ADVANCED TECHNOLOGY HOMESTEAD

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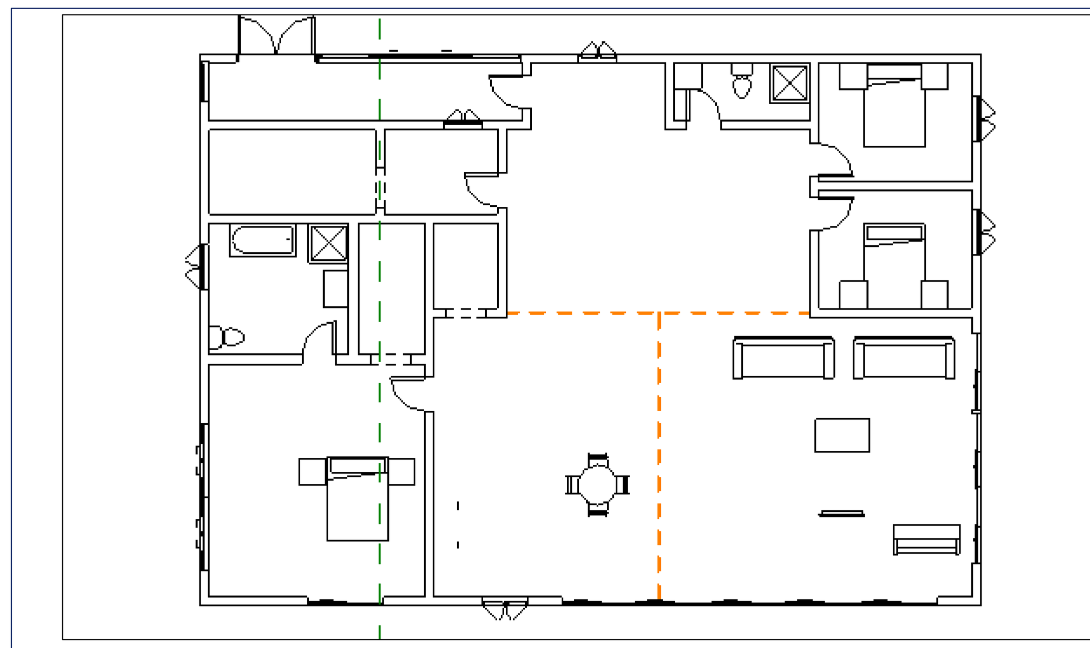
Introduction

The aim of this project was to design a hyper-efficient, energy positive homestead by integrating passive house principles with algae cultivation and energy production. Inspired by the BIQ building in Hamburg, the design uses algae systems to generate biomass that can be harvested, gasified, and converted into usable energy, as well as sold for therapeutic and scientific needs.

This approach aligns with systems such as the University of New Hampshire cogeneration plant, which produces energy from methane. Similarly, algae biomass can be converted into combustible gasses for on-site energy generation.

The project involves designing a 2,500 ft^{2}home and an energy barn for algae processing. It also evaluated the feasibility of raceway pond cultivation using the Lamprey River as a natural water and nutrient source, expanding on algae's potential as a sustainable energy solution.

