM:shop – London, 2010 – Something & Son

A farm used as workspace, café and events venue in a once a derelict shop in London.

http://farmlondon.weebly.com/farmshop.html

Sweet Water Organics – Milwaukee, 2009

http://sweetwater-organic.com/blog/

A space-saving sensation at the International Green Week Berlin – Berlin, 1966

A 12 metre high tower greenhouse with automatic elevator system in 1966.
http://www1.messe-berlin.de/vip8_1/website/Internet/Internet/www.gruenewoche/englisch/Press-Service/Photos/Historic_Photos/index.jsp

RETROFIT

HERITAGE

TECHNICAL CHALLENGE

The vertical farm will not be sustainable if it uses more energy than conventional agriculture. The balance between what we put in and what we get out has to make sense environmentally. The drive for cheaper food has led to a new wave of energy intensive greenhouse horticulture. Popular fruit and vegetables are grown 24 hours a day, 365 days a year using artificial lighting and heating.

Our aim is to explore how we far we can minimise the energy required for the growing systems to work. We believe we can achieve this through careful attention to lighting and heating and by selecting crops according to the available conditions. In seeking to do this we have been exploring the following issues:

Energy

1. How much natural light can we capture in the building?
2. How much light do we need to grow healthy and nutritious plants?
3. How can we minimise the energy demands of artificial lighting?
4. What temperature range do we need to maintain within the building?
5. What changes do we need to make to the building to achieve this?

Nutrients and water

6. What symbiotic relationships can we develop within the farm?
7. How can we recycle naturally obtained nutrients within the farm?
8. How much nutrient will we need and where will we source this from?
9. What will the water demand be and can we meet this by capturing water within the building footprint?

Growing Systems

10. What should we be growing and when?
11. Which growing systems should we be using?
12. Which growing systems should we locate where?

We set out to answer these questions in the following sections

Why design a resource sensitive system?

On what we know so far the potential running costs could be up to...........

LIGHTING BILL	WATER BILL	HEATING BILL
£20,000 PER YEAR	£1,600 PER YEAR	£5,000 PER YEAR

Integrated system design has the potential to reduce the running costs down to...........

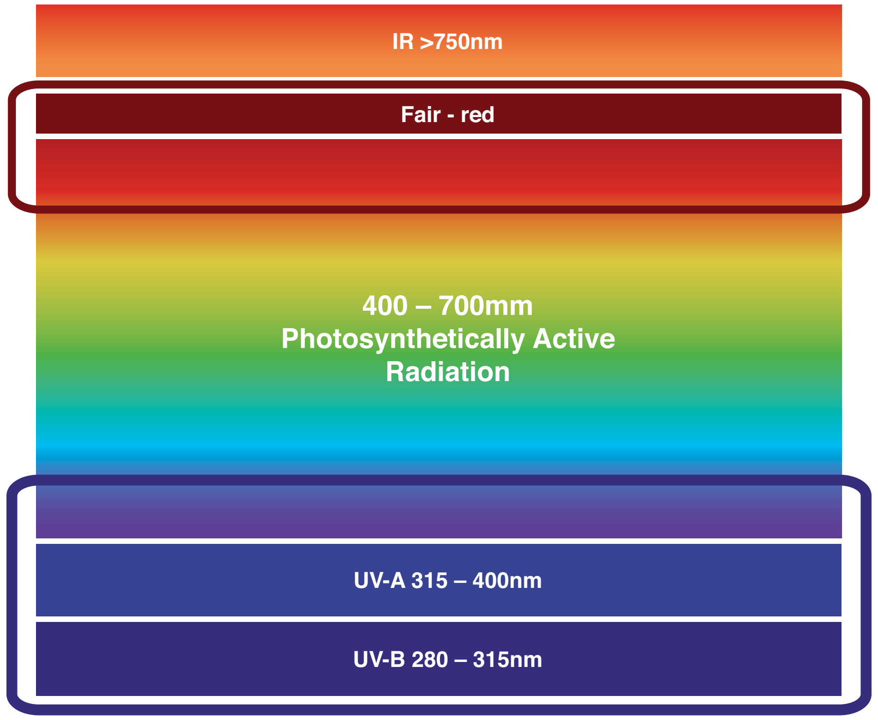
LIGHTING BILL	WATER BILL	HEATING BILL
£0 PER YEAR	£0 PER YEAR	£750 PER YEAR

** These numbers are high level estimates and should not be used for cost purposes*

TECHNICAL CHALLENGE // LIGHTING

Lancaster University Plant Testing Area

Growing under UV lamps



Plant Growing Spectrum

Plant growth depends not just on the quantity of light but on the quality. This means we need to think about lighting in a completely different way.

We have been seeking to answer the following questions:

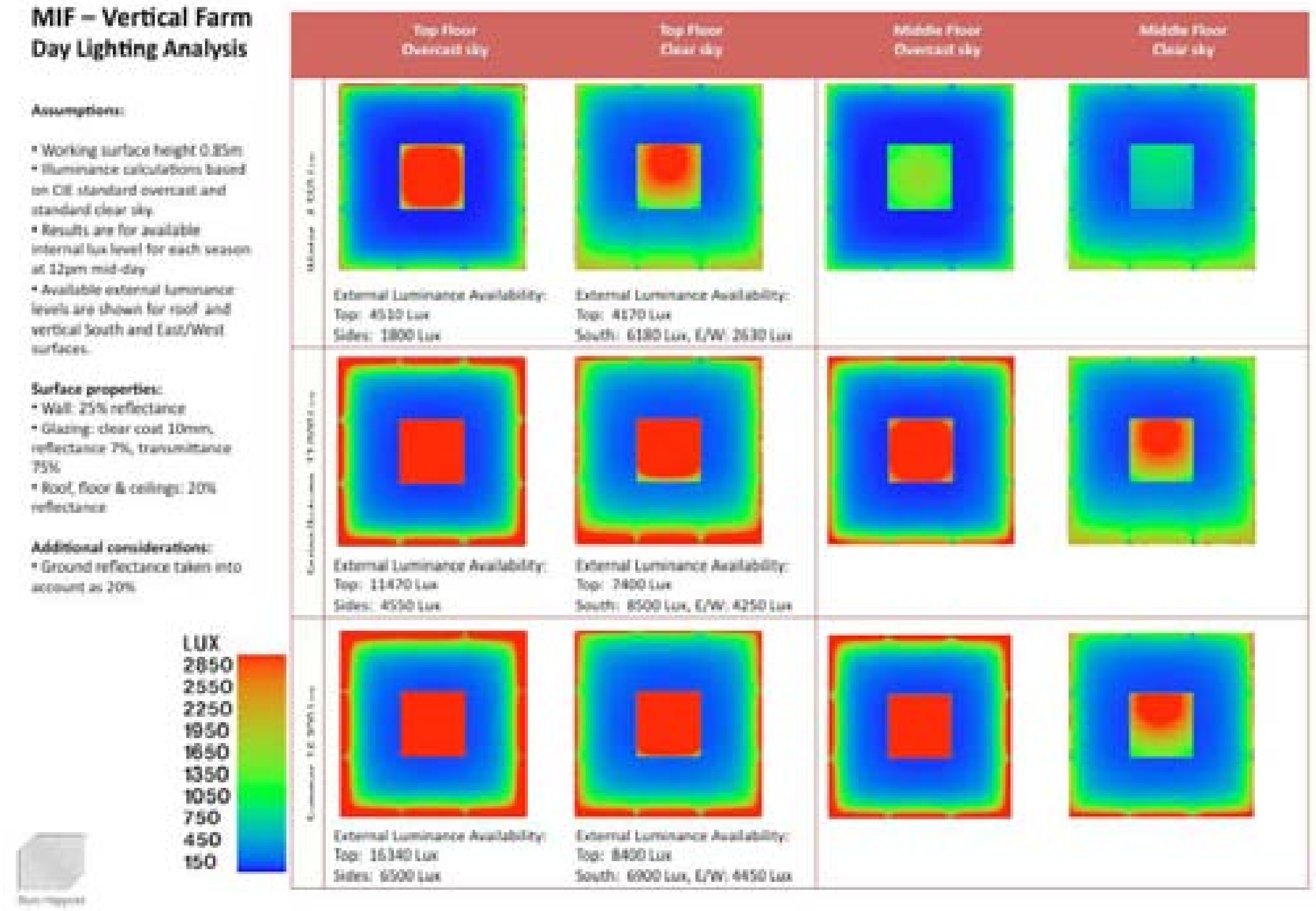
- **How much natural light can we capture in the building?**
- **How much light do we need to grow healthy and nutritious plants?**
- **How can we minimise the energy demands of artificial lighting?**
- **How much energy can we generate from solar pv?**

There are 2 major elements to the lighting design that have to be dealt with.

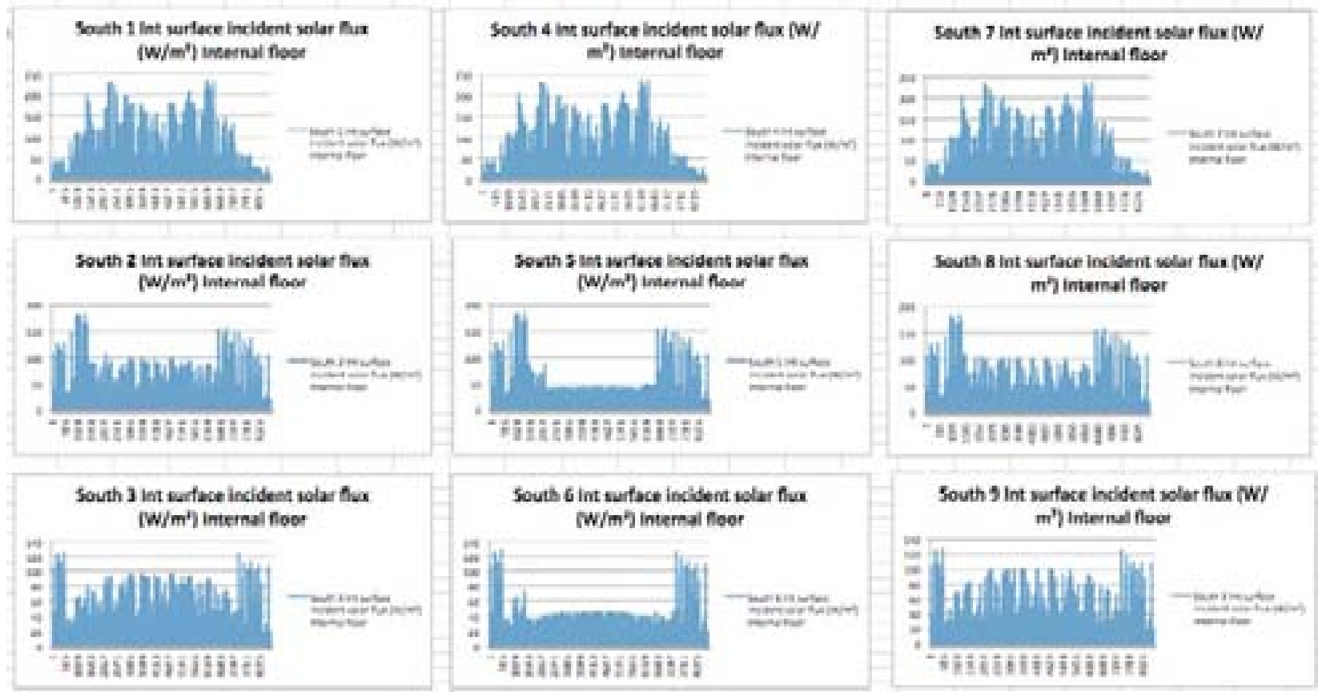
The first as can be seen in the plant growing spectrum above is that plants are more sensitive to parts of the spectrum that lighting for humans seeks to at best control, at worst omit, namely Far Red and Infra Red at one end of the spectrum UV-A and UV-B at the other. This creates challenges as well as opportunities for lighting design. The first in finding light sources that contain all the necessary parts of the spectrum to maximise plant yields per kilowatt the second in that by using light sources that can be tuned less useful parts of the spectrum do not need to be provided thus saving energy

The second key issue is that plants ability to function i.e. grow is directly proportional to the amount of light they receive, if watered, up to a surprisingly high level before other factors such as CO2 concentrations and nutrient levels come into play.

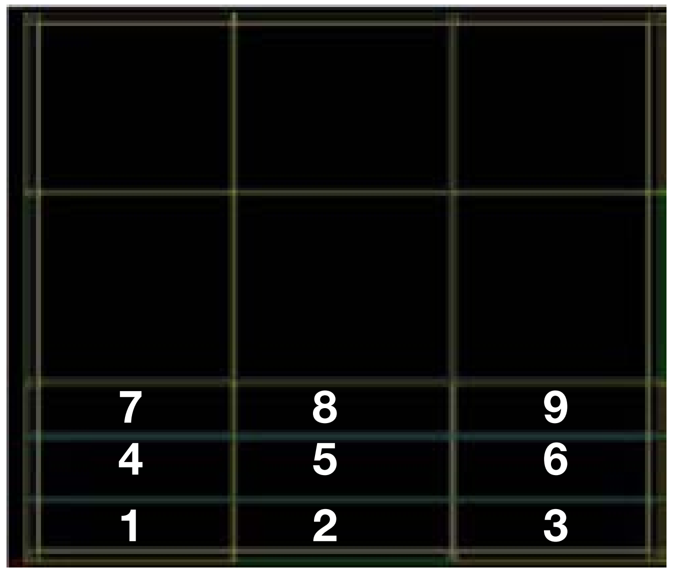
Humans will not start to think an environment under lit until about 100 lux, a good office environment is about 300, much over that and it can start to feel a bit overpowering for general lighting. Full daylight however will deliver between 10,000 and 25,000 lux, direct sunlight carries on up from there. The average greenhouse will deliver about 5,000 lux, commercial growers aim at about 10,000 lux. Using one of the most efficient light sources available, High Intensity Mercury discharge lamps would equate to between 90 and 180 W/m2 respectively if there was no daylight assistance.



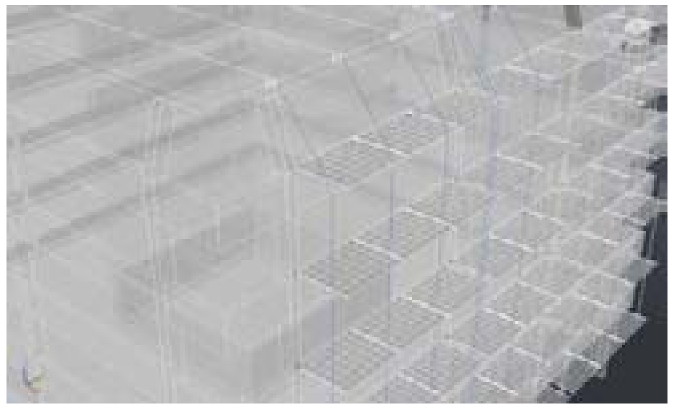
Day lighting analysis of existing conditions within the building (Buro Happold)



Sample data from of light levels (Buro Happold)



Light Grid Areas within southern edge of the floor plate (Buro Happold)

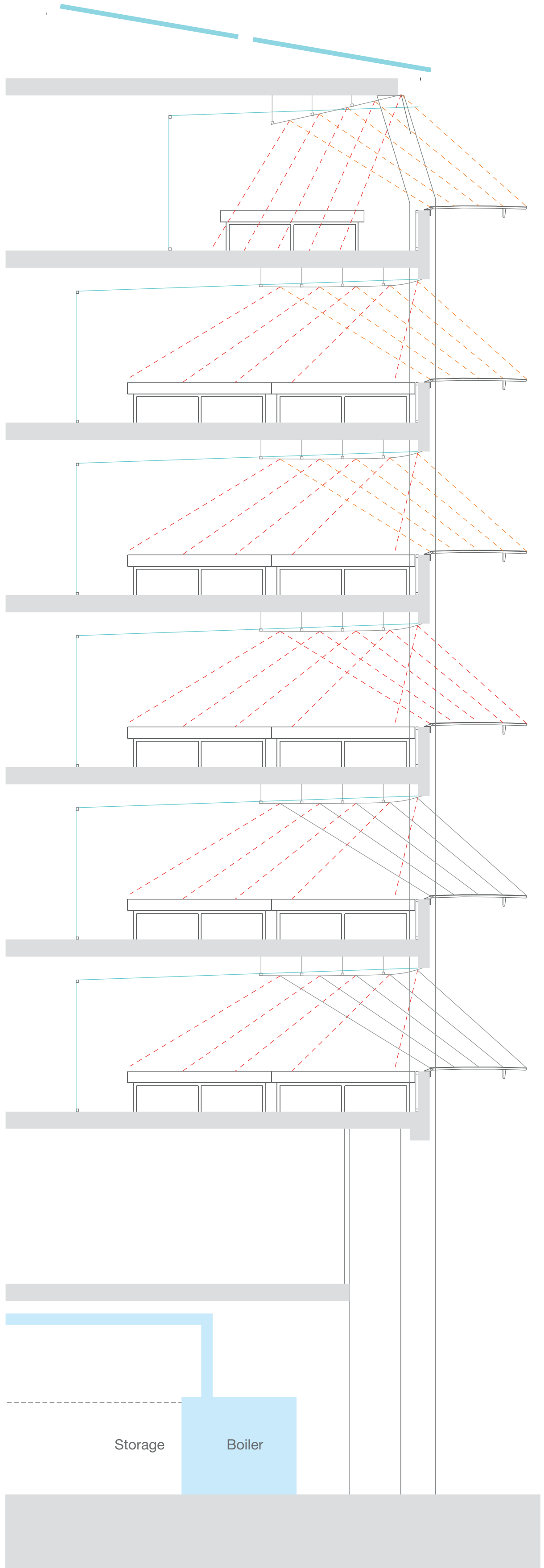


Render of mirror system

This is nearly 13 times the average family's annual electricity use per floor with a commensurate CO2 production to match. This meant than an early part of the design process was to try and make the most of the daylight outside. The building is about 60% glazed with a bank of concrete panels up to a low cill height. Early daylight modeling suggested that we could get to a viable growing illumination in a 2.5m zone in front of the windows in direct Summer sun but that this would need topping up during the rest of the year.

