Sustainable Master Plan at the Rühstaller Farm & Brewery

Final Report

06.11.2019

—

Meg Slattery & Mekdem Wright

ABT 212 001: A Path to Zero Net Energy!

UC Davis

Executive Summary

Rühstaller brewery has just purchased a 5-acre property in Dixon which they'll be developing into their new full-scale brewery and tap room as they scale up their business. The new facility is a blank slate and Rühstaller wants to take advantage of this opportunity to design it from the start to be not just sustainable, but also independently self-sustaining - they're interested in opportunities to go off-grid and utilize all available resources on-site including energy, water, and waste. Our graduate student team, which includes backgrounds in energy systems, civil and environmental engineering, and business management, helped them to identify viable technologies, processes, and practices to maximize the sustainability of their operations and integrate them into a comprehensive roadmap - their Sustainable Master Plan.

There is no silver-bullet solution or one-size-fits-all approach to sustainability. It requires a diverse portfolio of technologies, processes, and practices arranged and integrated in the right way, and continually monitored and managed through an iterative process of designing, testing, learning, and improving. Discussed in this report is a strategy for Rühstaller to get started on that sustainability journey.

The following technologies, processes, and practices are ones which we still believe have potential to be a good fit for Rühstaller:

- **Wind Turbines & Rooftop Solar PV** - Wind and solar can meet a significant part of Rühstaller's electricity demand, but not all of it always. Invest in those resources, but without electric storage Rühstaller must maintain its grid connection.
- **Reduce Propane with Rooftop Solar Thermal Heat Generation** - Can be used to either:
    - preheat water (for hot water heater or steam boiler),
    - create superheated water, or
    - create steam.

  This can also be coupled with a "thermal Battery" for dual-purpose water and heat storage.
- **Waste Heat Recovery** - Recover waste heat from throughout the brewing process (boiler or other). Also, if a solar PV system is installed, it can be designed as a "hybrid solar collector" - harvesting heat from the PV panels themselves and increasing the efficiency of the PV system by keeping it cool.
- **Supply-Driven Production** - "If the sun ain't shining and the wind ain't blowin, we ain't brewing…"
- **Rainwater Capture for Potable Use** - Rainwater can meet about 12% of expected annual potable water demand (30% in February), but will still need to rely heavily on groundwater. Rainy winter months are also when there's the least sun for solar power to pump from wells.
- **Biomass to Biogas** - Future partnership with the UC Davis Renewable Energy Anaerobic Digester (READ).

Table of Contents

Acknowledgements

We would like to thank:

JE, Xo, and Ken from Rühstaller for the beer-and-pizza-powered late night meetings with us and always keeping it fun and quirky,

Kurt, Lisa, Josh, and Nico for their guidance and feedback, and

our many peers in the ZNE class and at the Energy and Efficiency Institute for their help and resources.

Background

Who is Rühstaller Brewery?

Rühstaller is a local company with an R+D brewing facility in Dixon that tests new beer creations each week. Named after Captain Frank Rühstaller, a pioneer of California beer, the company prides itself on its unique style and use of local ingredients.

Brewing (and drinking) beer is a tradition that goes back thousands of years. Over that time, the practices, techniques, and methods have been continuously perfected and standardized. The Bavarians actually codified the rules of brewing in the "Reinheitsgebot" (or beer purity law). Still today, the understanding among most brewers is that quality equates to control and consistency.

Rühstaller's approach to making beer goes against this convention. They value creativity and experimentation. They want to bring more art to the science of beer-brewing and draw inspiration from French winemaking culture with its love for varietals and vintages, in contrast to the precise, fine-tuned "german-engineering" approach. These values are core to who Rühstaller is as a company, and they apply them to everything they do.

Their Growth Plans

Currently, Rühstaller produces about 30,000 cases annually but is planning to increase operations to 75,000. They have recently acquired a parcel of land where they are planning a new full-scale brewing facility and tap room. The new property has two existing buildings that will be repurposed as office space, storage, and the brewing and packaging facilities. Two new structures will also be constructed: kilns that will serve as a taproom for customers when they aren't being used to dry hops. They hope to plant the first hops on the site this Spring and begin construction by early 2020.

Their Sustainable Master Plan

Rühstaller Brewery is a farm, not a factory. Yes, they produce beer. But there's a lot of growing that goes into that beer; the hops, the grain. Now, they're looking to harvest even more on their land - like the sun, the wind, the rain, and the energy and nutrients in their own waste - to make sure that everything that goes into that beer and comes out of it is given as much thought as the beer itself.