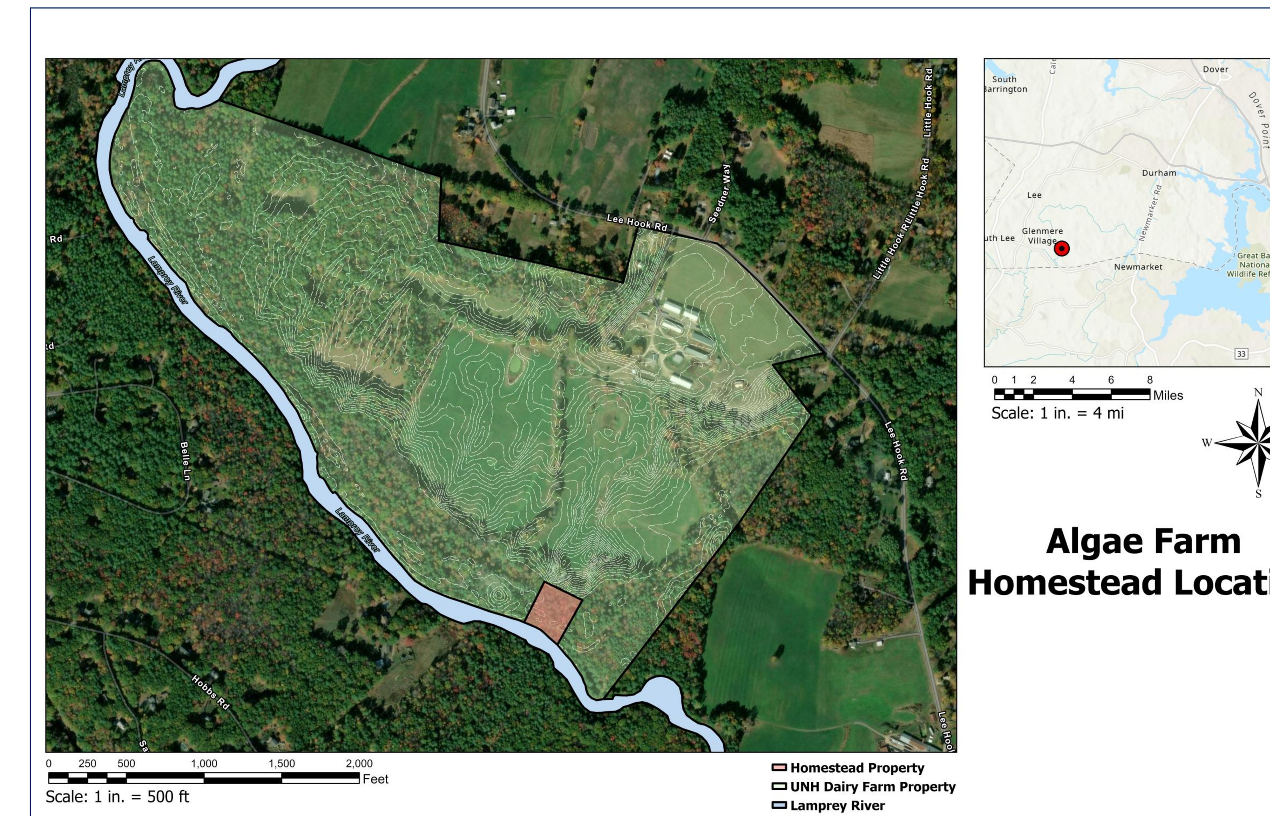
Homestead Design and Layout



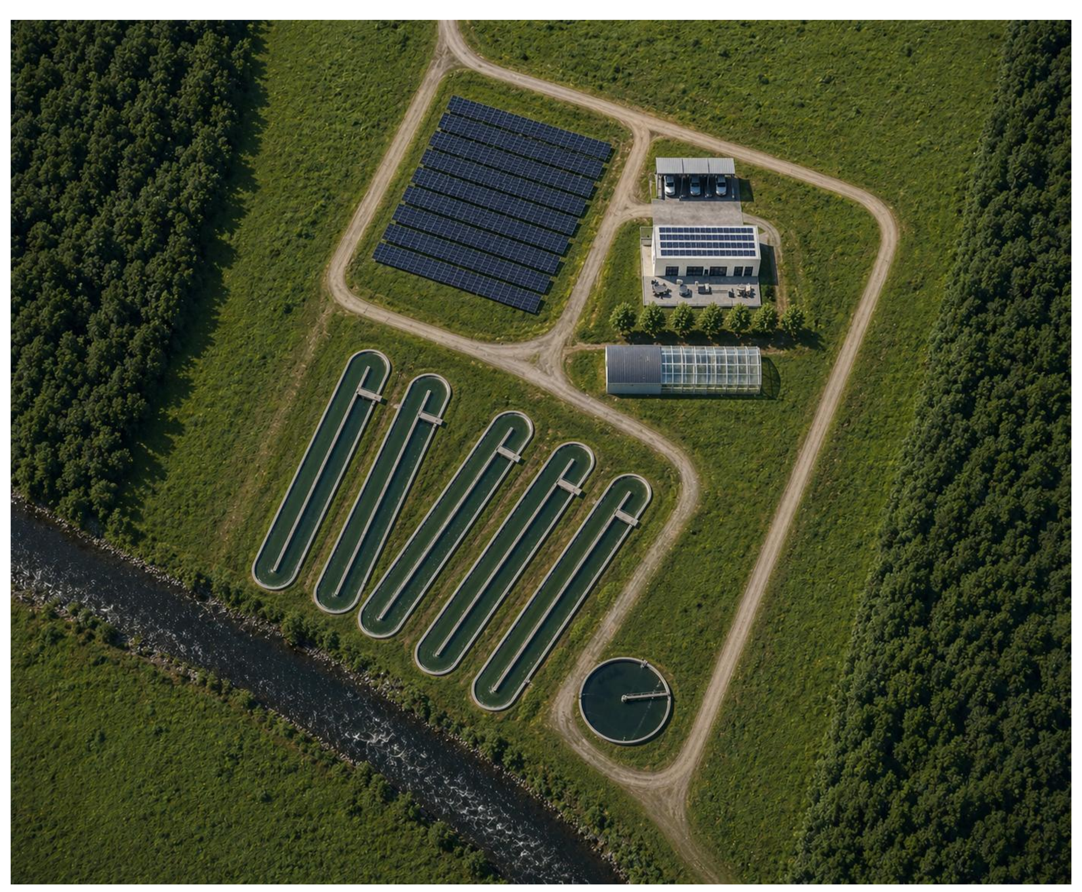
The floor plan reflects the Hyper Haus concept, prioritizing energy efficiency and passive performance. Communal areas are positioned to maximize solar gain, while the compact layout reduces heat loss and improves overall efficiency.

The rendering above illustrates the proposed home upon completion, presented from a southeast perspective. Large sliding window doors along the south face of the building maximize solar passive gain in the winter months, decreasing heating demands.

ArcGIS Map



Site Map



Algae

Small-scale Algae Cultivation Using Open Raceway Ponds

Chlorella vulgaris, Spirulina, and A. flos-aquae were assessed, and **Chlorella vulgaris** was selected due to its cold tolerance, productivity, and depth of research available.

Five raceway ponds (150ft x 20ft each), operating seasonally (May - October) to avoid winter damage.