The next stage was then to collect the sunlight that was landing on the external concrete ad redirect that into the building. The most cost effective method looked like it might be a set of mirrors on the outside of the building that bounce sunlight onto the ceiling where another mirror directs it back onto the plants. The outer ones could all be on a single remote controlled motor that would track the sun angles throughout the year and so not block light onto the floor below. The internal mirror could then be optimised to give the best spread internally. This has a further advantage for insulation. Glass absorbs UV, as it can be harmful to humans this is a disadvantage..

Modeling in various software has proved difficult both because of the double reflections and also because the mirrors are intended to move with the sun so analyzing a static state will not produce appropriate results. Interrogating illuminance levels on the 3d model has suggested that the deepest depths of each floor are unfeasible for growing without full time artificial lighting. However the mirrors can top up the daylight on the first 6m of the floor plates, leaving the back part of the floor for circulation and ancillary facilities. The estimate is that by shaping the internal mirror we can top up the daylight in the front 3m by 25% and put the rest of the reflected light onto the second bay. This will enable the front 3m to be productive throughout the year and the middle strip of the floor to be productive for 9 months of the year, using an amount of energy that could be generated by a photovoltaic array on three quarters of the main roof.



FL7
AEROPONICS

FL6
HYDROPONICS
- THIN FILM

FL5
AQUAPONICS
- EXPANDED CLAY MEDIUM

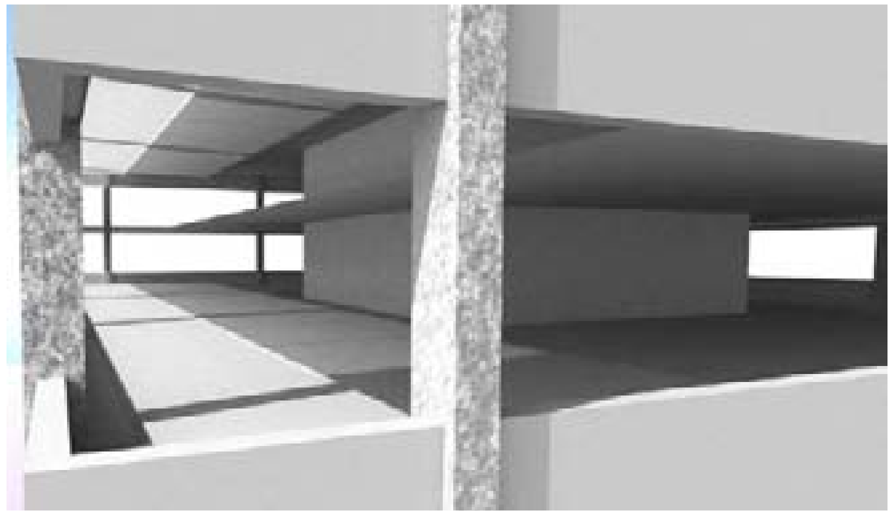
FL4
AQUAPONICS
- DEEP WATER

FL3
HORTICULTURE
- DRIP FED IRRIGATION

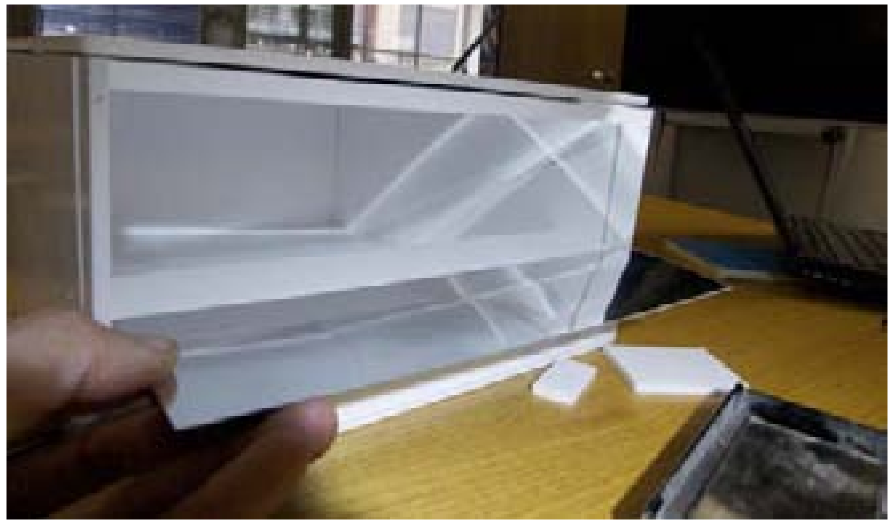
FL2
HORTICULTURE
- DRIP FED IRRIGATION

FL1

GF



3D render illustrating the increased light levels using a mirror system



Model Testing Mirror System

OUR FINDINGS

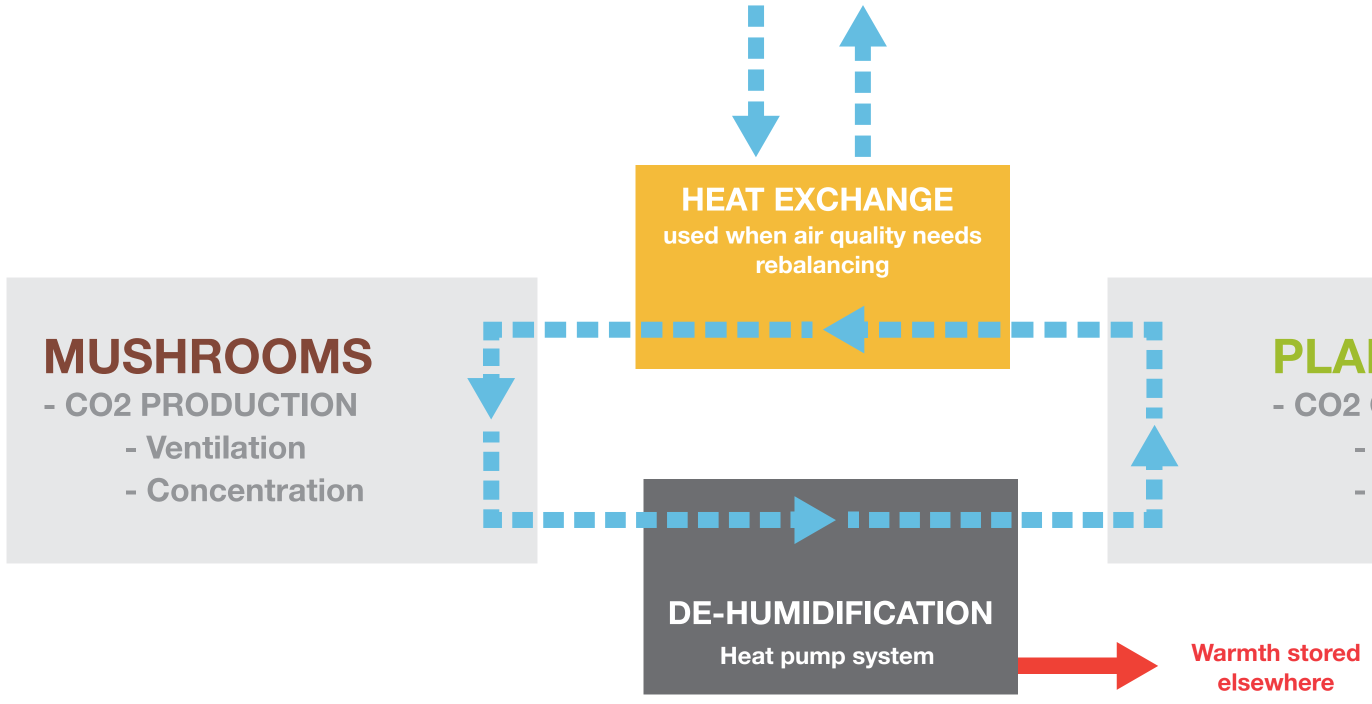
What we have found out

- To grow at commercial crop yields even with the mirrors the bills are astronomical along with the cost of the kit
- By reducing the lighting levels to slightly above normal greenhouse conditions the lighting needed can be provided by 2/3rds of the roof covered in PV and supplemented by the light from the mirror system 5m deep into the plan on the south face
- LEDs have yet to replace high pressure sodium lights (street lights)

Questions still outstanding

- Are there further efficiencies to be had from the LEDs?
- How do we reliably calculate yields based on the moveable mirrors?

TECHNICAL CHALLENGE
// AIR QUALITY



CO2 circulation within the building

We know that we will need to circulate air between the different growing areas, and between floors, in order to manage humidity, oxygen and carbon dioxide levels.

We have been seeking to answer the following questions:

- **Can we balance the CO_2 / O_2 requirements of the different growing systems within the building?**
- **What are the ventilation / air movement paths with the building?**

Ventilation Model

A principle in commercial growing facilities is that the sealed nature of the space means that the CO_2 levels can be increased which as long as there is sufficient light and nutrient can have a significant impact on crop output, which can rise by xxx%. The maximum yield would require that we increase the lighting level of 10,000 lux but as we are going for nearer 5,000 lux we will only be able to increase yields by 30% (TBC).

If we were to simply ventilate the building naturally this CO_2 would need to be topped up from other sources. Furthermore if we naturally ventilate the building then in the heating season we would be wasting heat, throwing that air to the outside. Mushrooms create CO_2 whereas plants consume it. It seems logical therefore to make use of this natural atmospheric symbiosis. The table on the opposite page shows a calculation based on the consumption of CO_2 by the plants relative to the production of CO_2 by the mushrooms. The other important role of the ventilation system is to deal with the moisture levels. Plants can transpire as much as 250ml of water per square meter per hour. The table on page 39 shows the quantities of this. The proposal therefore is primarily to recirculate air between the mushrooms and the growing areas with a dehumidifier between.

Air in the plant growing areas is depleted of its CO_2 but becomes very humid, this is then fed to the mushroom growing areas, the CO_2 rich and now very damp air is then partially dehumidified and fed back to the plants. The dehumidification process will create low grade heat that can be stored in the central heat stores discussed later for use either to heat the building or to heat the water in the irrigation system. In the hot periods of the summer this system will have to be opened to avoid overheating but the cost of cooling equipment seems prohibitive. In addition the mushrooms will continue to grow at night while the plants will stop, so they will continue to need ventilating while the plants do not.

Major CO2 producers in the farm

CO_2 SOURCES

		TARGET	REQ ACH	CONCENTRATION
CONSUMPTION	PLANTS	600	4	880PPM
PRODUCTION	MUSHROOMS	800	6	2520PPM

RATIO	2.9

The proposal is that vent in the roof are opened along with perimeter vents on each floor so that the natural stack effect will draw cool air into the building and expel moist CO2 rich air into the atmosphere. From an energy consumption point of view, it would be advantageous to put a ventilation heat recovery unit on the connection to outside so that the atmosphere can be replenished during the heating season without loss of heat however these units are expensive and the saving is unlikely to be recouped. Confirmation of this would require more detailed thermal modelling that has not been possible within the scope of this piece of work.

OUR FINDINGS

What we have found out

- Would require continuous human occupation to meet CO2 so we've replaced them with mushrooms
- But these require heavily modified conditions at points in their growing cycle
- Plants will grow a lot better with more co2 but it has to be balanced with heat and light
- Plants create a lot of water vapour when growing
- We may be able to get rid of this without losing the heat and water through use of the thermal cycle

Questions still outstanding

- How do we ascertain the gas production and consumption of the different parts of the system?
- This will affect yields - we'll not know till we try it
- How big does the compressor actually need to be, how much warmth will it create?
- How many air changes are required to replenish O2 levels and remove pathogens?

TECHNICAL CHALLENGE
// GROWING SYSTEMS

Produce	Growing season	Where does the local supermarket source them from?
Broad beans	Mid-June – mid-September	UK
Broccoli	April – October	UK, Spain, Kenya
Carrots	Mid-May – October	UK, France, USA
Lettuce	Mid-May – Mid-October	UK, Spain, Holland, 'many countries'
Mushrooms	September –October	UK, Holland, France
New potatoes	April – July	UK, France
Onions	Mid-June – Mid-October	UK, Holland, Spain, Israel, Egypt, Mexico
Parsnips	Mid-October – February	UK, Spain
Potatoes	Mid-July –February	UK, Austria, Israel
Spinach	Mid-March – Mid-June	UK, Italy, Spain
Strawberries	Mid-May -–July	UK, Egypt
Sweet peppers	February – September	UK, Spain, Israel
Tomatoes	Mid-June – October	UK, Spain, Holland, Morocco, Italy

Our aspiration is that the vertical farm should produce fresh, healthy food in a sustainable way. In order to test whether it can meet this aspiration we are looking in more detail at what can realistically be grown in the building, and the improvements we might have to make to the growing conditions.

We have been seeking to answer the following questions:

- **What should we be growing and when?**
- **Which growing systems should we be using?**
- **Could it grow a sufficient range of produce that it would provide a balanced diet?**
- **Could it grow produce in a way that could provide balanced nutrition all year round?**
- **Could it grow produce that the local community is familiar with and have experience cooking?**

An aspiration of the project is to explore if we are able to grow a sufficient range of produce to provide a balanced diet. The drawing opposite sets out what we are aiming to grow within the farm. This is based on the Department for Health's 'eatwell plate' which identifies a range of food that should be present in a healthy diet.

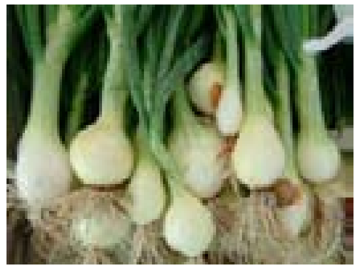
We have also looked at the fresh produce being sold in Wythernshawe' local supermarket in order to look at which of these products we could look to grow with the farm.

On the following pages we describe the growing systems that will be integrated into the farm. These are:

Growing System 1: Plants
Growing System 2: Fungiculture (Mushrooms)
Growing System 3: Vermiculture (Worms)
Growing System 4: Aquaculture (Fish)







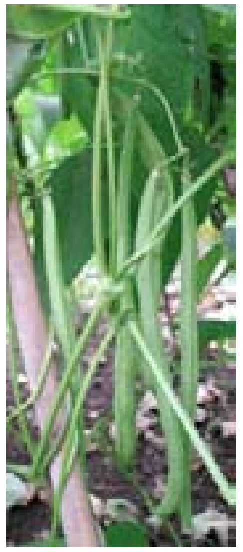




FRUIT AND VEGETABLES

BREAD, RICE, POTATOES AND PASTA

MEAT, FISH, EGGS AND BEANS


Range of food to be produced in the farm based on the Department for Heaths eat well plate.

http://www.dh.gov.uk

GROWING SYSTEM 1
PLANTS

Plants will be grown within the farm using soil based techniques and hydroponic techniques.

Soil Based

- The growing of plants in a soil based medium.

- Drip fed irrigation

Water and nutrients fed to the plants through a drip irrigation system

Hydroponic

Hydroponics is the growing of plants without using soil. Plants are instead grown in an inert medium, and fed a nutrient solution which includes all the elements necessary for plant growth.

- Substrate

Plants are grown in buckets. Nutrient solution is delivered to the plants through drip emitters on a timed system.

