HydroTower
Gardening Solutions

Feed People More Efficiently Through Hydroponics

Final Presentation May 7, 2011
HydroTower Team

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Front Row (L to R): Brian DeKock (ME), Nathan Meyer (EE), Brenton Eelkema (EE)

Introduction – Problem Definition – Hydroponics Defined – HydroTower Systems – Business/Competitions – Summary
Outline

- Introduction
- Problem Definition
- Hydroponics Defined
- HydroTower Systems
- Business Plan/Competitions
- Summary
- Questions
Defining the Problem

- 80% world population by 2020 in cities
- 70% increase for agricultural production by 2050
- Produce travels an average 1,500 miles before reaching the market.
Defining the Problem (Cont.)

Source: http://thefarmery.com
Hydroponics Defined (Cont.)

Source: CityScape Farms, San Francisco, CA
Design Norms

- Transparency
  - Users will know what HydroTower does and how HydroTower functions
- Stewardship
  - Pertinent use of resources and energy
- Trust
  - Safety and reliability for food production in residential and urban settings
HydroTower Requirements

- Outdoor garden indoors
- Grow plants in controlled environment
- Stackable and modular
- Reduce transportation distances and cost of produce
- Increase produce availability
Target Market

- Women ages 25-39 years old
- Approximately 30 million potential customers

### Source: US Census Bureau Data

<table>
<thead>
<tr>
<th>Subject</th>
<th>Total Population</th>
<th>Total</th>
<th>Margin of Error</th>
<th>Male</th>
<th>Margin of Error</th>
<th>Female</th>
<th>Margin of Error</th>
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<td>Total population</td>
<td>301,237,703</td>
<td><strong>6.9%</strong></td>
<td>+/-0.1</td>
<td><strong>7.1%</strong></td>
<td>+/-0.1</td>
<td><strong>6.6%</strong></td>
<td>+/-0.1</td>
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<td>AGE</td>
<td></td>
<td></td>
<td></td>
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<td>Under 5 years</td>
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<td>+/-0.1</td>
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<td>5 to 9 years</td>
<td></td>
<td>6.8%</td>
<td>+/-0.1</td>
<td>7.1%</td>
<td>+/-0.1</td>
<td>6.5%</td>
<td>+/-0.1</td>
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<td>10 to 14 years</td>
<td></td>
<td>7.2%</td>
<td>+/-0.1</td>
<td>7.5%</td>
<td>+/-0.1</td>
<td>6.9%</td>
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<td>15 to 19 years</td>
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<td>+/-0.1</td>
<td>7.3%</td>
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<td>+/-0.1</td>
<td>6.6%</td>
<td>+/-0.1</td>
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<tr>
<td>25 to 29 years</td>
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<td>6.9%</td>
<td>+/-0.1</td>
<td>7.1%</td>
<td>+/-0.1</td>
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<td>30 to 34 years</td>
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<td>+/-0.1</td>
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<td>35 to 39 years</td>
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<td>7.1%</td>
<td>+/-0.1</td>
<td>6.9%</td>
<td>+/-0.1</td>
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</table>
Opportunities

- Hydroponic market growth
- Demand for food
- Accessibility
- Multiple applications
  - Homes (initial market)
  - Schools
  - Healthcare partnerships
  - Community programs
Structure

- Major Components
  - Base Unit
  - First Grow Level
  - Second Grow Level
- Base Unit
  - Contains all electrical and mechanical components
- Grow Levels
  - Growth of different plant varieties
Structure

Some Issues

- Accuracy and Precision
- Prototype VS. Production
- Design Changes
- Integration
Water System

The Valves:
- Diaphragm solenoid valves
- Normally-open solenoid valves
- Gravity-fed solenoid valves

The Pump:
- 25 foot max head marine bilge pump
Water System
Water System

- Some Issues
  - Algae growth in pumping valves
  - Broken nutrient adapter
  - Trouble Shooting
    - Like washing windows
Nutrient Control System
# Nutrient Control System

## Nutrient Control System Decision Matrix

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<tr>
<th></th>
<th>Cost</th>
<th>Implementation</th>
<th>Patentability</th>
<th>Waste Water</th>
<th>Nutrient Supply</th>
<th>Customer</th>
<th>Total</th>
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<td>1. Electrode Analysis</td>
<td>2</td>
<td>0</td>
<td>3</td>
<td>8</td>
<td>4</td>
<td>9</td>
<td>4.55</td>
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<td>2. Spectrophotometry</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>8</td>
<td>4</td>
<td>9</td>
<td>4.55</td>
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<td>3. D. Savvas</td>
<td>7</td>
<td>4</td>
<td>7</td>
<td>7</td>
<td>4</td>
<td>8</td>
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<td>Autoreplenishment</td>
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<tr>
<td>4. Macronutrient</td>
<td>6</td>
<td>5</td>
<td>7</td>
<td>5</td>
<td>7</td>
<td>7</td>
<td>6.1</td>
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<td>Replenishment</td>
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<td></td>
<td></td>
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<td></td>
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<td>5. General Hydroponics</td>
<td>6</td>
<td>7</td>
<td>1</td>
<td>2</td>
<td>8</td>
<td>4</td>
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<td>6. No replenishment</td>
<td>10</td>
<td>9</td>
<td>0</td>
<td>2</td>
<td>10</td>
<td>2</td>
<td>5.65</td>
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</tbody>
</table>

| Weight               | 30%  | 15%  | 10%  | 15%  | 5%   | 25%   | 100% |

Note: 10 indicates favorable rating / 0 indicates unfavorable rating
pH Sensor

EC Sensor

Lighting System: Requirements

1. Provide optimal light for plant photosynthesis
2. Must be low maintenance
3. Must be under 200W
Lighting System: Research

