Combined logic of ecology and technology
Binary intelligence and 10 competitions

Student Leads

Zachary Gould
Engineering

Justin Gravatt
Business

Jackson Reed
Architecture

Alex Arshadi
Landscape

Arjun Choudhry
C.S.

Faculty Advisors

Georg Reichard
Faculty
Technical Lead

Deidre Regan
Faculty
Design Lead
Student Team Lead: Zachary Gould

80% Undergrad | 20% Graduate

Landscape
Alexander Arshadi
Amanda Hayton
Brooke Pagliarini
Owen Baylosis
Sam Snyder
Tess Reeves

Special thanks to
Delie Wilkens

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Arjun Choudhry
Ikechukwu Dimobi

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Connor Leidner
Ian Edwards
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Vidusha Sridhar
Nate Bennett
Mustafa Shafique

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Tolulope Adesoji

Engineering
John Hinson
Kewal Agarwalla
Young Kwang Ju
Michelle Baker
Sagar Karki
Racim Badsi
Tori Deibler
Partnerships

Academic

Industry
Concept

TreeHAUS is inspired by the way trees collect and distribute resources in the forest:

- **ENERGY**
- **FOOD**
- **WATER**
Roots

Engineering systems:

- Blockchain Energy Exchange
- AD / Biogas Back-up Power
- Condensate Irrigation
Branches

Agroforestry landscape:

• Food Production
• Ecosystem Services
• Seasonal Energy Savings
Architectural design:

- Dowel Laminated Timber (DLT) ceilings
- All wood exterior wall
- Stomatal window screens
Canopy

Resource capture:

• Solar PV Conversion
• Rainwater Collection
• Food Waste
INTRODUCTION

Regenerative Design

Restorative Landscape

Mindful Intelligence

Scalable Modularity

Accessibility
Regenerative Design

- Stronger surrounding ecosystem
- Stronger surrounding population
- Stronger surrounding municipality
Design Goals

Restorative Landscape

• Native genetics
• Remediation of disturbed land
• Edible agroforestry landscape
Design Goals

Mindful Intelligence

- Blockchain energy distribution
- Behavioral learning over time
- Seamless biometric integration
Design Goals

Scalable Modularity

- Reduction of project cost
- Shorten construction timelines
- Minimize waste and site disturbance
Design Goals

Accessibility

- Multi-tiered affordability
- Promotion of (bio) diversity
- Connection to local transit and trails
Real Estate Affordability Crisis

70% of VT Grad Students are Housing Insecure

Percent of Stipend Spent on Housing

- 10-20%
- 20-30%
- 30-40%
- 40-50%
- 50-60%
- 60-70%
- 70-80%
- 80-90%
- 90-100%
- > 100%
Unit Layouts

- Shared living arrangements
- Accommodating diversity
- Flex spaces

Level 1
Unit D 4BR
Unit C 3BR
Unit B 2BR
Unit A 1BR

Level 2
Unit D 4BR
Unit C 3BR
Unit B 2BR
Biophilic Design

Green Spaces
- Exterior courtyards
- Interior green walls
- Strategic viewsheds

Light & Ventilation
- Cross-ventilation
- Equitable daylight access
Lighting Analysis

Daylighting
- Living spaces at south end
- Bedrooms at north end
- Services and systems at core
Modularity

Building consists of 16’ modules
- Stud framing with DLT ceilings
- Shared walls provide acoustic/fire separation
- Installed by crane, with joints sealed on-site
Stomatal screens

Inspired by the way plant stomata open & close

- Insulated panels improve window R-value at night
- Slats operate independently to control daylight
Interior Design

Natural Materials

- Dowel-Laminated Timber
- No glues/VOCs
- Green wall promotes biophilia
Elements of Resilience

Earth
Water
Air
Energy
Food
Agroforestry

- "Agricultural Forestry"
- Resilient Food Source
Tree Guilds
Landscape Design

CrumPacker Woods

Tree Guilds

- White Oak
- Peach
- Chinquapin
- Persimmon
- Serviceberry
- American Plum
- Hazelnut
- Pawpaw
Water System Integrations
UV Purification Skid