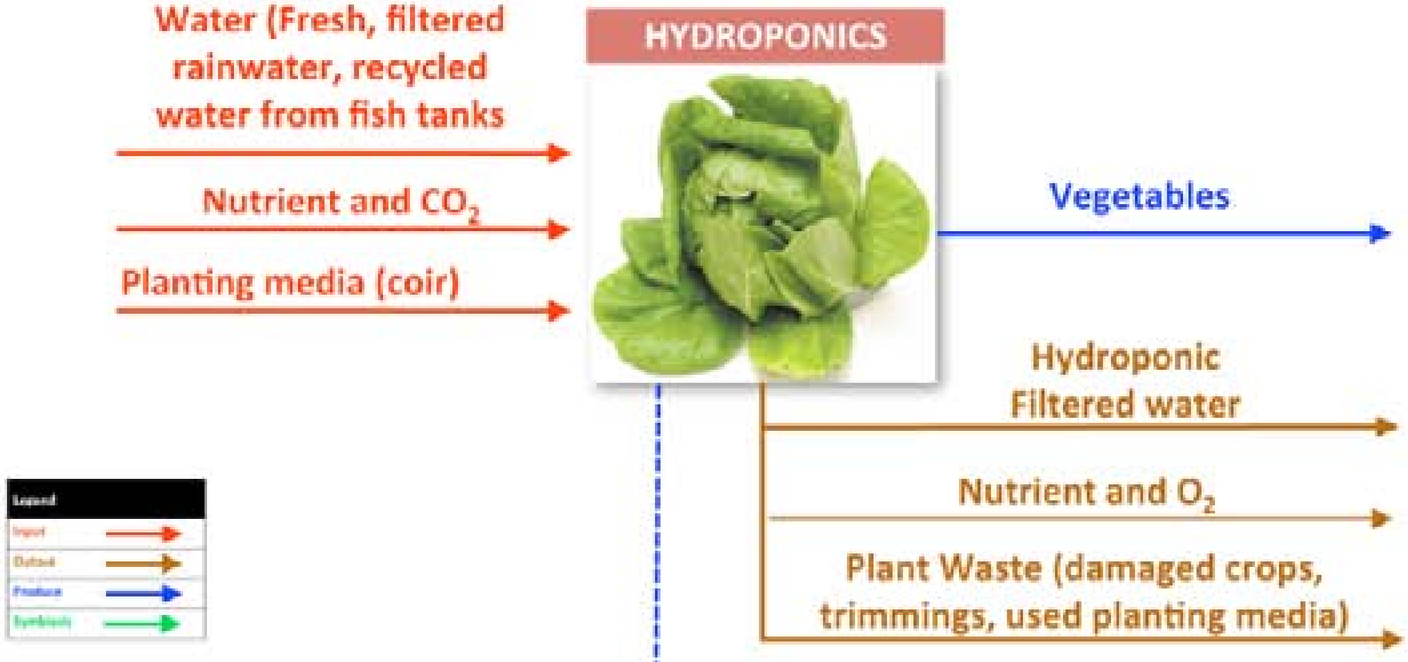
- Thin Film

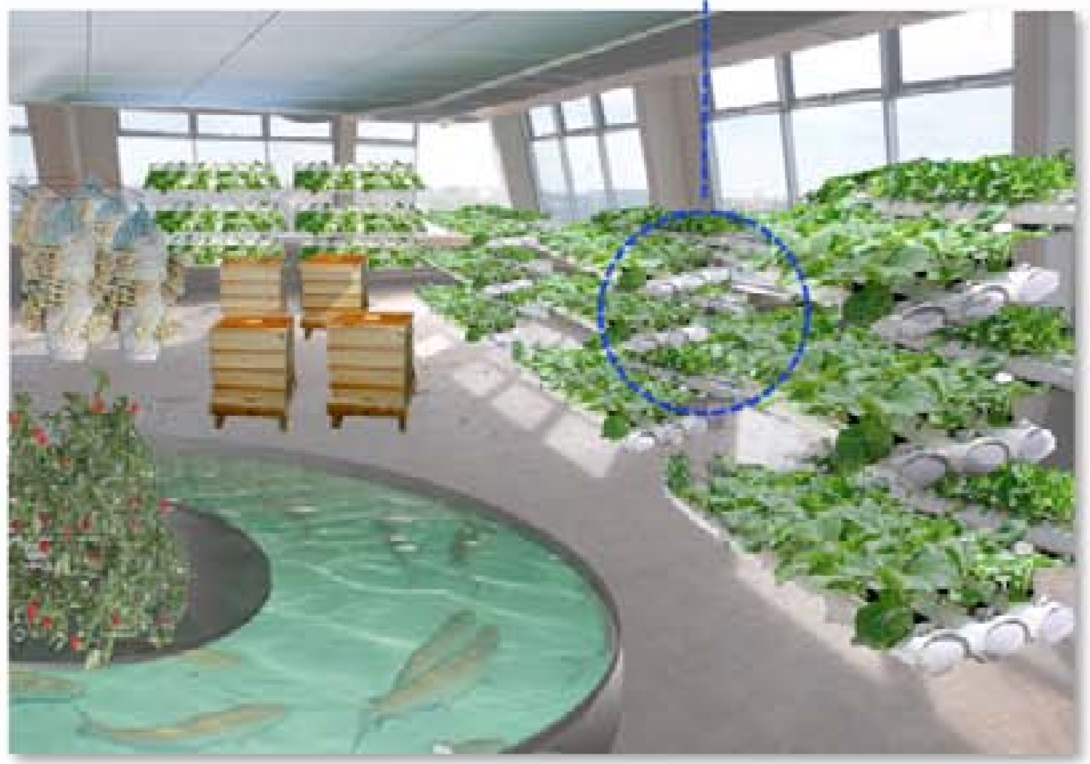
Plants are grown in channels which the nutrient is pumped through. The plant routes are kept moist by the thin film of nutrient solution as it passes by.

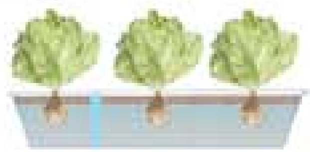
RESOURCES	Dry Mineral/Nutrient Supplements	Organic Liquid Mineral/ Nutrient Supplements	Green Organic Waste	Carbon Source: Paper/Cardboard, Leaves, Straw etc.	Light Source: Natural or Artificial	Filtered Rainwater	Fresh water	Pelleted Fish feed	Electricity / Process Energy
BIOMATRIX WATER	• Zeolite • Limestone • Gypsum • Basalt • Azomite • Natural NPK	• Essential Nutrients • Liquid Calcium • Humates • PH balancer • Seaweed extract • Biological inoculants						(Reserve only) 	

HYDROPONICS

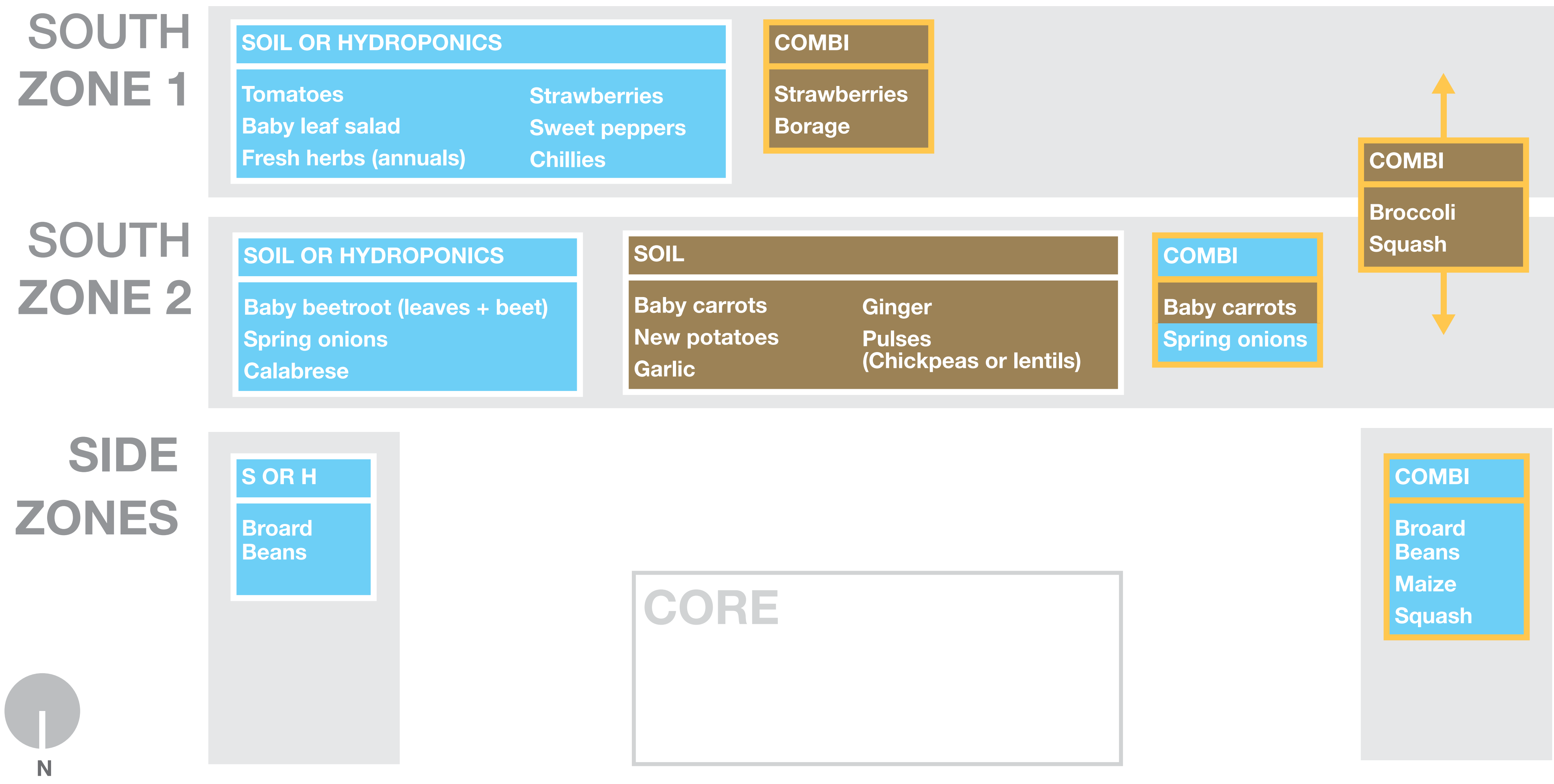
Growing System Component Flows





Grow Bed Options	
Deep Water Culture (DWC) 	• Plants grown in rockwool or coir before being transferred onto trays with net pots, directly above to contact water • Water re-circulated typically needs to be aerated to avoid root putrification. Water to be concealed from light to avoid algae growth
Nutrient Flow Technique (NFT) 	• Very shallow streams of water with nutrient re-circulated passed the bare roots of plants in watertight gully (channels), at a specific slope, to achieve desired water flow rates. • Water temperature can fluctuate (extra care if water is to be recirculated back to a fish tank)
Grow Beds (media filled) 	• Grow media: ○ LECA balls act as pH buffer, and improve aeration due to micro-pore structure ○ Gravels. ○ Dosing Siphon • Potential for Vermiponics

Essential plant nutrients and categories (Different plants have different requirements) Nutrients & Minerals to be Bio-Complexed through vermi-processing, for enhanced plant availability.		
Primary Macronutrients (required in large amounts)	• Nitrogen (N) • Calcium (Ca) • Phosphorus (P) • Potassium (K)	(Note: Where Vermi-complexing is excluded, microbial inoculants can be considered)
Secondary macronutrients (required in lesser amounts)	• Sulphur (S) • Magnesium (Mg)	
Micronutrients (required in trace amounts)	• Zinc (Zn) • Iron (Fe) • Copper (Cu) • Manganese (Mn)	• Boron (B) • Molybdenum (Mo) • Chlorine (Cl)



Planting schedule for standard floor

In collaboration with Lancaster University we have designed a planting schedule for a standard floor in Alpha Farm. The schedule is designed around 3 main growing zones:

South Zone 1: This is the zone closest to the windows so will receive the highest levels of light.

South Zone 2: This is the second zone into the plan. Light levels with be supplemented by the mirror system but will still be lower than South Zone 1.

Side Zones: These Zones are on the front zone of the East and West sides of the building. These will receive less light than South Zone 1 & 2 but will receive either early morning or evening light.

Within each planting zone we have identified the plants most suitable to the growing conditions of the zone and also if the plant is suitable for growing hydroponically/

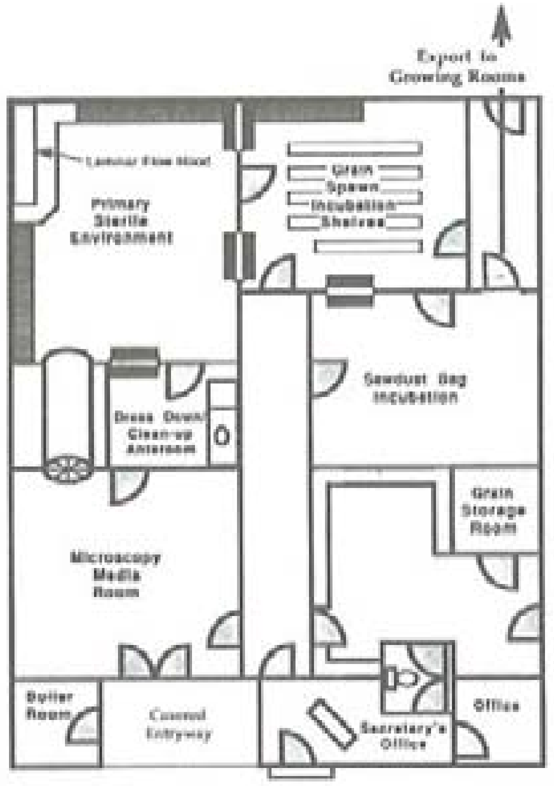
We have also included a number of planting combinations where plants benefit from being grown in proximity to other types of plants. For example growing Broccoli close to Squash.

GROWING SYSTEM 2
MUSHROOMS

To assist the growing of the plants and to provide an additional food product we are looking to grow mushrooms in the farm. The aim is to utilise the CO_2 produced by the mushrooms to stimulate the growth of the plants and to use the higher levels of O_2 from the plants to increase the growth of the mushrooms.

We are looking to grow 3 different variety of mushrooms:

- Button
- Chestnut
- Shiitake



Floor plan of a mushroom spawn laboratory. Lost of the substrate enters the clean room through the autoclave (midway left). Spawn is exported from the laboratory to the mushroom growing rooms. Spawn is rotated frequently out of the laboratory

GROWTH PARAMETERS

Spawn Run:
Incubation Temperature: 70–75°F (21–24°C)
Relative Humidity: 95–100%
Duration: 20–28 days (+ 20-day resting period)
CO_2: >10,000 ppm
Fresh Air Exchanges: 0–1 per hour
Light Requirements: n/a

Primordia Formation:
Initiation Temperature: 45–55°F (7–13°C)
Relative Humidity: 98–100%
Duration: 10–14 days
CO_2: 1,000–2,000 ppm
Fresh Air Exchanges: 1–2 per hour
Light Requirements: 200–500 lux

Fruitbody Development:
Temperature: 50–60°F (10–16°C)
Relative Humidity: 90–95%
Duration: 10–14 days
CO_2: 1,000–5,000 ppm
Fresh Air Exchanges: 1–2 per hour, or as required
Light Requirements: 200–500 lux

Cropping Cycle:
Two crops, 4 weeks apart

GROWTH PARAMETERS

Spawn Run:
Incubation Temperature: 70–75°F (21–24°C)
Relative Humidity: 95–100%
Duration: 20–28 days (+ 14–28 day resting period)
CO_2: >10,000 ppm
Fresh Air Exchanges: 0–1 per hour
Light Requirements: n/a

Primordia Formation:
Initiation Temperature: 50–60°F (10–16°C)
Relative Humidity: 98–100%
Duration: 8–12 days
CO_2: 1,000–2,000 ppm.
Fresh Air Exchanges: 1–2 per hour
Light Requirements: 100–200 lux

Fruitbody Development:
Temperature: 50–60°F (10–16°C)
Relative Humidity: 90–95%
Duration: 7–14 days
CO_2: 1,000–5,000 ppm
Fresh Air Exchanges: 1–2 per hour or as required
Light Requirements: 100–200 lux

Cropping Cycle:
Two crops, 2 weeks apart

GROWTH PARAMETERS:

Spawn Run:
Incubation Temperature: 70–80°F (21–27°C)
Relative Humidity: 95–100%
Duration: 35–70 days (strain-dependent)
CO_2: >10,000 ppm
Fresh Air Exchanges: 0–1 per hour
Light Requirements: 50–100 lux

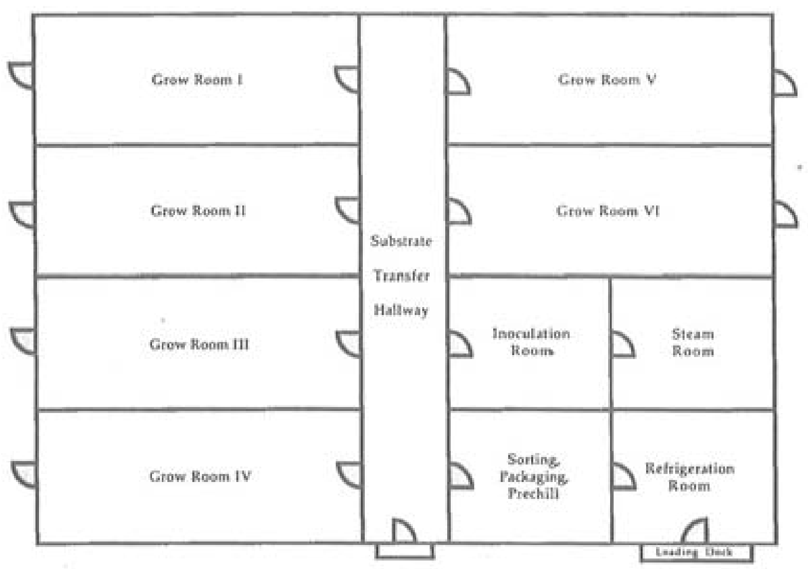
Primordia Formation:
Initiation Temperature: 50–60°F (10–16°C)*
60–70°F (16–21°C)**
Relative Humidity: 95–100%
Duration: 5–7 days
CO_2: <1,000 ppm
Fresh Air Exchanges: 4–7 per hour
Light Requirements: 500–2,000 lux at 370–420 nm

Fruitbody Development:
Temperature: 50–70°F (16–18°C)*
60–80°F (21–27°C)**
Relative Humidity: 60–80%
Duration: 5–8 days
CO_2: <1,000 ppm
Fresh Air Exchanges: 4–8 per hour
Light Requirements: 500–2,000 lux at 370–420 nm***

Cropping Cycle:
Every 2–3 weeks for 8–12 (16) weeks

* Cold-weather strains; ** Warm-weather strains. Fluctuations of temperatures within these ranges are beneficial to the development of the mushroom crop. *** Light levels below 500 lux cause noticeable elongation of the stem.