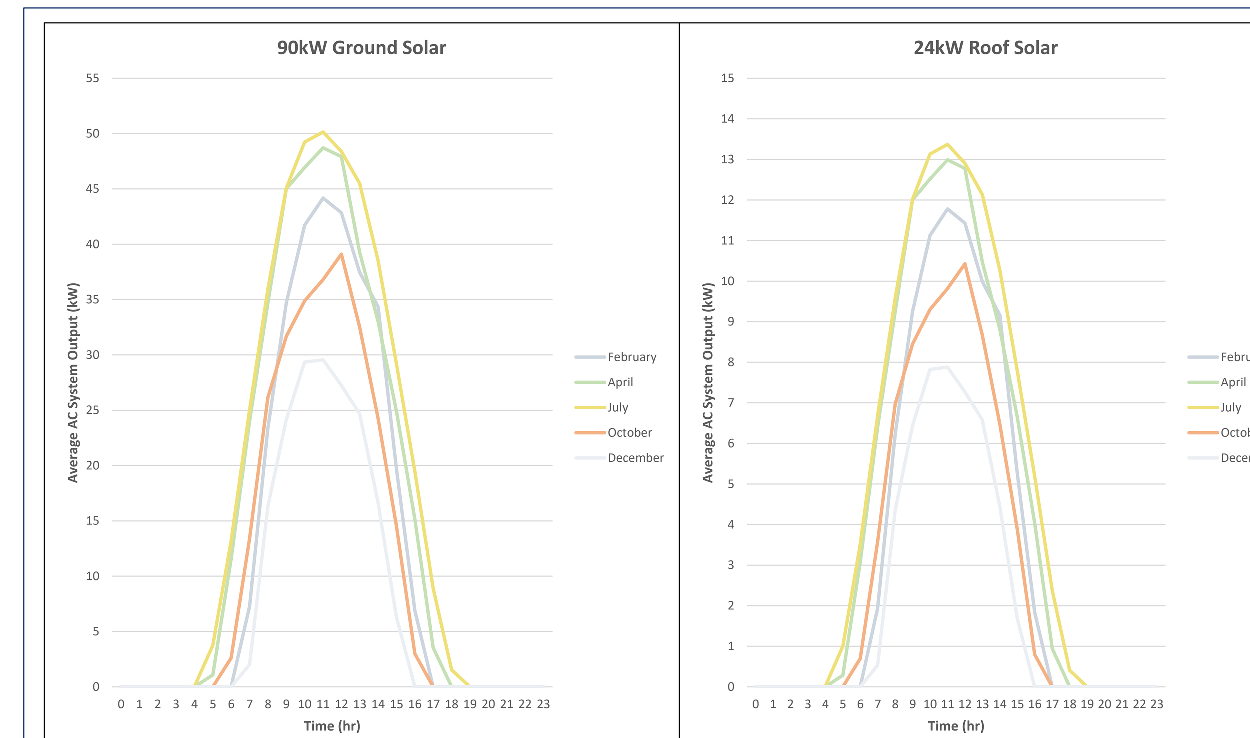
Five Stage Batch Cultivation Process:

1. Inoculation: Ponds filled with stream water and seeded with algae culture.
2. Growth: Continuous paddle-mixing with dairy waste nutrient supplementation.
3. Flocculation: Auto-flocculation to form algae cell flocs.
4. Separation: Settling tanks to concentrate biomass and recycle treated water.
5. Drying: Solar and wind drying in an energy barn.

Environmental Impact: Water will be drawn and discharged into the Lamprey River. Discharge nitrogen levels should be lower than 0.5 mg/L, and water withdrawals will not exceed 600,000 gallons a month.

Production	
Total Algae Pond Area (m^2)	1,393.5
Algae Biomass Production (g/m^{2}d)	15
Daily Dry Algae Production (kg/d)	21
Grow Season Yearly Proportion	0.5
Yearly Dry Algae Production (kg/yr)	3,815
Nutrients	
Total Nitrogen Required (kg/yr)	343
Total Available N from Dairy Cow Waste (kg/yr)	5,715
Power	
Circulation Power Required (W/m^2)	2.5
Continuous Energy Load (kW)	3.5
Yearly Energy (kWh)	30,520