ITEM LIST
1. BAG FILTER W/ DRAIN & GAUGE
2. BAG FILTER W/ DRAIN & GAUGE
3. BALL VALVE
4. CARBON FILTER
5. UV LIGHT
6. DRAIN
7. RAINWATER FLOWMETER
8. CHECK VALVE
9. SINGLE POINT POWER SOURCE
10. PRESSURE DIFFERENTIAL
11. UV LIGHT POWER SUPPLY
12. RMS 200 CONTROLLER
13. DAY TANK (POLY)
14. DOMESTIC SOLENOID
15. DOMESTIC FLOWMETER
16. PRV
17. 2" DOMESTIC RPPZ
18. BOOSTER PUMP SKID
19. PRESSURE TANK

UV Flow Switch
Site Succession

Original Forest
Site Succession

Original Forest

Dairy Barn
Site Succession

Original Forest

Dairy Barn

Present Day
Site Succession

Original Forest

Dairy Barn

Present Day

10-Year Plan
Site Succession

- Original Forest
- Dairy Barn
- Present Day
- 10-Year Plan
- 30 Year Plan
Site Succession

Original Forest

Dairy Barn

Present Day

10-Year Plan

30 Year Plan

Post TreeHAUS
i-Tree

- USDA Software
- Forestry Benefits Analysis
i-Tree Results

50-Year Cumulative Breakdown

- Stormwater: $238,171
- Air Quality: $3,992
- CO2 Capture: $13,558
- Summer Shade: $34,235
- Winter Heat: $4,103

Total Benefits Worth: $294,059
Investor Profile and Opportunity Zones

Dr. John E. Dooley
CEO, VT Foundation
Rental Model Financials

3 Bedroom Rental Analysis (Per Bedroom)

<table>
<thead>
<tr>
<th>Unit Style</th>
<th>Base Rental Rate</th>
<th>Final Rental Rate</th>
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</thead>
<tbody>
<tr>
<td>One Bedroom</td>
<td>$650</td>
<td>$474</td>
</tr>
<tr>
<td>Two Bedroom</td>
<td>$513</td>
<td>$411</td>
</tr>
<tr>
<td>Three Bedroom</td>
<td>$500</td>
<td>$368</td>
</tr>
<tr>
<td>Four Bedroom</td>
<td>$406</td>
<td>$355</td>
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</tbody>
</table>

45% of Average Stipend

24.5% of Average Stipend
Overview of Construction Costs

Cost Breakdown with Options

- Site Work: 16%
- Framing & Insulation: 11%
- MEP: 8%
- Contingency: 4%
- Exterior Finishes: 11%
- Interior Finishes: 2%
- Soft Costs & Fees: 2%
- Saltwater Battery Bank: 3%
- Rain Water Harvesting and Purification: 2%
- Anaerobic Digestion: 2%
- Phytoremediative Green Wall: 4%
- Optional Adds: 37%

FINANCIAL FEASIBILITY

MARKET POTENTIAL
Interviews – Informing the Design

Must-Have Features

- Bathtub
- Open Floor Plan
- Outdoor Entertainment Space
- Private Garden Space
- Extra Bathroom
- Guest Bedroom
- Big Kitchen
- Storage
- In-Unit Laundry

Importance of Local Amenities

- Onsite Parking
- Bus Service
- DayCare
- Communal Outdoor Space
- Bicycle Storage
- Electric Car plug-in port
- Sidewalks
- Benches
- Playground
- Dog Park
- Community Garden Space
- Walking Trails
Must Have Features
Operations and Maintenance

Low Maintenance Materials
- Pest-resistant
- Weather-resistant

Academic partnerships
- Student Upkeep
- Agroforestry Education
- Research Opportunities

Metal Roof
Standing Seam

Shou Sugi Ban

FINANCIAL FEASIBILITY
MARKET POTENTIAL
ENGINEERING
Free Fuel From Nature

ENERGY
400 MWh/yr

WATER
180K gal/yr

FOOD
558 tons/yr
Mechanical Design

- Mitsubishi HyperHeat ASHPs
- Zoning with Keen smart vents and Nest averaging thermostat
- MERV 8 filtration on all central units
Electrical Design

- GreenRock Salt Water Batteries
- Fermata Two-way EV Charging
- 33 West-facing PV Panels
Plumbing Design

- EPA WaterSense adherence
- Modular interface in pipes
- Orbital Showers and condensing instant HWH
All Wood Exterior Wall

- Production Timber and Post Process Waste
- Gutex Multitherm with integrated weather barrier
- Formaldehyde free and FSC certified