Grow Room Layout



Floor plan of standard growing-room complex. This configuration allows for 6 growing rooms and processing areas to be housed under one roof.

Mushrooms growth occurs in 3 distinct stages:

Spawning: This is the period when you have inoculated your substrate with spores and placed them in a warm and dark place so they can germinate and grow to healthy mycelium.

Primordia Formation and Fruitbody development: The period when you place the mycelium for the first time in a place with (indirect) sunlight and a lower temperature. The mycelium will start to form mushrooms. The mushrooms in their smallest state are called pinheads. Fruitbody Development

Cropping: When the first pinheads have shown up it's time for cropping, growing up to adulthood. A lot of fresh air and a somewhat lower humidity is preferred.

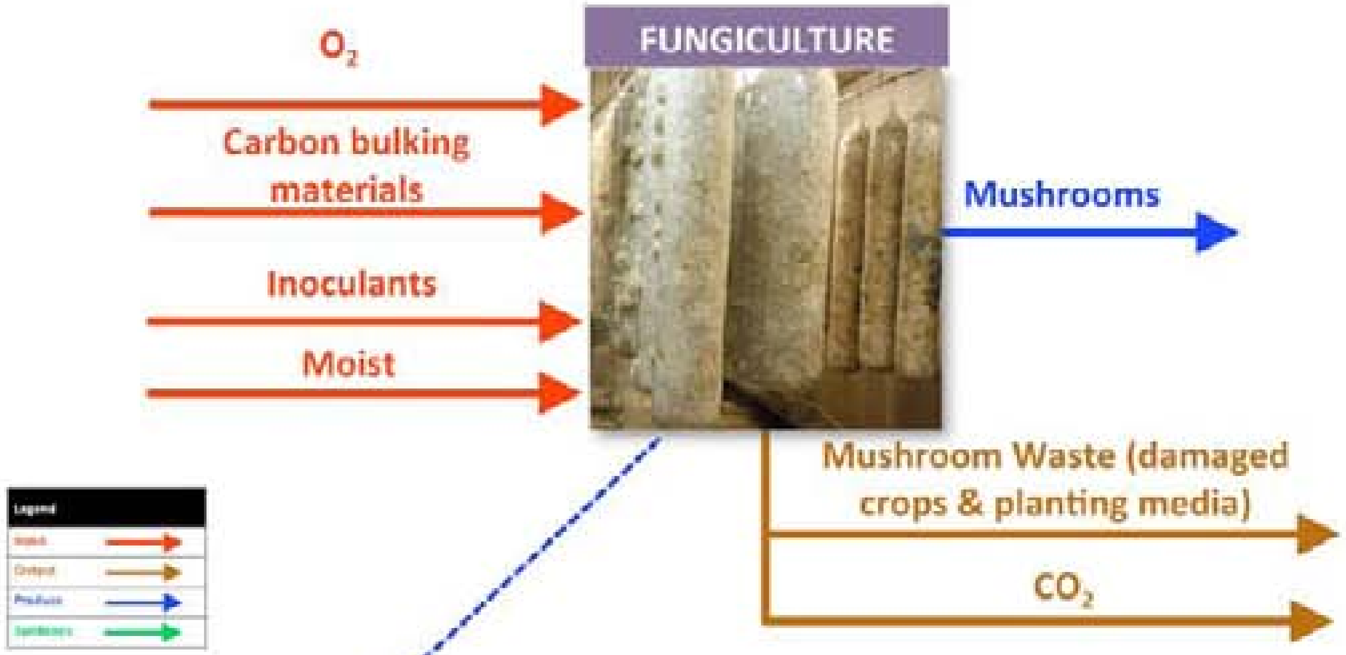
Conditions

The mushrooms will be grown in 2 separate areas. Spawning will occur in the mushroom spawning laboratory and the Primordia Formation and cropping will take place in separate grow rooms. The plans opposite demonstrate how these facilities might be laid out. The mushrooms are very susceptible to contamination so the mushrooms have to be grown in a sterile environment to avoid contamination. Different varieties of mushrooms require different conditions to grow. These are set out in the lists above.

RESOURCES	Dry Mineral/Nutrient Supplements	Organic Liquid Mineral/ Nutrient Supplements	Green Organic Waste	Carbon Source: Paper/Cardboard, Leaves, Straw etc.	Light Source: Natural or Artificial	Filtered Rainwater	Fresh water	Pelleted Fish feed	Electricity / Process Energy
BIOMATRIX WATER	• Zeolite • Limestone • Gypsum • Basalt • Azomite • Natural NPK	• Essential Nutrients • Liquid Calcium • Humates • PH balancer • Seaweed extract • Biological Inoculants						(Reserve only)	

FUNGICULTURE

Growing System Component Flows



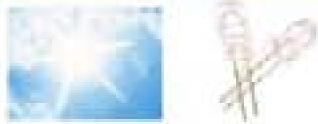
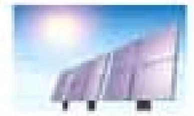
Recommended Notes on Mushroom Farming	
Types of Indoor Mushrooms	• **Tray Cultivation**: White Button Mushrooms or when mature, the Portobello Mushrooms (*Agaricus bisporus or Agaricus bitorquis*) • **Bag Cultivation**: Shiitake and Oyster Mushrooms • **Autoclavable grow vessels.** Japanese mushrooms e.g: Enokitake, Shiimeiji and Hiratake.
Substrate:	• **Carbon** source (cellulose, hemicellulose, lignin): Straw, hardwood, softwood, logs, saw dust, wood chips, hay, corn cobs, sugarcane bagasse, etc. • **Nitrogen** Source (Proteins and amino sources of Nitrogen): Bran from rice, wheat, spelt, seed meals of soybean, corn and cotton seed meals. Poultry manure, etc. • **Occasional Additives**: Gypsum, molasses, sugar, or limestone

GROWING SYSTEM 3
VERMICULTURE

Vermiculture is the artificial rearing or cultivation of earth worms.

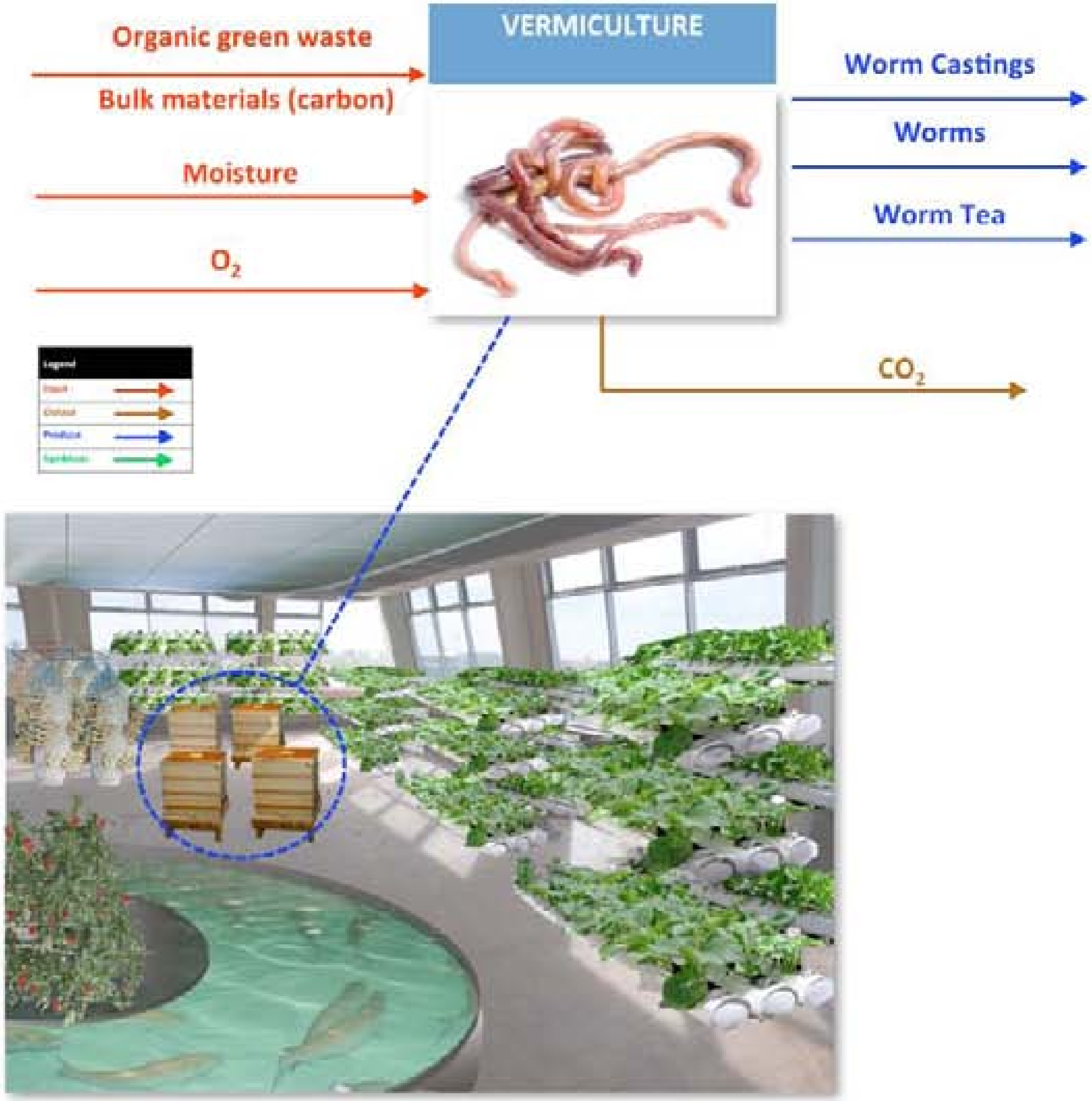
The works are used to compost organic green waste. The worm castings are used as a nutrient source for the plants and the worms can be fed to the fish as part of the aquaculture.

See the diagram on the following page for a more detailed explanation
.

RESOURCES	Dry Mineral/Nutrient Supplements	Organic Liquid Mineral/ Nutrient Supplements	Green Organic Waste	Carbon Source: Paper/Cardboard, Leaves, Straw etc.	Light Source: Natural or Artificial	Filtered Rainwater	Fresh water	Pelleted Fish feed	Electricity / Process Energy
BIOMATRIX WATER	• Zeolite • Limestone • Gypsum • Basalt • Azomite • Natural NPK	• Essential Nutrients • Liquid Calcium • Humates • PH balancer • Seaweed extract • Biological Inoculants						(Reserve only) 	

VERMICULTURE

Growing System Component Flows



Worm options	Typical Conditions for Breeding *E. foetida*, *E. andrei* and *D. veneta* in Organic Wastes *(C.Edwards et.al 2011)*
Red wigglers (*Eisenia foetida* & related sps)  	• Temperature: 15 °C to 25°C (limits 4°C to 30°C) • Moisture content: Typical 70%-90% • Oxygen: Aerobic • Ammonia (Can accept manure in some applications) • Salt content: More tolerant, • Typical pH : 5-8.0 • More volatile inputs.
European Nightcrawler (*Dendrobaena veneta*) 	• Typical Temperature: 12 °C to 25°C • Moisture content: 70%-90% • Oxygen: Aerobic • Prefers lower Ammonia • Salt content: Prefers Lower • pH : 5-8 • Lower volatility feed, more lignin cellulose, trial fungi residue.

NOTES:

- Species contain both sexes, bands shed forming egg capsules.
- Provide multi layered vermi-substrate with variable moistures, textures and breeding roughage for optimal reproduction conditions.
- Substrate layers must have moisture and air flow conveyance capacity.
- Avoid overfeeding, substrate compaction or saturation.

GROWING SYSTEM 4
AQUACULTURE

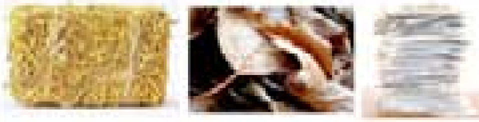
Aquaculture is the farming of aquatic organisms such as fish, crustaceans, molluscs and aquatic plants.

We are looking to grow the following breeds of fish:

-Tilapia: Omnivorous species which eat phytoplankton, algae and aquatic plants.
- Trout: Carnivorous species that eat insects, small fishes, shrimp etc
- Perch: Carnivorous species which eat small fish, can be supplemented with insects/live worms

Aquaponics

The nutrient rich waste water from the fish tanks can be used as a nutrient source within a hydroponic growing system. In consuming the nitrate and other nutrients in an aquaponic system, the plants help to purify the water.

RESOURCES	Dry Mineral/Nutrient Supplements	Organic Liquid Mineral/ Nutrient Supplements	Green Organic Waste	Carbon Source: Paper/Cardboard, Leaves, Straw etc.	Light Source: Natural or Artificial	Filtered Rainwater	Fresh water	Pelleted Fish feed	Electricity / Process Energy
BIOMATRIX WATER	• Zeolite • Limestone • Gypsum • Basalt • Azomite • Natural NPK	• Essential Nutrients • Liquid Calcium • Humates • PH balancer • Seaweed extract • Biological inoculants						(Reserve only) 	

AQUACULTURE

Growing System Component Flows

Water (Fresh, filtered rainwater, recycled water from hydroponics) →

O_2 →

Fish feed (worms, vegetation, larvae) (pellets in reserve) →

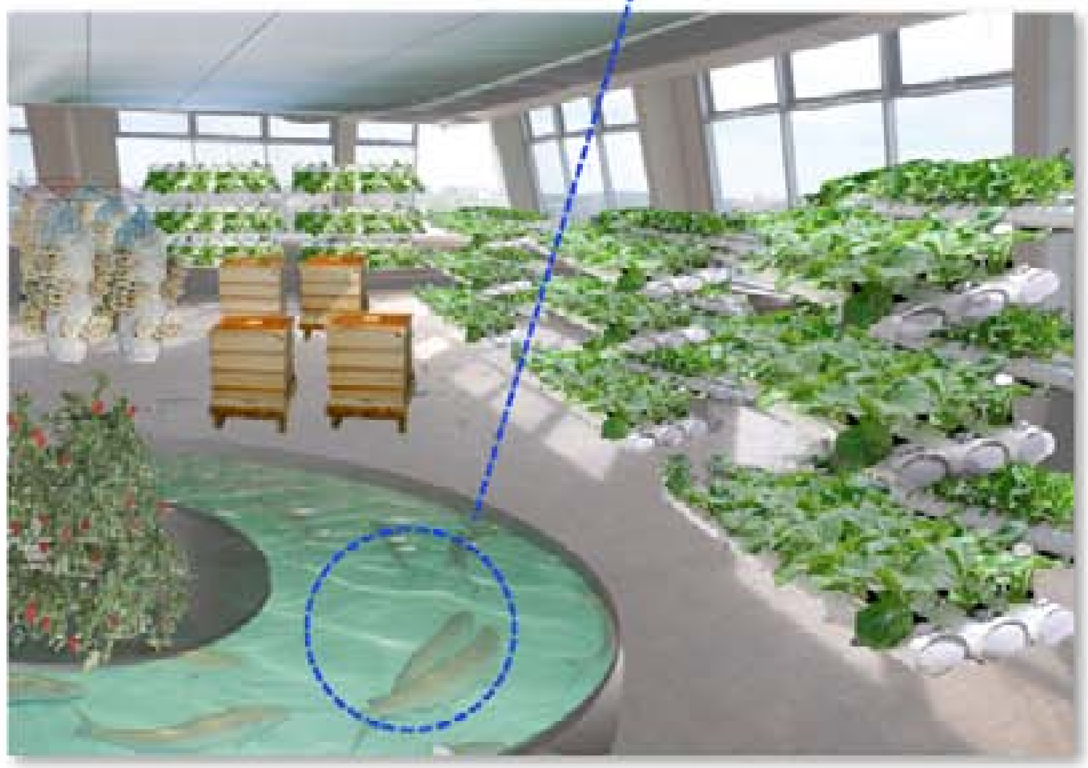
AQUACULTURE

→ Fish

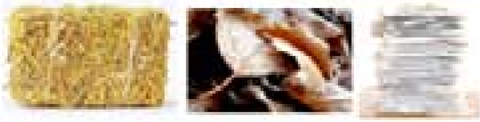
→ CO_2

→ Water with fish waste

Legend	
Input	→
Output	→
Produce	→
Symbiosis	→



Recommendedn Notes	
Water	• Refer to Aquaponics Section for different types of fish species growth requirements. • If water is used to irrigate hydroponic system, temperature and nutrient balance will fluctuate. Water needs to be monitored closely, and should be changed in reasonable volumes to avoid shock to the fish and the system, the gradual, % replacement fresh water added, adjusted to maintain nutrient, balance.
Fish feed	• Worms or vegetable trimmings can be used as feed, depending on fish preferred diet. • Nutrient content of feed should be carefully selected. • Imbalanced nutrient concentrations in the tank can be due to over/underfeeding. • Fungi Culture residue may be suitable for some species. • Fish food pellets may supplement the systems as a back up reserve when needed.
Fish size	• Fish grow at different rates, even within the same species. Some species live well together, while others may eat fingerlings. It is important to harvest the fish when they reach desired sizes or to keep equal size fish in the same tank, to allow optimum feed and healthy grow for every fish and to allow multiple growing circuits to isolate disease if necessary. • A final separated clean water tank, may be desirable, to enhance fish taste, just before harvest. (~ Last 5-14 days)

