To: Martha's Vineyard Commission
From: Marc Rosenbaum, P.E.
Subject: Review of Energy and Emissions Materials Submitted by Meeting House Place Applicant
Date: July 1st, 2020

Overview

I have reviewed the information submitted by the Applicant, which includes annual energy modeling by CLEAResult and proposed renewable energy installation to offset the end use loads. This memo will offer my assessment of the plausibility of the end use energy loads, the greenhouse gas emissions associated with this energy usage, and the suitability of the proposed renewable energy installation to offset those loads and emissions.

Credentials To Undertake This Review

- Over 40 years consulting in the design and construction of energy efficient buildings and renewable energy, including the first LEED building in New England; the 5th and 17th Living Building Challenge buildings world-wide; founding Board member of the Passive House Institute of the US; Lifetime Achievement Award from the Northeast Sustainable Energy Association.
- MIT Mechanical Engineering, undergraduate and graduate degrees
- MA Licenses: Mechanical Engineer #34682 and Unrestricted Construction Supervisor #106611
- Zero Energy Building pioneer; Creator/instructor of Zero Energy Homes 10 week online training for design and construction professionals – over 330 students.
- Extensive experience reviewing end use loads and annual energy models for buildings ranging from houses to university scale buildings.
- Extensive experience in energy monitoring of real buildings and their energy use, both on Martha's Vineyard and elsewhere in New England.
- Please note that although I have completed RESNET HERS Rater training I am not a HERS Rater.

Energy Model Loads Assessment

I concentrated on the two models of the detached 3,800 sf home, one of which assumed the use of propane for the heating and hot water loads, the other of which assumed all loads including heat and hot water were served by electric heat pumps. I have not reviewed complete input/output files for these models, just summary pages from the Ekatrope modeling software, with subsequent questions that have mostly been answered by the Applicant. Note that the model uses certain standard inputs embedded in the HERS Rating Standard (for example, for hot water usage), and some of my assessment below does not mean that the model has errors, but rather that the model may not represent real houses on Martha's Vineyard. The British statistician George Box's quote "all models are wrong, but some are useful" applies here.

The End Use Loads are broken down into Heating, Cooling, Water Heating, and Lights and Appliances. A *load* is how much energy needs to be delivered to serve a given function, such as heating a house. It differs from *consumption*, which is the energy consumed by a system in satisfying a load. As an example, take water heating. The *load* might be 10 million BTU/year. If a gas water heater is 60% efficient, the energy consumed will be 16.7 million BTU/year. Energy *consumption* of a fossil-fueled system (heat, hot water, pool heat) will always be more than the load, because they are not 100% efficient. The reverse is true for heat pumps.

The load reported for cooling is *substantially* lower than what I would expect based on my monitoring actual homes on MV, and the water heating load is also lower than I'd expect in a house of this size. Nonetheless, the *total* annual energy load of this house is plausible, and sufficient to serve as the basis for this analysis. The two cases modeled for some reason have slightly different end use loads, most notably in heating load, which I don't yet understand – to compare two cases, one starts with the same loads. However, the total load of each case only differs by about 4%, and in the interest of time, this seems close enough to proceed with the analysis. The propane-fueled case has an As-Designed annual load of 83.4 million BTU; the all-electric case has an As-Designed annual load of 87.1 million BTU.

Model Results for the Two Cases

Fuel Usage

Case	Propane, gallons/year	Electricity, kWh/year
Propane plus electricity	1106.7	7548.1
All-electric	n.a.	20117.3

Energy Usage in Common Units

Case	Million BTU/year
Propane plus electricity	127.0
All-electric	68.6

Conversion factors above are 91,500 BTU/gallon of propane; 3,412 BTU/kWh.

Greenhouse Gas Emissions (GHG)

Case	Carbon Dioxide (CO_2), Metric tons/year
Propane plus electricity	9.17
All-electric	7.45

Based on 12.7 pounds CO_2 per gallon of propane, and 0.817 pounds CO_2 per kWh (most recent ISO-NE data for MA)

The reason the all-electric case has lower energy usage is that heat pumps use electricity to extract heat from the air around them, so one unit of energy input to the heat pump delivers 2-3 units of energy to the building (and even more when used for pool heating). The reason the all-electric case has lower GHG emissions is that the emissions from burning fossil fuels is fixed, but the energy used to make electricity comes from a mix of fuels and New England has a relatively clean grid mix (e.g., oil and coal represent only 2% of the total). From 2016 to 2018, GHG emissions per kWh in MA have dropped annually, from 0.897 to 0.861 to 0.817, as the fuel mix gets cleaner.

Note that fuel cost annually for the two cases is likely to be similar. With propane costing $3 per gallon, and electricity costing $0.25 per kWh, the propane case costs about $5,200/year, and the all-electric case costs $5,000/year. The price of electricity is regulated and stable; propane fluctuates much more and is more likely to rise over time. In addition, electricity can be generated on site, lowering annual energy costs; propane must be imported and purchased.