Solar Energy System

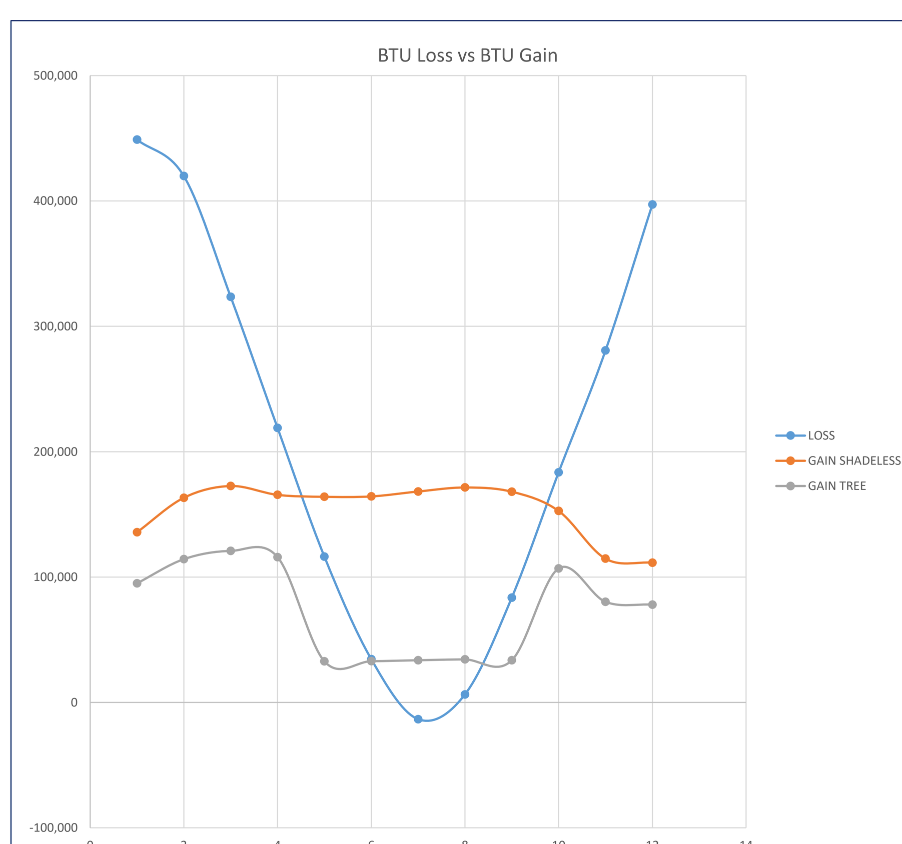


Two solar systems were designed for this property. A 90kW ground solar array, and a 24kW roof mounted array. Both produced a combined 144.5 MWh a year.

Energy Balance

Battery Size (kWh)	70
Battery Efficiency	0.9
Solar Production (kWh)	144,400
Power Consumption	
House, Electric (avg) (kW)	1.21
House, Heating (avg) (kW)	1.0
Pond Circulating Pump (kW)	2.5
Additional Algae Production (kW)	1.0
Energy Balance	
Total Annual Energy Load (kWh)	49,052

Resultant Energy Demands



Plot of BTU Loss against BTU Gain and the effect of shading elements.

All elements of the site and home design were optimized for energy efficiency. The home was designed to use the most recent and proven Passivhaus technology as well as passive energy efficiency methods.

The energy goal of the home is an average of less than 100,000BTU/Day annually; This value is represented by the gap between our thermal loss (blue) and gain (orange and gray) lines. The closer they are, the closer our losses and gains are to net 0, which in turn means the less energy demand of heating and cooling the building. The heat needs of a building vary over the year, so static design will have variance; active systems such as the external heat pump and energy recover ventilator account for this. This graph shows the effect of deciduous trees that provide shade in hot months and shed leaves in colder months. In the end this design Averaged 113,000BTU/day, for shaded, and 37,000BTU/day for unshaded.

Cost Analysis

Capital Costs	Annual O&M Costs
Algae Systems: $630,000 - $1,015,000	Algae Systems: $34,200 - $52,700
Hyper House: $707,000 - $940,000	Hyper House: $1,450 - $3,000
Solar Systems: $94,000 - $167,000	Solar Systems: $450 - $700

- Raceway ponds remain as one of the lowest-cost algae cultivation systems, but New England's climate introduces seasonal downtime and higher construction costs.
- Hyper House construction costs are relatively high upfront, however yield long-term operational savings.
- The Solar systems provide the largest and most reliable energy return per each dollar spent.

Acknowledgements

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