RESOURCES	Dry Mineral/Nutrient Supplements	Organic Liquid Mineral/ Nutrient Supplements	Green Organic Waste	Carbon Source: Paper/Cardboard, Leaves, Straw etc.	Light Source: Natural or Artificial	Filtered Rainwater	Fresh water	Pelleted Fish feed	Electricity / Process Energy
BIOMATRIX WATER	• Zeolite • Limestone • Gypsum • Basalt • Azomite • Natural NPK	• Essential Nutrients • Liquid Calcium • Humates • PH balancer • Seaweed extract • Biological Inoculants						(Reserve only) 	

AQUAPONICS

Growing System Component Flows

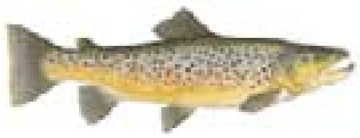
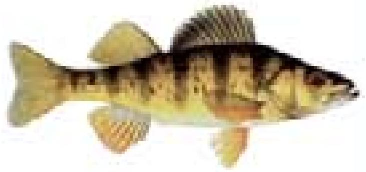
Inputs:

- Water (Fresh, filtered rainwater, recycled water from hydroponics)
- Nutrient, O_2 and CO_2
- Fish feed (worms, vegetation, pellets)
- Planting media (Coir)

AQUAPONICS

Outputs:

- Vegetables
- Fish
- Plant Waste (damaged crops, trimmings, and planting media)
- Water with fish waste
- Nutrient and O_2

Types of Fish Commonly Farmed in Aquaponics and general information.	
Tilapia (white, red) 	• Diet: Omnivorous: Phytoplankton, algae & aquatic plants. Can be supplemented with plant cut-offs, worms & other invertebrates. • Growth: May reach harvest size of 500g after 6months, males typically being larger than females at each age. • Conditions: Temp: 24-32°C, D.O: 3-8mg/l, pH: 6-8. • Fish Flavor variable.
Trout (rainbow, brown) 	• Diet: Carnivorous and diets are typically high in energy/lipids, eats insects, small fishes, shrimp etc. • Growth: Market size at 30-40cm in 9-18months, 'pan-size' under favorable conditions. • Temp: Around 8°C, mortality risk at above 18°C, D.O: 6-8mg/l, pH: Around neutral.
Perch 	• Diet: Carnivorous, eats small fish, can be supplemented with live insects/worms. • Conditions: Temp: 16-24°C, D.O: 5-8mg/l, pH: 6-9.

Recommended Notes	
Hydroponic system	• Refer to Hydroponic Section • Plants, green and leafy such as lettuce, herbs, spinach, Bokchoy. Mint should be avoided as they will overtake available growth space and around piping /tank systems (*Murray Hallam, Aquaponics Aust.*)
Lights and nutrient	• Water circulation from fish tank to hydroponics, should be protected from light to avoid algae blooms. (Vermi-Tea helps to balance algae growth) • PH, DO and NH3, among other tests should be carried out everyday for the first 6 months. • Worms can be introduced (Vermiponics) to help balance nutrient flow. • Vegetables can be planted on coir, which may be digested in worm bins later.

Aquaponic growing system

OUR FINDINGS

What we have found out

- It looks like its possible to cover most of the Eatwell plate
- Different crops are suited to different growing systems and conditions
- We need to select crops that have shorter season
- Mushroom growing is a complex process that needs careful management
- Worms need careful management to produce beneficial nutrients
- Fish farming can be split into cold and warm water varieties
- Stocking density will need to be considered

Questions still outstanding

- More options for companion planting
- Best fit for crops and systems on each floor
- Best fit for different nutrient systems
- Mushroom fruiting CO2 limiting factor
- Potential rate of ‘vermiliquour’ and ‘tea’ production
- How often the fish tank water needs changing

TECHNICAL CHALLENGE // NUTRIENT FLOWS

The vertical farm will not be sustainable if it is reliant on fossil fuel based fertilisers. Furthermore, the requirements for mains water, oxygen and carbon dioxide will need to be met in a sustainable way.

- **What symbiotic relationships can we develop within the farm?**
- **How can we recycle naturally obtained nutrients within the farm?**
- **How much nutrient will we need and where will we source this from?**

Modern industrial agriculture, horticulture and aquaculture is almost entirely dependent on fertilisers that are manufactured from fossil fuels or unsustainable sources of protein. Furthermore, food prices are influenced by oil prices, which are projected to rise as oil resources dwindle and the energy required to obtain oil increases. We believe we can create a sustainable system integrating growing systems that recycle nutrients and by sourcing of nutrients from organic waste that is available in the surrounding area.

We have been exploring the following possibilities:

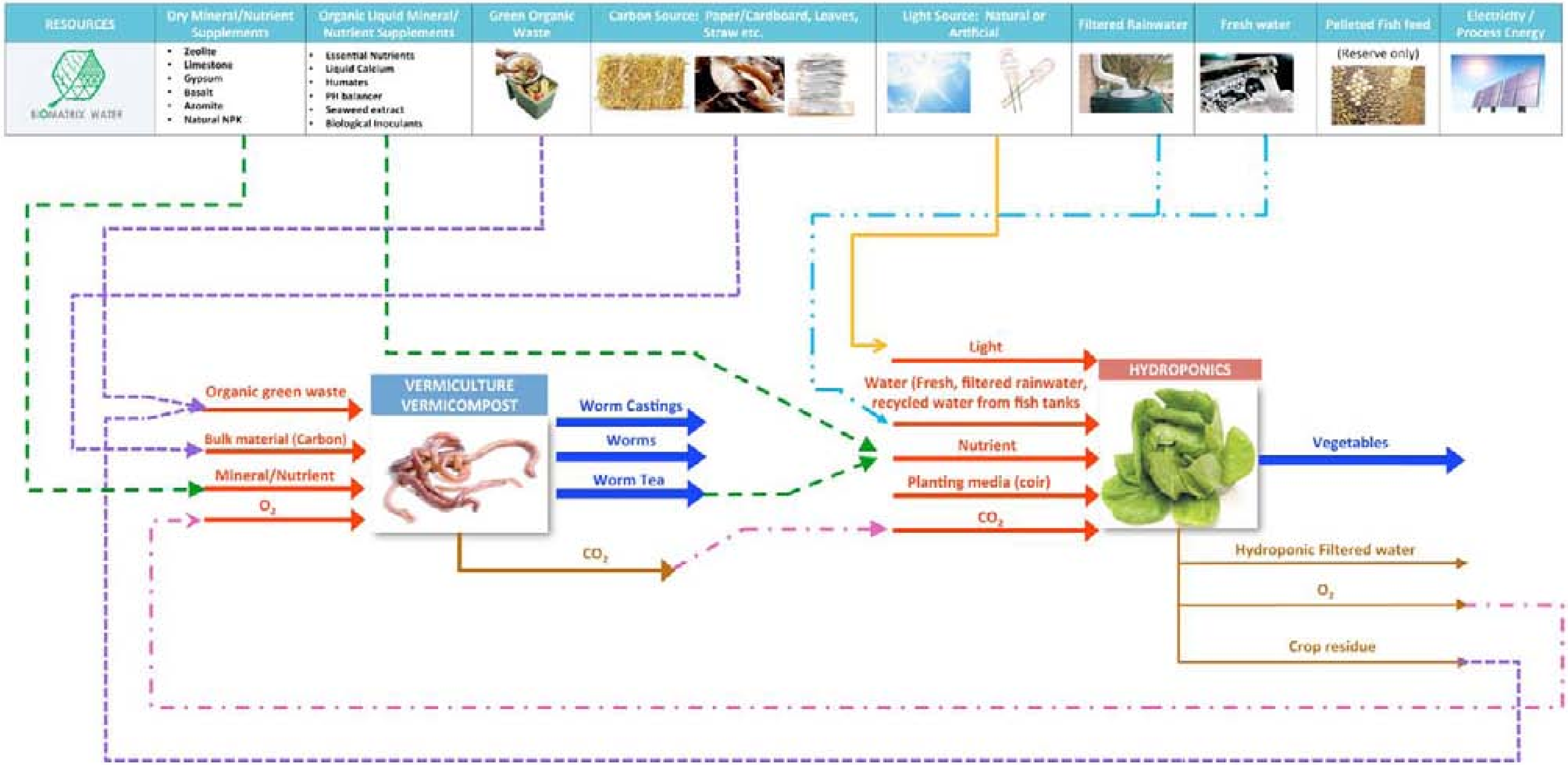
Growing its own nutrients: We can include growing systems that produce food and fertiliser for the rest of farm. These symbiotic relationships could enhance the farm's overall productivity.

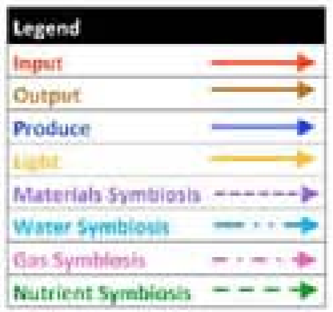
For example, the farm could produce worms using 'vermiculture' techniques, which would feed fish in an aquaculture growing system. The worms in turn would require organic waste for food, which could be grown in the fish tanks.

Fish produce nitrogen rich waste, which can be used, following treatment, as fertiliser for plants. Fungi also produce a nutrient rich leachate. These could also be used to fertilise the plant growing systems but may require special treatment to minimise bacterial or fungal infections.

Oxygen and carbon dioxide are key 'nutrients' that are required by plants and fungi in order to grow. The excess oxygen produced by the plants could be used to enhance mushroom growing. In turn these will produce large amounts of carbon dioxide, which could then enhance plant growth.

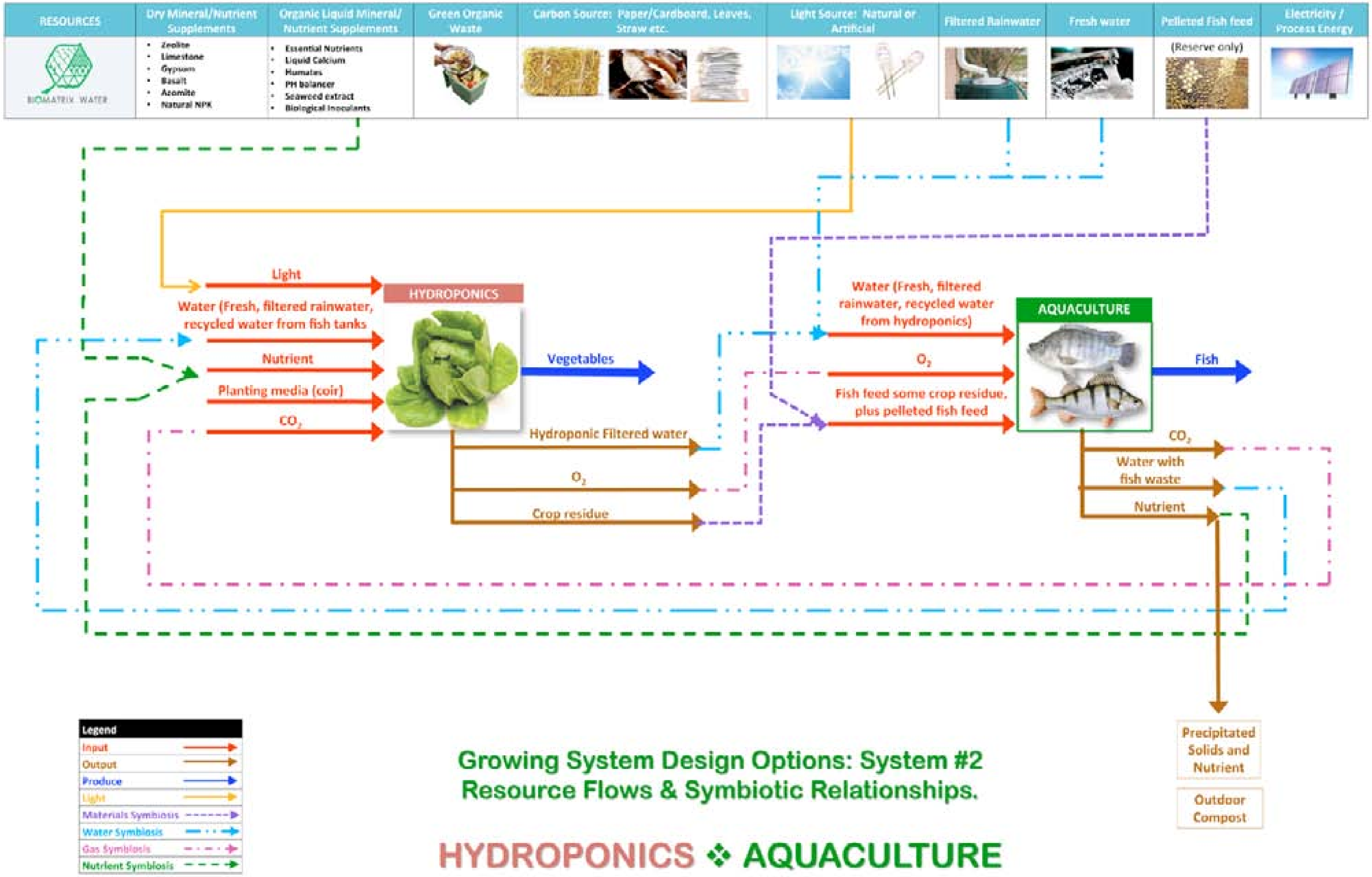
Bringing in organic nutrients: The farm will require a supply of new nutrients. This could be obtained from local sources of organic waste but we would need to be sure they are safe for food production. Options we are exploring include the composting of local household organic waste or using liquid 'digestate' from Davyhulme sewage works or the waste treatment plant at Sharston.





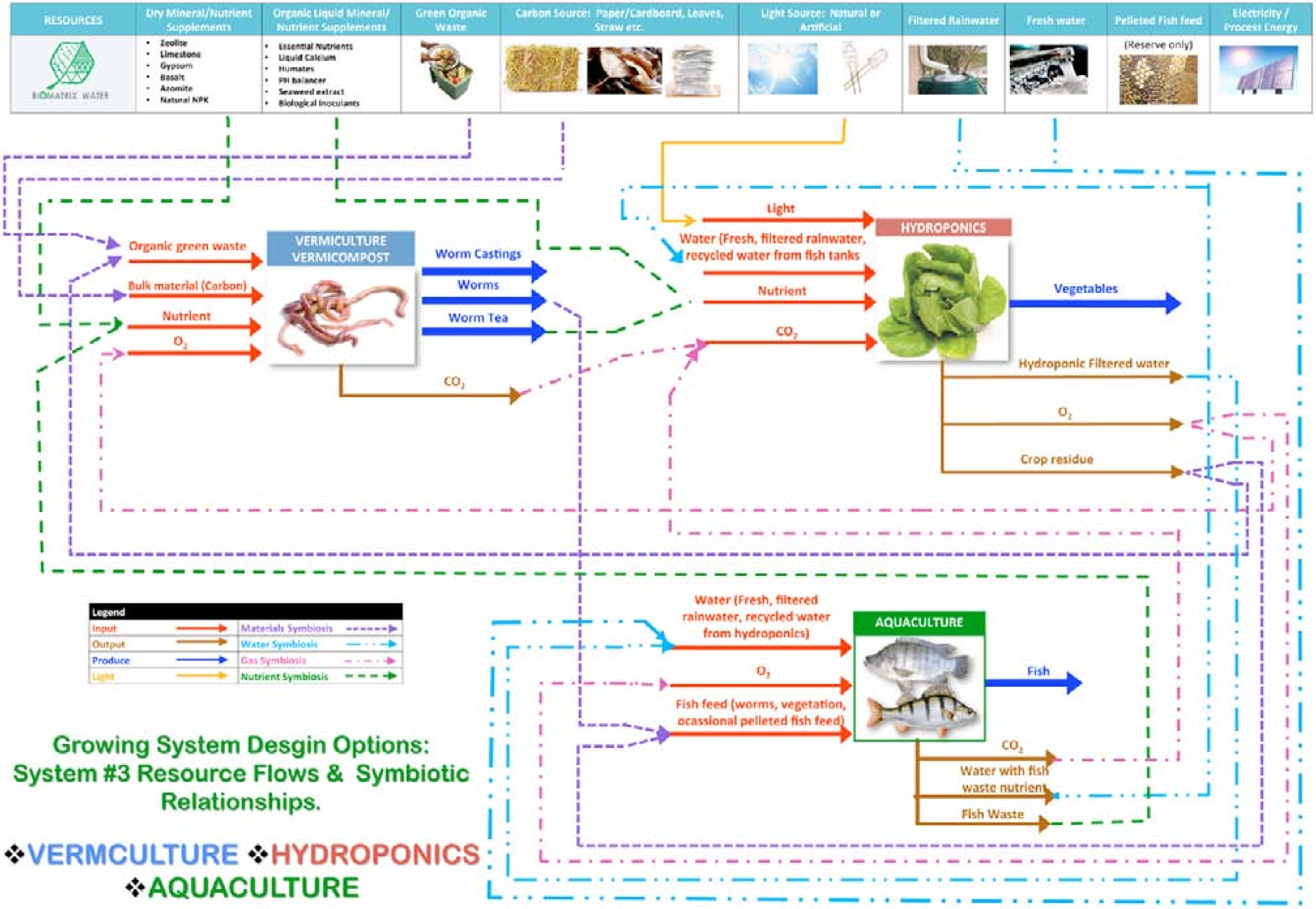
Growing System Options: System #1
Resource Flows & Symbiotic Relationships.