7. Shou Sugi Ban Cladding (3/4”)
6. Pine Furring Strips (3/4”)
5. GUTEX MultiTherm WRB (3”)
4. GUTEX MultiTherm (3”)
3. Blue Ridge Fiberboard (1/2”)
2. GUTEX ThermoSafe (3 1/2”)
1. Richlite Finish (1/2”)

12 in
Hygrothermal Check

- Ubakus simulations show low RH
- WUFI confirms breathability year over year
- No risk for condensation in the cavity

< 80% RH
Control Layers

Shou Sugi Ban

INTELLOPLUS®

GUTEX®

NATURALLY MADE FROM WOOD

AEROBARRIER™

Breakthrough Envelope Sealing Technology
True Cost Accounting

- Embodied Carbon comparison
- Raw material extraction, fabrication, and transport
Energy Modelling

- Southland Log Home Baseline
- HERS -1 with 50kW PV Array
- RemRate iterations
HVAC Investigations

- Geothermal roots too expensive!
- 200 year ROI compared to ASHP
- HyperHeat models at -13°F

PV Annual kWh Req'd For HERS 0

- Dual Fuel Heat Pump
- Air Source Heat Pump
- Ground Source Heat Pump
Tree Shading Analysis

- REM / Rate shading analysis very limited
- i-Tree revealed 4000 kWh average annual savings
- Increases year over year
Mycorrhho-Grid Simulation

- Weather Station adjacent to our site: TMY-724113
- DOE's Open Energy Information (OpenEI): Base, High, and Low
- Adapted to our unit types
- PVWatts for PV production
- Smart contract logic
Acoustics – Site Noise

Site proximity to freeway and local airport

- Recorded baseline octaves
- Envelope will reduce overall site noise by ~40dB
- Only 1/16th of noise will be perceptible

Site consultation with Acentech
Acoustics - Between Units

**Targets:**
- Shared walls: STC 50
- Exterior walls: N/A
- Floors & Ceilings: IIC 50

**Actual ratings:**
- STC 63
- STC 57
- STC 58, IIC 50
Acoustics - Within Units

Acoustic channels are routed into DLT panel:

- Attenuated to 1000hz for human voice
- Filled with wood-wool fiber
- Fiber also sequesters VOCs
Phyto-remediative Green Wall

Green wall is integrated into HVAC

- Air is pulled through the soil
- Meets ASHRAE 62.2 standards
- Also supplemented by ERV
Blockchain Platform

One Integrated Dapp

Prediction Engine
Prediction Engine

User Consumption ➔ Behavioral Learning

Forecasting ➔ Estimating Peak Load Demands

INNOVATION
Blockchain Applications

- Transparent Energy Transactions
- Geofencing Security control
- Immutable Maintenance Log
Our blockchain platform is powered by EOSIO
Back to our Roots

ENERGY

FOOD

WATER

ENERGY

WATER

FOOD
Back to our Roots

ENERGY: Mycorrho-GRID

WATER

ENERGY

FOOD
Back to our Roots

FOOD: Anaerobic Digestion

WATER

ENERGY

FOOD
Back to our Roots

WATER: Condensate Raingardens
Back to the Earth: Succession

Although TreeHAUS is Built to Last we have designed for a truly regenerative future.

- Design for deconstruction
- Design for recyclability
- Design for biodegradability
“Far into the future, once our structures disappear, the remedial grasslands will be overtaken by trees. Through natural succession, the entire site will regrow into an extension of Crumpacker woods.”

- Delie Wilkens
Thank You!

And a special thanks to our crowd-funding sponsors:

**Gold:**
Juan Del Alamo, Charlie Regan, Lisa and Bruce Gould, in Memory of John T. Regan, Samuel Piper, Jeff and Isa Warner, Saeid and Stacy Arshadi, Gretchen Gruenhut, Chris Fong

**Silver:**
Rachel Peacock, Elaine and Steven Strongwater, John Nuckols of JRN Environmental Health Service, Lorann Stallones, Kimberley Homer, Brad Tilley, Taryn Gould, Sharon Jaffe Dan