Lighting System: Experiments

- 14.7MJ/(m^2 d)
- Red = 64.22 µE = 27.25 LED’s
- Blue = 90.36 µE = 12.54 LED’s
Lighting System: Circuit Design
Lighting System: Thermal Calculations

- 1.82W for red
- 2.8W for blue
  - High power = Need heat dissipation

Design for use in desert where ambient temp is 85°C:

\[ T_A = 85K + 273.16K \]
\[ T_{\text{max}} = 125K + 273.16K \]

\[ \theta_{S,\text{Amax}} = \frac{T_{\text{max}} - T_A}{P_{\text{min}}} - \theta_{S,\text{typ}} - \theta_S = 192.7 \frac{K}{W} \]
\[ \theta_{S,\text{Amax}} = \frac{T_{\text{max}} - T_A}{P_{\text{typ}}} - \theta_{S,\text{typ}} - \theta_S = 38.455 \frac{K}{W} \]
\[ \theta_{S,\text{Amax}} = \frac{T_{\text{max}} - T_A}{P_{\text{max}}} - \theta_{S,\text{typ}} - \theta_S = 8.385 \frac{K}{W} \]

\[ \theta_{S,\text{Amax}} = \frac{T_{\text{max}} - T_A}{P_{\text{min}}} - \theta_{S,\text{max}} - \theta_S = 188.5 \frac{K}{W} \]
\[ \theta_{S,\text{Amax}} = \frac{T_{\text{max}} - T_A}{P_{\text{typ}}} - \theta_{S,\text{max}} - \theta_S = 33.955 \frac{K}{W} \]
\[ \theta_{S,\text{Amax}} = \frac{T_{\text{max}} - T_A}{P_{\text{max}}} - \theta_{S,\text{max}} - \theta_S = 3.885 \frac{K}{W} \]

Using typical \( \theta \) js

Using max \( \theta \) js

For finding area:

\[ \theta_S = \frac{L}{k \cdot A} \quad k = 386 \frac{W}{m \cdot K} \]

\[ L = 5 \text{mm} \quad \theta_S = 1 \frac{K}{W} \]

\[ A = \frac{\theta_S}{k - L} = 5.181 \times 10^3 \frac{\text{g} \cdot \text{cm}^2}{\text{kg}^2 \cdot \text{m}^6} \]

\[ \text{sideLength} := \sqrt{A} = 719.81 \frac{s^3 \cdot K}{\text{mm} \cdot \text{kg}^2 \cdot \text{m}^6} \]
Lighting System: Mounting

Power System

System Automation

- The Brain:
  - Arduino-based Microcontroller

- The Arms:
  - Relays
  - Sensors
  - Transistors
System Automation

Valve Logic -- Current

- Valve Enable
- Level Select
- Lvl. 1 Drain
- Lvl. 1 Splitter
- Lvl. 2 Drain
- Lvl. 2 Split
Pump Circuit with Water Sensor
User Interface

- Touchscreen
- Easy to use
- Flexible

- TouchShield Slide
- Compatible with Arduino

```c
void timeScreen_refresh() {
    // Display the current time
    char number_holder[2];
    text tüca(current_hr, number_holder, 10), 90, 110, 12);
    text tüca(current_min, number_holder, 10), 90, 110, 12);
    if (current_am) text ("AM", 190, 110, 12);
    else text ("PM", 190, 110, 12);
}

void timeScreen_check() {
    if (back.GetTouch()) {
        setupScreen_show();
    }
    if (apply.GetTouch()) {
        Serial.print (SETTIME);
        delay (50);
        Serial.print (current_hr);
        delay (50);
        Serial.print (current_min);
        delay (50);
        Serial.print (current_am);
    }
    if (plus_hr.GetTouch()) {
        if (current_hr == 12) {
            current_am = !current_am;
        }
        current_hr = (current_hr + 12) + 1;
    }
    if (minus_hr.GetTouch()) {
        if (current_hr == 12) {
            current_am = !current_am;
        }
        current_hr = current_hr - 1;
        if (current_hr == 0) {
            current_hr = 12;
        }
    }
    if (plus_min.GetTouch()) {
        current_hr = (current_hr + 1) % 60;
    }
}
```
User Interface

- **Welcome**
- **Menu**
  - **Setup**
    - **Time**
    - **Scheduling**
  - **Manual Run**
  - **Logged Data**
    - **Temperature**
    - **Humidity**
    - **Water Cycles**
- **Status**
- **Maintenance**

Business Competitors

- New and unique
- Closest competitors and how we differ

AeroGarden Pro200
Nano Garden
HydroTower Prototype

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Business Cost and Price

- Current $1,400 working budget
- Projected Cost: $250
- Projected sale price of $750
- Initial Startup:
  - $100,000 from investors
  - $50,000 from loans
HydroTower Competitions

Third Place Overall

Second Place Overall

Currently in Final 15
Summary

- Working prototype
- More learning than anticipated
  - Plant physiology
  - Chemistry
- Positive outlook
  - Business
  - Market potential

Photo Courtesy of John Corriveau; Corriveau Photography, LLC
Acknowledgements

Calvin College
- Professor Steve “357 Comments” VanderLeest - Team Advisor
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- Professor David Wunder - Nutrient System
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- Professor Uko Zylstra - Plant Biology
- Professor Bob Medema – Business Professor
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- Richard Huisman - Chemistry Lab Services Mgr.
- Scott Prentice - Science Division Lab Technician
- Lori Keen – Calvin Lab Services Manager

Industry
- SoundOff Signal - donated LEDs.
- Steve & Kris Van Haitsma - Mud Lake Farm
- Tim Theriault - Team Industrial Consultant

General
- Family and Friends– Kept us all sane with listening ears and great advice
Questions?