❖VERMICULTURE ❖ HYDROPONICS



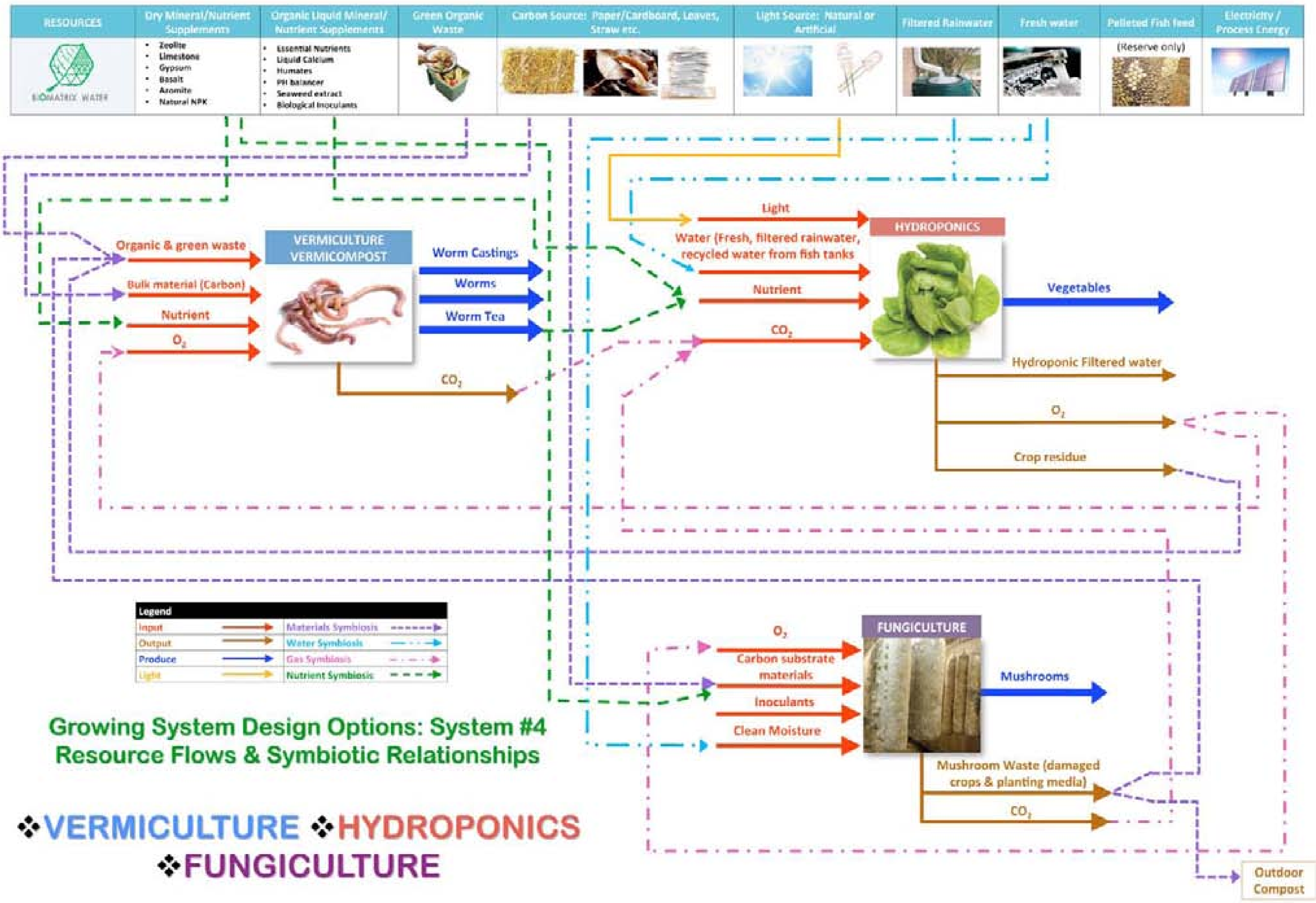
Growing System Design Options: System #2
Resource Flows & Symbiotic Relationships.

HYDROPONICS ❖ AQUACULTURE



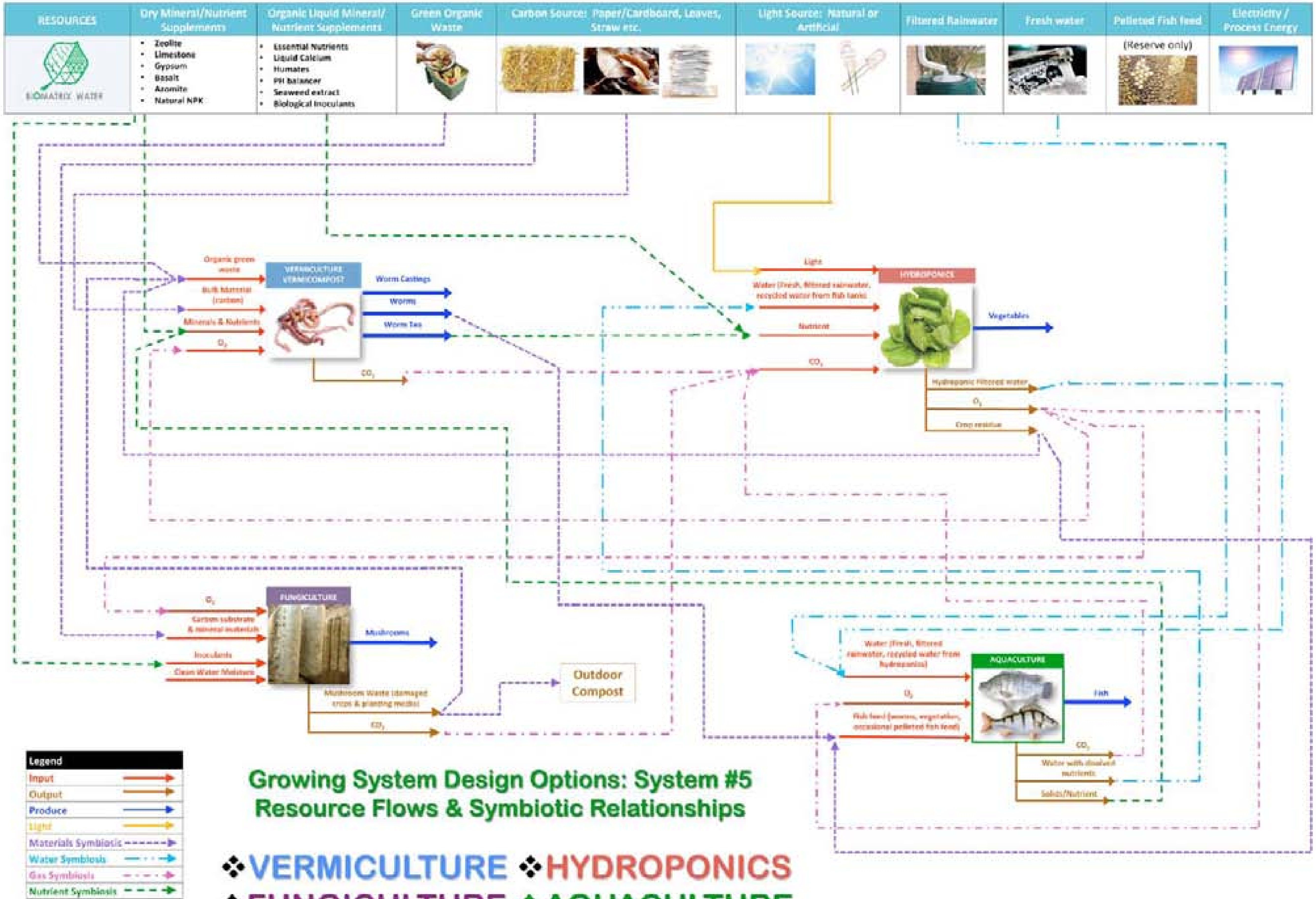
Growing System Desgin Options: System #3 Resource Flows & Symbiotic Relationships.

❖VERMCULTURE ❖HYDROPONICS ❖AQUACULTURE



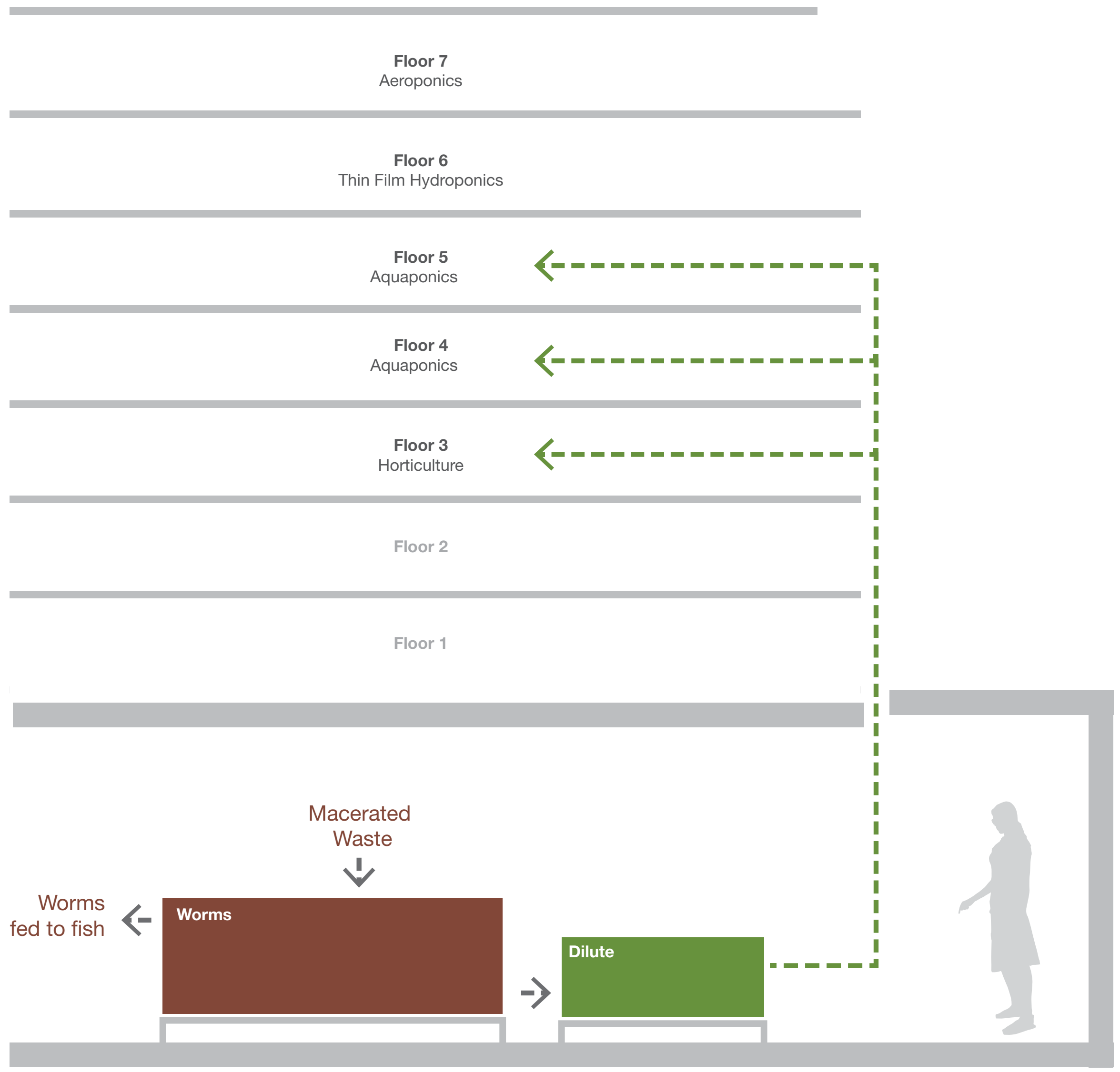
Growing System Design Options: System #4
Resource Flows & Symbiotic Relationships

❖VERMICULTURE ❖HYDROPONICS
❖FUNGICULTURE



Growing System Design Options: System #5
Resource Flows & Symbiotic Relationships

❖VERMICULTURE ❖HYDROPONICS
❖FUNGICULTURE ❖AQUACULTURE



Vermicultural flows

OUR FINDINGS

What we have found out

- It is very complicated
- The most biologically complex may be the most robust and sustainable to manage
- The scientific looking simple system may carry higher risk
- The micro-organisms and plants in the top floor water storage can be replaced with a vary large number of worms.
- Worms systems will play an important role in processing nutrients
- There's no leachate from fungiculture!

Questions still outstanding

- Relative quantities of each part to keep it balanced and everything fed
- Fish welfare and conditioning in relation to water nutrient dilutions

Nutrient Model

Translating the diagrams on the previous pages into the physical structure of this building, the proposal is to create a kind of nutrient main up the service core, fed primarily from the ground floor but also partially from the top floor. The nutrient flow diagram is not just a simple linear one, but also a series of loops so waste will arrive from householders and participating businesses such as restaurants or fruit and veg suppliers, so that this waste stream is reliable and free of pathogens which would be dangerous to the system. This is put in a macerator and fed to the worm bins on the ground floor next to the shop. The leachate from the worm bins is then diluted and piped up the building to floors 3, 4 and 5. Surplus worms are fed to the trout in the tanks adjacent on the ground floor east side, where the building is cool so the fish will not become stressed by overheating. The water from those trout, again filled with nutrients, is then pumped to floors 3 and 4.

Floor 6 is fed from Tilapia aquaculture on the top floor. These are warm water fish so more suited to upper floors where the spaces will get some direct sunlight and as this is also where the cafe is proposed to be, will need to be heated. As a control Level 2 will not be fed by any of these systems, but will be fed by a more traditional drum composting arrangement. This will also make the whole system more resilient to failure.

TECHNICAL CHALLENGE // WATER

Summer Water Use		
total transpiration	159	m3
so plant take up	1.6	m3
vented	79.5	m3
flushed growing volume	94.4	m3
flushed tanks	11.9	m3
total summer water use	187.3	m3
monthly	**62.4**	**m3**

Winter Use		
so plant take up	1.6	m3
transpiration is recovered		
flushing	106.26	
monthly use	**35.9**	

Water Collection		
roof areas	700	m2 roof area
	306	m3 at front
	356	m3 at back
	662	**m3 total additional roof area**

Rain fall

		jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec
Rainfall mm		71.5	51.8	64	49.1	53.8	66.8	59.5	70.9	69.9	86	81.9	81.4
Monthly on roof - m3		50.05	36.26	44.8	34.37	37.66	46.76	41.65	49.63	48.93	60.2	57.33	56.98
Use		35.9	35.9	35.9	35.9	35.9	62.4	62.4	62.4	35.9	35.9	35.9	35.9
Surfeit		14.1	0.3	8.9	-1.6	1.7	-15.7	-20.8	-12.8	13.0	24.3	21.4	21.0
Cumulative with tank	50	50.0	50.0	50.0	48.4	50.0	34.3	13.5	0.7	13.7	37.9	50.0	50.0

The farm will require a lot of water to feed the plants and fungi and to replenish water in the fish tanks. Drainage and waste-water will also require treatment using ecological systems. The farm will aim to conserve, treat and recirculate water in order to minimise mains water use, control salinity and pre-vent cross-contamination.