**Bronze:**
Halley Futterman, Don Janus
Appendices
# Loads

<table>
<thead>
<tr>
<th>UNIT TYPE</th>
<th>HOT WATER LOAD</th>
<th>INITIAL TOTAL WATER LOAD</th>
<th>TOTAL WATER LOAD W/ SAVINGS</th>
<th>HEATING LOAD</th>
<th>COOLING LOAD</th>
<th>VENTILATION LOAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1Bd (1Ba)</td>
<td>3.5 GPM</td>
<td>5 GPM</td>
<td>4.5 GPM</td>
<td>3.4 kBTU/hr</td>
<td>3.7 kBTU/hr</td>
<td>42.2 CFM</td>
</tr>
<tr>
<td>2Bd (1.5Ba)</td>
<td>5.5 GPM</td>
<td>8.5 GPM</td>
<td>7.5 GPM</td>
<td>5.3 kBTU/hr</td>
<td>6.0 kBTU/hr</td>
<td>70.5 CFM</td>
</tr>
<tr>
<td>3Bd (2.5Ba)</td>
<td>7.5 GPM</td>
<td>12 GPM</td>
<td>10.5 GPM</td>
<td>7.7 kBTU/hr</td>
<td>8 kBTU/hr</td>
<td>98.7 CFM</td>
</tr>
<tr>
<td>4Bd (2Ba)</td>
<td>7.5 GPM</td>
<td>12 GPM</td>
<td>11 GPM</td>
<td>12.8 kBTU/hr</td>
<td>13.8 kBTU/hr</td>
<td>117.5 CFM</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>HEATING</th>
<th>FRIDGE</th>
<th>30% LIGHTS &amp; APPLIANCES</th>
<th>H2O PURIFICATION PUMPS</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>DAILY PER CLUSTER</td>
<td>15 kWh</td>
<td>4 kWh</td>
<td>14 kWh</td>
<td>16 kWh</td>
<td>49kWh</td>
</tr>
<tr>
<td>DAILY PER DEVELOPMENT</td>
<td>45 kWh</td>
<td>12 kWh</td>
<td>42 kWh</td>
<td>48 kWh</td>
<td>147 kWh</td>
</tr>
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---

APPENDICES
Passive Sensors
Hybrid Back-end Architecture
# CFM Calculations

<table>
<thead>
<tr>
<th></th>
<th>Area (sf)</th>
<th>A/C CFM Calc.</th>
<th>CFM ASHRAE 62.2 (Air Flow)</th>
<th>Green Wall Area for 62.2 Compliance (sf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit A</td>
<td>640</td>
<td>-</td>
<td>34.2</td>
<td>42.3</td>
</tr>
<tr>
<td>Bedroom</td>
<td>77.25</td>
<td>111.1</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Living Room</td>
<td>383.5</td>
<td>379.6</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Unit B</td>
<td>1152</td>
<td>-</td>
<td>57.06</td>
<td>70.5</td>
</tr>
<tr>
<td>Living Room</td>
<td>405</td>
<td>385</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bedroom (Single)</td>
<td>96</td>
<td>126</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bedroom (Double)</td>
<td>104</td>
<td>133</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Unit C</td>
<td>1664</td>
<td>-</td>
<td>79.92</td>
<td>98.7</td>
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<tr>
<td>Bedroom (Level 1)</td>
<td>138</td>
<td>162</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Living Room</td>
<td>536</td>
<td>494</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bedroom (Level 2 single)</td>
<td>96</td>
<td>127</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bedroom (Level 2 Double)</td>
<td>104</td>
<td>133</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Unit D</td>
<td>1920</td>
<td>-</td>
<td>95.1</td>
<td>117.5</td>
</tr>
<tr>
<td>Bedroom (1)</td>
<td>112</td>
<td>139</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bedroom (2)</td>
<td>107</td>
<td>123</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bedroom (3)</td>
<td>110</td>
<td>126</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Living Room plus hallways</td>
<td>524</td>
<td>497</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Bedroom (level 2)</td>
<td>150.5</td>
<td>172</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>
# Mechanical Schedule