Zero Net Energy and/or Net Energy Neutral

The expression Zero Net Energy is widely understood to mean that renewable energy system(s) in place at a building/site *generate* at least as much as the energy that the building *consumes* annually. This includes *all* energy, including fossil fuels and electricity. The Applicant's proposal excludes counting the propane in the assertion that the project will be, in their term, net energy neutral. To be net energy neutral, the renewable energy produced on site should offset the propane as well as the electricity.

Heat Pumps

In the document entitled Applicant Questions with Answers (6-10-20), question 2 asks why heat pumps are not being used for heat, and the response is that heat pumps would require a back-up propane system because they are only effective to (+/-) -5˚F. In the ten years I have lived on Martha's Vineyard I have been involved with over fifty projects ranging from detached bedrooms to a heating system replacement at the MV Public Charter School. None of the projects have or have needed back-up heating. I have projects heated with modern air source heat pumps north of the NH White Mountains, without back-up heat (including a public school in west central NH). In addition, heat pumps are being installed cost-competitively with fossil-fueled systems that include air conditioning. Using heat pumps for heating houses, hot water, and pools is well reduced to common practice on Martha's Vineyard.

Smartflower 2 Axis Tracking Solar Electric System

Experience with several hundred solar electric systems on Martha's Vineyard shows that an unshaded and optimally oriented (tilt and compass orientation) roof or ground mounted system will generate roughly 1,300 kWh per kW annually. Differences in weather patterns cause this to vary each year. This value also degrades slightly over time.

An unshaded 2-axis tracker such as the 2.5 kW Smartflower can increase production over a fixed array by 35%, leading to an annual output of roughly 1,750 kWh per kW of panel vs. the 1,300 kWh per kW of a fixed array, or a total of 4,375 kWh/year. The information submitted by the Applicant suggests an annual output of 5,065 kWh. I believe this is optimistic by about 15%, because it would suggest that a fixed array would generate 1,500 kWh/kW/year, which we know is optimistic. It would be helpful to see at least one year's worth of in-place production data in MA, which could be compared to a fixed system for the same time period in as close a location as possible to vet this claim.

I find some aspects of the Smartflower product to be concerning. The Austrian parent manufacturer filed for bankruptcy in 2017 and the US division is apparently independent of that, and going forward.

An important aspect of selecting a solar electric system is the production warranty. This is different from a functional warranty which states that a product will work for a given period of time. A production warranty guarantees a minimum power output over an expected life of the system. Premium solar products guarantee 90% or more of rated output for 25 years. The Smartflower production warranty over 25 years is 80%. The functional warranties are short – the panel warranty is 10 years, and the system warranty, which includes the moving parts and controls that enable the system to retract in high winds, and track the sun, is 5 years with a maintenance contract, and 2 years without. These are far below industry standard warranties for both power output and for functional operation. And if the company's financial health is tenuous, any warranty may have little value.

Garage-over space, Pools, Seasonal Energy Usage

If the space over the garage is heated or cooled, it must be built to the energy code. The plans show a full bathroom. Experience shows that these high end houses remain conditioned throughout the winter, and that the plumbing isn't drained, because people visit them in the winter. Because spaces like this are small and are over an unheated garage, they have more surface area per sf of living area and tend to use more energy per sf than the main house if conditioned to similar temperatures. To keep it simple, my recommendation is to increase the energy usage values by the ratio of floor area for the space over the garage to the floor area of the house. In this case, 400 sf / 3,800 sf is 11%, and in the all-electric case that represents an additional 2,100 kWh/year.

Data from heated pools on MV shows that the Applicant's projection for pool energy is low, especially for heating the pool, even though it is for a minimal 90 day season. The pool pump is not the only electrical user, usually there is a jet booster pump and these days a salt generator to reduce the chlorine needed to sanitize the pool. Assuming usage of a pool cover and heat by a heat pump pool heater (substantially lower energy required compared to propane, because the heat pump is operating in much warmer air temperatures than a heat pump heating a house), a pool will use 4-5 kWh per sf during June through August, and double that if the season is extended to May through September. A 20 ft x 40 ft pool therefore would use between 3,000 and 6,000 kWh annually. Roughly 1/3 of that is pumping and accessory electrical use and the balance is heating. If propane were the heat, usage would be in the range of 300 – 1,000 gallons annually, for the June through August season, and the May through September season, respectively. Note that because most of the energy use comes from evaporation off of the surface of the pool, the amount of time that a pool is covered dramatically affects energy use.

Seasonal usage of high end houses in round numbers is about *half* that of full time occupancy. Usually they are heated to a reduced temperature setpoint in the 50-55˚F range, which yields roughly half the heating energy use of a year round house. Note that many of the appliances (refrigerators, phone and internet, etc.) remain operational and using energy. Water heaters run to offset their tank and piping standby losses. The estimate submitted of 2,313.8 kWh/year assumes the house is completely unheated and all power is cut to the house for nine months. This is far from reality.

Townhouses

No information on these units beyond the HERS Summary pages was received therefore no detailed analysis was done. However, observations in this report would apply to these housing units as well (cooling and water heating energy appear low), and energy use and greenhouse gas emissions would be higher if propane is used as a fuel vs. the all-electric version.