We have been seeking to answer the following questions:

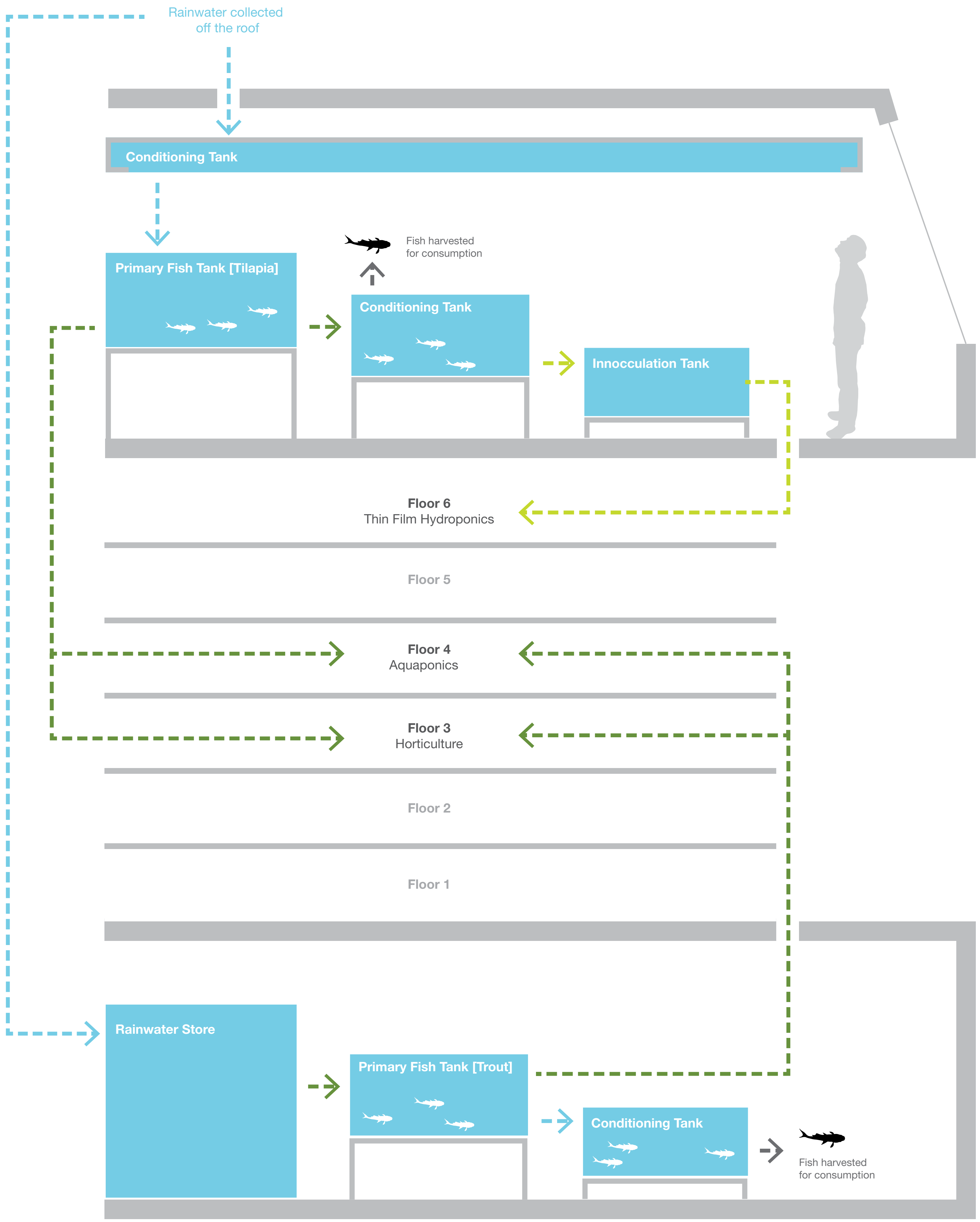
- **What will the water demand be**
- **How clean does it need to be**
- **Can we meet this by capturing water within the building footprint?**

Counter-intuitively for many designers, the water flow in this model is not for clean water as it is carrying the nutrients from other parts of the system. The primary source of irrigation water is from the fish tanks. As is shown in the table on the following page if moisture transpir-ing through the plants is collected in the dehumidifying systems as described, the building can be self sufficient for water, still allowing for periodic changing of the water in the hydroponics beds and fish grow-ing tanks to ensure the health of both.

So water is collected off the roof and passes initially into a ceiling level tank on the top floor. An overflow from this will pass into the rainwater storage tank on the ground floor. The rest of the water in this ceiling level tank will form a conditioned reservoir for the primary Tilapia tank, allowing for the temperature of incoming water into the Tilapia tank not to be so different from the temperature in it, so as not to cause harm to the fish. Some of the overflow water from the ceiling level tank will pass directly into a second tank where fish will be given a chance to swim in much cleaner water prior to harvesting. Overflow water from this fish tank and the primary tank will pass into an inocu-lation tank where micro-organisms will change some of the chemicals in the fish water such as the ammonia, so that it is in a form that the plants can directly process on the sixth floor. Overflow from this pri-mary tank will be passed to floors 3 and 4 where the inoculation of the water can be dealt with directly in the growing beds.

Month	Max Temp [°C]	Min Temp [°C]	Days of Air Frost [days]	Sunshine [hours]	Rainfall [mm]	Days of Rainfall ≥ 1mm [days]	Wind at 10 m [knots]
Jan	6.9	1.5	9.4	49.6	71.5	13.6	9.4
Feb	7.3	1.6	8.9	67.0	51.8	10.1	9.2
Mar	9.5	3.1	4.5	95.2	64.0	12.1	9.3
Apr	11.9	4.5	2.1	138.9	49.1	10.5	8.4
May	15.7	7.4	0.1	188.8	53.8	10.1	8.1
Jun	18.0	10.1	0.0	172.5	66.8	11.5	7.4
Jul	20.3	12.3	0.0	183.8	59.5	10.0	7.0
Aug	20.1	12.1	0.0	170.5	70.9	11.0	7.0
Sep	17.1	10.0	0.0	127.2	69.9	11.3	7.5
Oct	13.5	7.2	0.8	97.7	86.0	13.2	8.0
Nov	9.6	3.9	4.9	60.6	81.9	13.6	8.3
Dec	7.6	2.3	7.6	42.8	81.4	13.4	8.9
Year	13.2	6.4	38.3	1394.5	806.6	140.4	8.2

Average rainfall figures for Manchester Airport



Water flows between the different floors

On the ground floor the 50 cubic meter rainwater store will buffer the growing systems, enabling the facility to be adequately watered during the drier periods of the year, avoiding having to irrigate plants with chlorinated water from the mains. Again the presence of this tank in the same space as the trout tanks will enable the water to be conditioned to a temperature closer to that already in the trout tanks to avoid affecting the fish health. Some of this water will be fed directly into the primary fish tank and on from there to floors 3 and 4.

Some of the water will be diverted into a cleaner conditioning tank where the fish will spend a few days before harvesting to improve flavour. This reuse of rainwater falling on the building should ensure that the water authorities will not have any additional load from the farm to deal with, other than the design load already experienced from the building. As the human occupation level for the building has fallen radically the waste water load will be commensurately reduced.

Water use					
Growing area	floors		5.5		
	growing tables area/floor		105.6	m2	
	h2o transpiration		250	ml/m2/hr	
	effective operational growing months		9		
	effective growing hours		16	hours/day	
	total growing area		580.8	m2	
	h2o transpiration		1095	litres/m2/A	
	total transpiration		636	m3/A	
	assume to vent in summer		50%		
	plant take up		1%		
	total water demand		**642**	**m3**	*662m3 rainwater collection*
	reclaimed from condensate		529.98	m3	
	total consumption from growing		112	m3	
Flushing					
Hydroponics	assume water turn around every		2	weeks	
	assume water level in system is		25	mm	
	system volume		14.52	m3	
	annual water use from flushing		378	m3/A	
Fishtanks	assume water turn around every		13	weeks	
		annual volume	47.52	m3	
Total Water Use	as designed		537	m3/A	
	without reclamation		1,067	m3/A	

OUR FINDINGS

What we have found out	***Questions still outstanding***
- That if we can capture the huge amounts of vapour the whole farm can live off water landing on the roof if stored till needed	

TECHNICAL CHALLENGE // HEATING

IBC containers used for water storage and transfer

The technical challenge on the heating is actually less onerous that was initially expected. This is partially due to the fact that we won't be able to improve plant yield a huge amount due to the lighting levels that have been decided upon.

We have been seeking to answer the following questions:

- **What temperature range do we need to maintain within the building?**
- **What changes do we need to make to the building to achieve this?**

The technical challenge on the heating is actually less onerous that was initially expected. This is partially due to the fact that we won't be able to improve plant yield a huge amount due to the lighting levels that have been decided upon. The table opposite shows the temperature ranges that we will need to meet on the building and it is probably no surprise that these follow very closely seasonal variations in temperature, with a fairly continuous demand for a 7 degree uplift throughout the heating season. Without more detailed thermal modelling it has not been possible to estimate the amount of heat required to achieve this.

At this stage it looks like we have two choices. One is to make use of the existing perimeter heating network on each floor to provide that top up warmth, if the existing boiler is serviceable. The better option, to make best use of the warmth that will be available both on and within the building, is to use fan coil units on the ventilation system. As air is being moved around anyway this would involve warm water being run through pipes that the ventilation air passes across. This warm water could come from heat stores up the building that had been warmed both by low grade warmth arising from the condensation process and also solar thermal energy.

TEMPERATURE RANGE

SUMMER	WINTER
DAY **MAX 24^{o}**	DAY **10 - 15^{o}**
NIGHT **10 - 12^{o}**	NIGHT **6 - 8^{o}**

The proposal would be that large plastic tanks called IBCs (Intermediate Bulk Container) be used on each floor. These are readily available and cheap. Two of these in the unused toilets on each floor could be easily linked together so that they would create a stratified thermal store up the building, so that the top tank could be at 80C dropping down to perhaps 25C in the bottom tank. Thermostatically controlled valves on each of these could ensure that appropriate levels of warmth would be available around the building when needed, with a small boiler - possibly as small as a large domestic boiler - providing top up to the system in periods of high use, as the boiler could run overnight to warm the tanks up. This system would also be able to easily provide cooling in the event of overheating during the day if the there was also a heat exchanger in the ground floor rainwater storage tank.

OUR FINDINGS

What we have found out	***Questions still outstanding***
- temperatures can be more variable - overall it doesn't need to be as warm as humans would like it	- how do we stop damage to the building form condensation (a lot of it) - can we store heat till we need it from other parts of the process - can we quantify those parts of the process

SCHEMATIC DESIGN

In this section we look at incorporating all of the knowledge developed so far into a schematic layout for Alpha farm.

We have been seeking to answer the following questions:

- **Which growing systems should be use?**
- **How should the growing systems be distributed across the building?**

The plan opposite developed by Biomatrix looks at how a single floor of the farm might be laid out if all of the different growing systems were incorporated onto a single floor. The result is a complex layout that incorporates a large number of elements and symbiotic relation-ships.

The layout incorporates:
- Vermiculture
- Aquaculture
- Hydroponics
- Fungiculture
- other general items

SCHEMATIC LAYOUT
FOR TEAM REVIEW

VERMICULTURE

- Worm Type A
- Worm Type B
- Worm Type C
- Worm Bins
- Leachate collector
- Vermicompost collector
- Compost screen
- Sanitary contained waste disposal
- Dosing syphon
- Dry Storage (carbon/feed)
- Dry Storage (Mineral/Nutrient)
- Worm Tea - Mineral - Nutrient brewer/blend tank
- Worm tea storage bottles
- Vermicompost Storage
- Refridgeration

AQUACULTURE

- Fish tanks 1000litre 1200x 1200
- Fingerlings tanks 1000litre 1200x 1200
- Pump
- Aeration
- Clarifier
- Dry Storage (carbon/feed)
- Dry Storage (Mineral/Nutrient)
- Sludge pump
- Water heater
- Analytical Lab
- Ballcock valve
- Refridgeration
- Freezer

HYDROPONICS

- Germination room
- Dosing timer
- Sludge pump
- Pump
- Nutrient Film Technique (NFT) Hydroponics
- Deep Water Culture (DWC) Hydroponics
- Media filled Hydroponics 500 x1000
- Vegetable Storage 800 x1000
- Refridgeration
- Humidity controller
- Mains water input
- Ecological Fluidized Bed
- Thermostat controller

FUNGICULTURE

- Mushroom inoculates
- Dry Storage (straw)
- Steambox/Autoclave Steriliser
- Mains water input
- Thermostat controller
- Humidity controller
- Leaf shredder
- Mushroom stuffing bench
- Refridgeration
- Tray mushroom racks
- Mushroom hanging bags
- Mushroom Storage

GENERAL ITEMS

- Disinfectant footpath
- Triple basin sink
- Fish cooler room
- Two stage sand filter
- Worker hygiene room
- UV filter
- First flush diverter
- Self decay coarse screen
- Water tank
- Door
- Solar radiance

The farm has been designed to demonstrate a variety of growing systems over the different floors within the farm. The diagram opposite sets out the different growing system for each floor and the which nutrient inputs are being utilised. The floors have been arranged according to the technical complexity of the system i.e aeroponics on the top floor and soil based horticulture on the second floor.

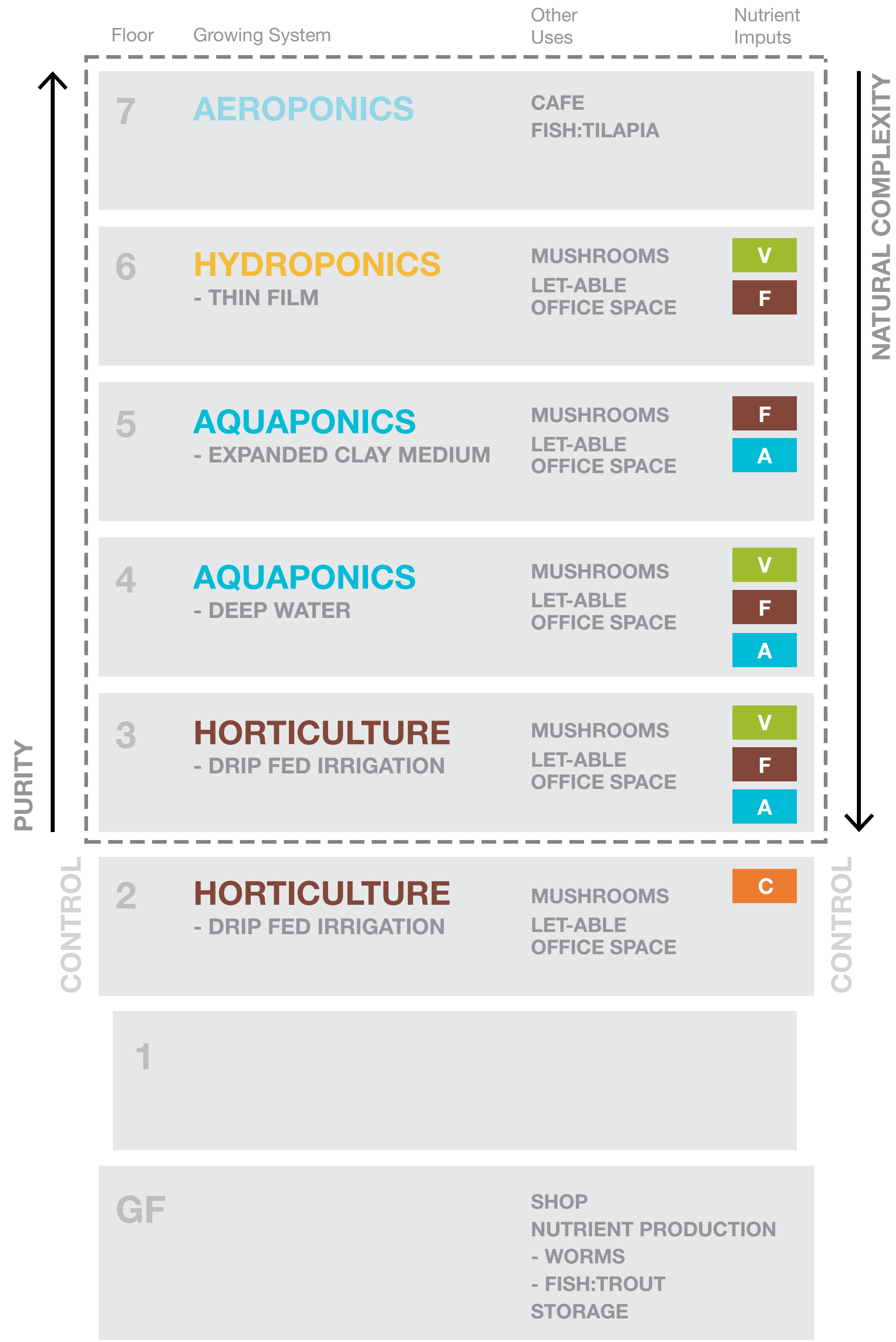
Ground floor

The shop is located on the ground floor and are accessed through the courtyard. This will be the main public entrance to Alpha farm. Located close to the shop entrance will be a waste drop off point where local residents and volunteers can drop off their organic waste that will be processed in the farm using the worm bins which are also located on the ground floor.

Due to the weight of the tanks the aquaculture tanks for the trout and the rainwater tanks are on the ground floor. The conditioning tank has been positioned so that it can be seen from within the shop.