## SPLIT SYSTEM HEAT PUMP (INDOOR SECTION)

<table>
<thead>
<tr>
<th>TAG</th>
<th>TON/BTU</th>
<th>EFFICIENCY DATA</th>
<th>V</th>
<th>Φ</th>
<th>Hz</th>
<th>BASIS OF DESIGN</th>
<th>HEAT CAPACITY (BTU/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AHU1</td>
<td>.5/6000</td>
<td>24.6</td>
<td>20</td>
<td>1</td>
<td>6</td>
<td>MITSUBISHI MSZ-GL06NA</td>
<td>7,200</td>
</tr>
<tr>
<td>AHU2</td>
<td>.675/8100</td>
<td>15</td>
<td>20</td>
<td>1</td>
<td>6</td>
<td>MITSUBISHI SEZ-KD09NA4R1.TH</td>
<td>10,900</td>
</tr>
<tr>
<td>AHU3</td>
<td>.96/11500</td>
<td>16</td>
<td>20</td>
<td>1</td>
<td>6</td>
<td>MITSUBISHI SEZ-KD12NA4R1.TH</td>
<td>13,600</td>
</tr>
</tbody>
</table>
Dual Fuel / Flex Fuel

Hot Water Heater Back-up heat considered
ASHPs efficient and better for modularity
Natural gas / Bio-gas interchangeability

Methane (CH₄)
Ethane (C₂H₆)
Propane (C₃H₈)
Butane (C₄H₁₀)
Condensates
(C₅H₁₂ – C₁₀H₂₂)
Nitrogen (N₂)
Carbon Dioxide (CO₂)
Hydrogen Sulphide (H₂S)
Helium (He)
Free Fuel From Nature

<table>
<thead>
<tr>
<th></th>
<th>SOLAR: ROOF RESOURCE</th>
<th>RAIN: ROOF RESOURCE</th>
<th>FOOD WASTE from TreeHAUS</th>
<th>FOOD WASTE from VT</th>
<th>ENERGY from FOOD</th>
<th>HEAT from FOOD</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL</td>
<td>400 MWh/yr</td>
<td>180,000 Gal/yr</td>
<td>8 Tons/yr</td>
<td>550 Tons/yr</td>
<td>89,000 kWh/yr</td>
<td>89,000 kWh/yr</td>
</tr>
<tr>
<td>HARNESSSED</td>
<td>60 MWh/yr</td>
<td>153,000 Gal/yr</td>
<td>8 Tons/yr</td>
<td>17 Tons/yr</td>
<td>28,480 kWh/yr</td>
<td>52,510 kWh/yr</td>
</tr>
<tr>
<td>EFFICIENCY</td>
<td>15%</td>
<td>85%</td>
<td>100%</td>
<td>3%</td>
<td>32%</td>
<td>59%</td>
</tr>
</tbody>
</table>
Net Carbon Sink

- DLT mass timber has the largest net negative impact
- Landscape impact over full lifetime doubles
- Gutex travels the furthest but still performs
All Wood Wall Section

7. White Oak Cladding (3/4’’)
6. Pine Furring Strips (3/4’’)
5. GUTEX MultiTherm*, ** (3’’)
4. GUTEX MultiTherm** (3’’)
3. Blue Ridge Fiberboard*** (1/2’’)
2. GUTEX ThermoSafe** (3 1/2’’)
1. Richlite Finish**, **** (1/2’’)

* Integrated Parafin-based weather barrier
** Post Production Waste (pulp, dust) -> Formaldehyde free binding
*** with optional Intello Plus variable moisture barrier, OSB corners
**** Recycled Paper product from VA, alternated with gypsum board
Mycorrho-Grid Simulation.

- Weather Station on our site! TMY-724113
- DOE's Open Energy Information (OpenEI) Base, High, and Low Profiles
  Building America House Simulation Protocols
  Residential Energy Consumption Survey (RECS)
- Adapted to our unit types
- Run through smart contract logic
- PVWatts CSV used for PV production
Acoustics – Site Noise

Our site’s relative proximity to a freeway and occasional air traffic brings acoustic challenges, which we consulted with Acentech to solve:

- We recorded baseline octaves with Acentech overnight
- Our envelope was analyzed, and predicted to reduce overall site noise by ~40dB
- This results in 1/16th as much noise perceived

<table>
<thead>
<tr>
<th>Environmental Noise</th>
<th>Overall A wt</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>74 dB</td>
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<table>
<thead>
<tr>
<th>Interior Noise Level Estimates</th>
<th>Overall A wt</th>
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</thead>
<tbody>
<tr>
<td>Only Glazing</td>
<td>39 dB</td>
</tr>
<tr>
<td>Only Doors</td>
<td>39 dB</td>
</tr>
<tr>
<td>Only Exterior Wall</td>
<td>29 dB</td>
</tr>
<tr>
<td>All Façade Elements</td>
<td>35 dB</td>
</tr>
</tbody>
</table>