

Four-Year Performance Data

Trail Magic: Home of Carl and Mary McDaniel
495 E. College Street, Oberlin, OH 44074
Operating Energy, Water Use, and Food Production

Summary

Operating energy: Trail Magic is *positive energy* because more energy than used comes from onsite sunshine and *climate positive* because it nets a removal of carbon dioxide from the atmosphere. About 50% of the energy to heat Trail Magic comes from sunshine via passive solar design features with the rest from onsite wood. A pond source heat pump can be used to heat and cool the house with onsite produced electricity. Energy for most local travel in a Prius plug-in hybrid comes from onsite produced electricity. Trees and fields sequester carbon. No energy is purchased where as the average US home purchased 110 million British Thermal Units (BTU) in 2005 for about \$2,100.

Energy and water: Compared to the average 2-person US home, Trail Magic uses 70% less electricity, 95% less electricity for lighting, 80% less indoor water, and 70% less hot water.

Food Production: A bit more than 30% of Trail Magic's food is grown onsite.

Electricity

Electricity use: 7.8 kilo Watt hours (kWh)/day or 2,839 kWh/year: The average annual electricity used in Oberlin and nationally is ~9,500 kWh/home (in Oberlin most use gas for heating and hot water; Trail Magic is all electric except wood for heating). Trail Magic uses about 70% less electricity than the average US home.

Electricity production by a 3.12 kW photovoltaic system (PV) is 8.9 kWh/day or 3,258 kWh/year and by a 2.1 kW PV system installed in September 2010 is 5.8 kWh/day or 2,123 kWh/year for a total annual production of 5,381 kWh. No carbon is used to produce these 5,400 kWh thereby reducing the carbon dioxide released by Oberlin Municipal Light and Power System by about 10,000 pounds. *NOTE: Embodied energy has been paid back by production.*

Annually Trail Magic sends ~2,500 kWh of carbon-free energy to the grid for others to use.

Water

Indoor water use is 26 gallons/day or 9,300 gallons/year: The average two person home in the US uses 140 gallons/day or 51,000 gallons/year. Trail Magic uses about 80% less than the average two persons in the US.

Hot water use is 7.1 gallons/day or 2,600 gallons/year: The average couple over 60 uses 22 gallons/day or 8,000 gallons/year. Trail Magic uses about 70% less hot water than the average couple over 60 in the US.

Hot Water Energy

The annual energy used to heat hot water with an electric, on-demand hot water heater is 360 kWh of PV electricity or \$36 if purchased at \$0.10/kWh. *NOTE: Originally we had an evacuated-tube solar hot water heater. Our data collection and analyses established that evacuated tube solar hot water heating systems are not cost effective for domestic hot water heating in Oberlin-like climates (our annual savings were \$3.00 for a \$6,500 investment). The system was removed and replaced with a 2.10 kW PV system in 2010.*

Heating Energy

Passive solar heating: ~50% of heating energy. Trail Magic was designed for passive solar heating. When it is 0°F outside on a sunny day, the sun warms the house from the low sixties to the high sixties without heat from the woodstove or heat pump. However, it is difficult to determine with any precision the energy gained by passive solar. Our best estimate is 15 million BTUs or at least 50% of heating energy is from passive solar.

Wood: ~1 cord of wood/year. Firewood from Trail Magic trees is burned in an airtight HearthStone Tribute woodstove to provide heat during cloudy days in the winter when passive solar heating is insufficient to keep the house at a comfortable temperature of ~68°F. We operate the stove at a chimney temperature range of 300°F to 1200°F that provides almost complete combustion with very little particulate matter released (EPA

rating: ~0.1 ounce/hour). *NOTE: Firewood is a carbon-neutral heat source because the carbon in trees is in the short carbon cycle (i.e., carbon was removed from the atmosphere less than 100 years ago and when a tree dies and decomposes, or is burned, its carbon is returned to the atmosphere). Carbon in fossil fuels (coal, oil, natural gas) is in the long carbon cycle and when burned, does increase carbon dioxide in the atmosphere because the carbon was removed from the atmosphere millions of years ago.*