Also located on the ground floor are the mushroom spawning incubator and laboratory. It is essential that these remain clean and free from contamination. The existing let able space has been retained in the plan and is accessed through the main front entrance.

VERTICAL ORGANISATION

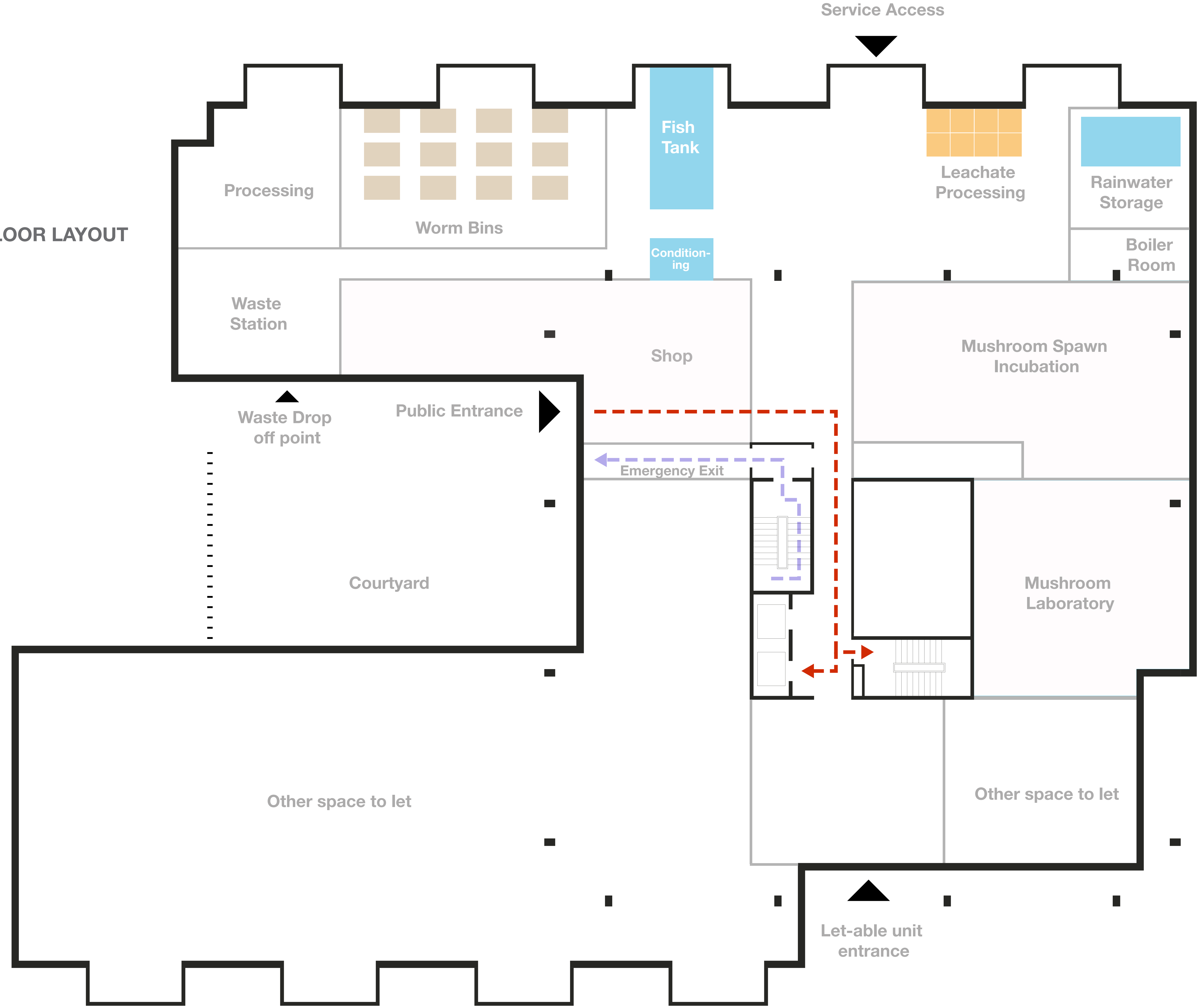


SCHEMATIC SECTION THROUGH BUILDING

Not to scale

GROUND FLOOR LAYOUT

Not to scale



TYPICAL FLOOR LAYOUT

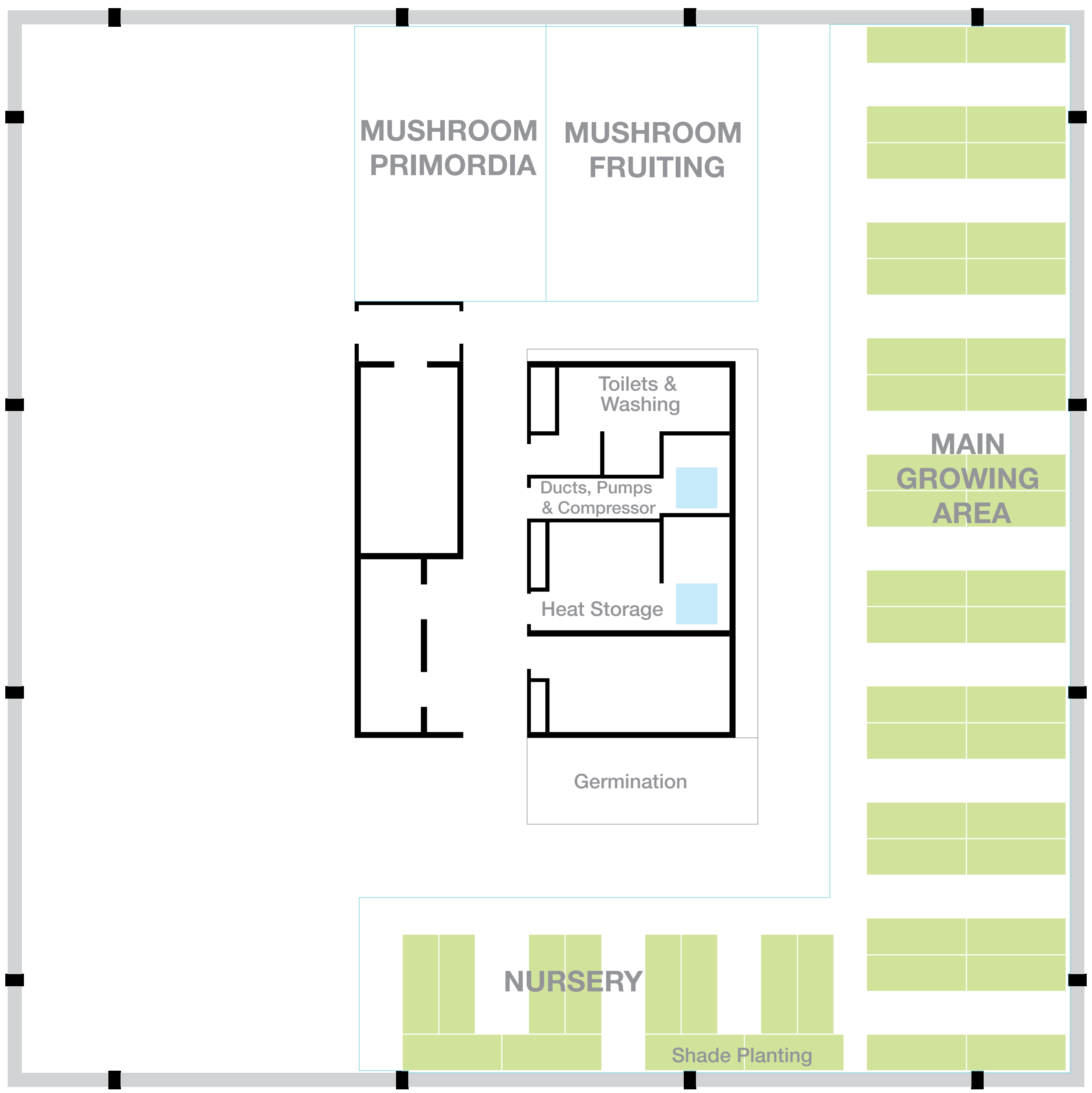
Not to scale

Upper floors

We are proposing that the 2nd floor is used as a control in which we use soil based drip fed irrigation using compost. This will allow us to test what can be grown using a ‘traditional’ growing system.

As you move up the floors we will test different growing systems. On the 3rd floor we will test horticulture but this time use nutrients from the vermiculture, fungiculture and aquaculture. On the 4th floor we will use the same nutrients as the second but replace the growing system with a deep water aquaponic system. The 5th floor will test an aqua-ponic system using an expanded clay medium and nutrients from the aquaculture and fungiculture. The 6th floor will test a tin film hydro-ponic system with nutrients from the vermiculture and the fungiculture. This will be a vegan floor as no fish produce will be used on this floor. On the top floor a aeroponic installation will be installed alongside a cafe that makes advantage of the views out across Wythernshawe.

All of the floors retain the potential to let out par of the foot print as office space.



APPENDICES

Appendix 1: Precedent Resource Sheet

APPENDIX 1: PRECEDENT RESOURCE SHEET

Projects details						Topics					
Project	link	Place	Date	Designer	Built?	vertical growing	combining aqua/horticulture	sewage/waste reuse	light	design concept	site retrofit
Dystopian Farm	www.evolo-archi.com	NY	2009	Eric Vergne	No	x				x	
Incredible Edible House	http://www.rchstudios.com/	-	2009	Rios Clement Hale Studios	No	x					
the Harvest Green Vertical Farm	http://webecoist.com/2010/01/13/3d-farming-26-vertical-farms-and-green-skyscrapers/10-harvest-urban-vertical-farm/	Vancouver	2009	Romses Architects	No	x	x				
Dubai Food City	http://www.gcla-international.com/home.html	Dubai	2009	GLA International	No	x				x	
Dragonfly Vertical Farm	http://vincent.callebaut.org/page1-img-dragonfly.html	NYC Roosevelt Island	2009	Vincent Callebaut	No	x		x		x	
Sea Based Vertical Farm	http://www.evolo.us/architecture/vertical-farms/	-	2010	Ruwan Fernando	No	x			x	x	
The Locavore Fantasia	http://work.ac/locavore-fantasia/	NY	2008	WORKac	No	x				x	
Shanghai Urban Masterplan	http://www.except.nl/design/shanghaiurbanplan/index.html	Shanghai	-	Except	No	x		x	x		
The Plant	http://www.plantchicago.com/?page_id=2	Chicago	2010	Chicago Sustainable Manufacturing Ceter / Illinois Institute of Techology	In process	x	x				x
VF - Type O.2	http://verticalfarmingaustralia.blogspot.com/2009/01/vertical-farm-type-o.html	Australia		Olivier Foster	No	x	x		x	x	
Pyramid Farm	http://inhabitat.com/pyramid-farm-vertical-agriculture-for-2060/	Dubai		Eric Ellingsen/Dickson Despommier	No	x		x		x	
Chris Jacobs' Vertical Farm	http://www.farmvertical.com/	-		Chris Jacobs	No	x		x		x	
Agro-Arcology	http://www.treehugger.com/files/2011/06/vertical-farm-arcology-self-sufficient-urban-environment.php	-		Gordon Graff	No	x		x	x		
Aberrant Agriculture	http://www.evolo.us/architecture/aberrant-architecture-residential-urban-farm-tower/	-	2010	Andrew Michler	No	x				x	
Urban Farm, Urban Epicenter	http://www.ecofriend.com/entry/farming-in-future-could-be-urban-farm-urban-epicenter-style/	-		Jung Min nam	No	x		x		x	
Oasis Tower - Zabeel Park Vertical Farm	http://verticalfarm-dubai.blogspot.com/	Dubai			No	x				x	
The Living Skyscraper	http://www.jessesuchoffdesign.com/the-living-skyscraper-farming/vertical-farm/8602885	Chicago		Blake Kurasek	No	x		x			
The Living Tower	http://www.ateliersoa.fr/verticalfarm_en/urban_farm.htm	-	2006	SOA Architects		x				x	
Fazenda Vertical	http://www.verticalfarm.com/designs?folder=872496d7-1a1b-4b14-9a95-f5d04f60f3b5	-		Rafael Grinberg Costa							
Agro-Wanus	http://www.thedailygreen.com/green-homes/latest/vertical-farms	NY		Andrew Kranis							
EVF: Experimental Vertical Farm	http://www.presidentsmedals.com/Project_Details.aspx?id=2432&dop=True&year=2009	Santiago	2009	Claudio Palavecino Llanos		x				x	x
Eco-Laboratory	http://www.treehugger.com/files/2008/12/eco-laboratory-wins-competition.php	Seattle		Weber Thompson		x	x				
and	http://vimeo.com/11720560										
Newark Vertical Farm	http://www.weberthompson.com/newark-vertical-farm.html#	NYC		Weber Thompson							
Skyfarm	http://www.treehugger.com/files/2008/07/skyfarm-gordon-graff.php	Toronto	2007	Gordon Graff							
Anna Karrington Systems Rendering	http://www.verticalfarm.com/designs?folder=0ba7a2b1-a763-4349-8da3-c2f878abd09a	-									x
Pla(n)tform: an alternative for urban growth	http://www.open-output.org/adi_r/project/8143	Tel Aviv		Ori Ronen / Adi Reich							
City of the Future	http://www.architecture-page.com/go/frame?exturl=http://www.fougeron.com	San Francisco		Fougeron Architects							
retrofitted green scryscrapers concept	http://webecoist.com/2010/01/13/3d-farming-26-vertical-farms-and-green-skyscrapers/16-retrofitting-skyscrapers-vertical-farms-daekwon-park/	-		Deakwon Park		x				x	x
Forwarding Dallas	http://webecoist.com/2010/01/13/3d-farming-26-vertical-farms-and-green-skyscrapers/1-revision-dallas-green-city-design/	Dallas	2009	Atelier Data & MOOV	2011						
A vertical farm	http://christianbarnardblog.blogspot.com/2009/06/vertical-farming-concepts-2.html	Paris		Charlotte Avignon Archtecte							
The Plantagon	http://webecoist.com/2010/01/13/3d-farming-26-vertical-farms-and-green-skyscrapers/9-plantagon-enclosed-vertical-farm-concept/	-		Plantagon	within 3-5years						
Eco-pods	http://webecoist.com/2010/01/13/3d-farming-26-vertical-farms-and-green-skyscrapers/11-howler-and-yoon-robotic-vertical-farm-boston/	Boston		Howeler and Yoon	No	x				x	x
London Bridge Vertical Farm Concept	http://webecoist.com/2010/01/13/3d-farming-26-vertical-farms-and-green-skyscrapers/13-london-bridge-vertical-farm-concept/	London		Chetwood Architects	No	x				x	x
Seawater-utilizing Vertical Farm	http://webecoist.com/2010/01/13/3d-farming-26-vertical-farms-and-green-skyscrapers/20-dubai-seawater-vertical-farm-concept/	Dubai		-	No	x				x	
Center for Urban Agriculture Concept	http://webecoist.com/2010/01/13/3d-farming-26-vertical-farms-and-green-skyscrapers/21-seattle-off-grid-vertical-farm/	Seattle	2007	Mithun	No	x				x	
Farming [Park]	http://webecoist.com/2010/01/13/3d-farming-26-vertical-farms-and-green-skyscrapers/25-urban-revision-farming-park-concept/	NYC		Austin Tragni	No	x				x	
Multi-Level Urban Farm Comcept	http://webecoist.com/2010/01/13/3d-farming-26-vertical-farms-and-green-skyscrapers/24-multi-level-urban-farm-concept/	Paris			No						
Hydroponic Fram	http://www.evolo.us/architecture/vertical-oasis-in-syria-is-a-hydroponic-farm/	Syria			No						
Rooftop farms	http://www.evolo.us/architecture/a-new-model-for-urban-agriculture/				No					x	x
Vertical Park	http://www.evolo.us/2010/01/07/vertical-park-for-new-york/	NY			No	x					
Vertical Farm	http://www.evolo.us/architecture/vertical-farm-in-prague/	Prague			No						
Vertical Urban Farmlands	http://www.evolo.us/2010/01/21/vertical-urban-farmlands/	France			No						
Green Tower	http://webecoist.com/2010/01/13/3d-farming-26-vertical-farms-and-green-skyscrapers/18-libeskind-new-york-city-green-tower/	NYC		Daniel Libeskind	No						
Greenhouse tower International Green Week	http://www.strangeharvest.com/2008/06/vintage-tradeshow-su.php	Berlin	1966		Yes	x			x		
The ABLE-Projekt	http://www.theableproject.org.uk/	Wakfield			Yes		x				
Plant Lab	http://www.plantlab.nl/4.0/	Netherland			Yes						
Nuvege	http://nuvege.com	Kyoto			Yes						
Sunlight Direct	http://www.sunlight-direct.com/				Yes				x		
Verticrop	http://www.valcent.eu/	paignton zoo uk		Valcent	Yes	x			x		
and	http://www.businessgreen.com/bg/news/1802219/uk-firm-vertical-farming-vision-reality										
LumiGrow Inc. Lightening system	www.lumigrow.com										
	http://www.iees.ch/cs/cs_5.html	Switzerland						x			
	http://www.hortikultur.ch/pub/files/5.pdf	Switzerland					x	x			

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