Pond source heat pump: backup heating. The pond source heat pump was used rarely except for experimentation to assess the cost of heating or cooling. Based on 1) the number of degree heating days in Oberlin for the past four years and 2) a nine day experiment in February 2010 with six 100% cloudy days and three partially sunny days, the heat pump can annually heat Trail Magic to a constant 68°F using ~2,100 kWh of onsite produced electricity. *NOTE: If electricity is purchased, the annual cost for heating would be ~\$210 at \$0.10/kWh; however, substantial passive solar heating will reduce significantly the kWh needed (Note: Because of excessively cloudy weather during the experiment, little passive solar heating occurred then).*

Cooling Energy

Passive cooling design features of Trail Magic: Wind tower, thermal mass, earth berming, and window shading suffice to keep the house between 60°F and 80°F in the summer except when the day temperature exceeds 90°F for several days.

Pond source heat pump: backup cooling. Based on 1) the number of degree cooling days in Oberlin for the past seven-years and 2) a five day experiment using the pond source heat pump in August 2010 established that the house can be kept at 75°F annually in the summer with ~910 kWh of onsite produced electricity. *NOTE: If electricity is purchased, the annual cost for cooling would be ~\$91 at \$0.10/kWh; however, using the wind tower at night will reduce significantly the kWh needed (Note: No windows opened during experiment).*

Lighting with Sunshine and Electricity

Trail Magic was designed for daylighting and during daylight hours sufficient natural light is provided for most tasks, including reading, in almost all rooms. The 50 light fixtures in Trail Magic have fluorescent tubes, compact fluorescent bulbs, or LED bulbs and flow a total of 500 Watts. Trail Magic uses less than 100 kWh annually for lighting or 95% less than the annual 2,800 kWh used by the average two person home in the US.

Food Production in 2012 from Garden

We weighted in pounds what we harvested to estimate the calories produced from our 6,000 square foot garden. We grew beets (79), broccoli (64), butternut squash (499), carrots (104), eggplant (10), green beans (90), lettuce (10), okra (80), onions (66), peppers (40), potatoes (230), soybeans (dry, 23), sweet potatoes (120), Swiss chard (195), tomatoes (368), Zucchini and yellow squash (100). We produced a bit more than 2,000 pounds of produce containing almost 400,000 calories or 3 to 4 months of our food calories.

Carbon Sequestration

Carbon is sequestered by several hundred established trees, by existing meadows, by more than hundred newly planted trees and shrubs, and by clover and tall grass prairie plants being established on ~0.5 acre.

Being Positive Energy and Climate Positive Cost Nothing Extra and Has a Dividend

Trail Magic: Trail Magic has many upscale features including metal roof, Hardi-board siding, Loewen windows, quartz counter top, tiled shower, sun patio, rain cistern, and custom beams, bookcases, counter top, floors, and shelves made from onsite trees. Cost per square foot of conditioned space: \$146 with upscale features (same as a modest, well-built custom home in Northeast with an energy bill) and \$110 without upscale features replaced by standard ones that provide similar performance (same as quality development home in Northeast with energy bill). Trail Magic has no energy bill resulting in an annual dividend of at least \$2,100 plus income tax savings of ~30% because dollars for energy don't have to be made.

Rehabilitated 1954, 1,200 ft² house with full basement: The Stoners in Troy, NY, by weatherization (sealing leaks, insulation) and conservation measures (compact fluorescent bulbs, night setback thermostat, clothes line, turning off lights) costing \$5,000, reduced energy use from 121 to 69 million BTUs saving \$1,200 per year and giving a payback time of ~4 years. By installing a new boiler mostly for hot water, an airtight woodstove, and a 3.3 kW PV system for \$25,000 (not including subsidies and tax credits), they further reduced net carbon dioxide release to less than zero making their home *positive energy* and *climate positive*, except wood is not from onsite trees. A savings of \$2,400/year for all these improvements yields a payback time of ~13 years.