JE Paino, the owner of Rühstaller, wants to ensure the company is making every effort towards sustainable operations. The holistic approach Rühstaller is taking to their Sustainable Master Plan (Master Plan) inevitably requires a very broad scope. Relevant elements which could be included in that scope include:

- **Renewable Electricity Generation** - The only grid-level service currently connected to the property is electricity (PG&E), and JE wants to rely on that connection as little as possible. Existing buildings boast large, nearly-flat roofs and are structurally sound enough to support solar PV. Wind resources are moderate and usually blow from North to South, but direction varies. Energy storage (battery or other) may also be a necessary component to enable full utilization of on-site renewables.
- **Hop-Kiln Energy Sourcing** - These would operate at temperatures of 120F for about 1 month straight during harvest (around August). For the remaining 11 months of the year, one kiln will be used as a taproom and will require space cooling. The owner of Rühstaller Beer wants to investigate more

sustainable methods of cooling and heating the kilns than propane and grid-supplied electricity. Good options exist for solar heating/cooling plus hot/cold water storage. Systems could also tie into those of a planned refrigeration/freezer room that will have hot and cold air as waste products from the conditioning process.

- **Process Heating and Cooling** - The brewing process itself - as well as the adjacent unit operations like the hop-kilns and cold storage - require heating and cooling (heating the mash, boiling the wort, washing bottles/kegs, and sanitation and cleanup, etc.). There may be opportunities to minimize and harvest heat losses, and source heat energy from renewable sources as an alternative to propane.
- **Water Resources and Wastewater Management** - As a rural farm and brewery, Rühstaller needs to capture, store, and treat water to supply the right quantity, quality, pressure, and temperature when needed. Water is currently supplied by a well from an underground aquifer, but this is unlikely to be sufficient to meet all their needs sustainably. The existing buildings' large roofs provide an opportunity for rainwater catchment. For every gallon of beer produced, Rühstaller will need at least three gallons of water - they expect to produce an average of 1 million gallons of wastewater per year (mostly from cleaning). An opportunity exists to reuse this process water for field irrigation[1] (hop fields + drip-irrigated walnut orchard) or other non-potable uses.
- **Organic Waste Management** - A variety of solid organic wastes (i.e. waste biomass) are produced on-site including spent beer grain, hop vines and leaves, grass, walnut hulls and more, creating an opportunity for on-site composting or anaerobic digestion.
- **Packaging Design and Waste Management** - Product packaging and beverage containers also become a waste material that can be better reduced, reused, and recycled.
- **CO2 Capture and Reuse** - Instead of being released into the atmosphere, CO2 can be harvested from fermenters and utilized elsewhere in the brewing process.
- **Agroecology** - Of the nearly 1000 breweries in California, there are only two that grow their own hops - one of these is Rühstaller - and unlike most farms, they own their land instead of leasing land. The property is also surrounded by a 35-acre orchard of young "5th-year" walnut trees, owned by Rühstaller. They want to leave this land better than they found it. This is an opportunity to implement beneficial land management practices, maintain healthy soils, and prevent toxic water or air pollution from pesticides or fertilizers. In the future, Rühstaller may also have animals on the farm like sheep, goats, chickens, and more!
- **Green, Efficient Buildings** - Minimizing water and energy demand from lighting, HVAC, and fixtures/appliances.
- **Sustainable Shipping** - Rühstaller's delivery fleet will grow with the business itself. There may be an opportunity to phase in zero-emission electric vehicles or run on biofuels.

Project Objective

Identify technically feasible and economically viable solutions (technologies, processes, and practices) to maximize the sustainability of Rühstaller's operations to be integrated into a comprehensive roadmap - the Master Plan.

Rühstaller's other wants, needs, and requirements include the following:[2]

[1] The growing season is only 6 months out of the year and this is primary when irrigation water is needed.
[2] Rühstaller is not opposed to sustainability certifications or product labels, but it is not a priority.

- Rühstaller wants to be not just sustainable, but also independently ***self-sustaining*** - they're interested in opportunities to go off-grid and utilize all available resources on-site including water, energy, waste, and more.
- The more **DIY** the better. Rühstaller is a scrappy, resourceful team and they want to be able to design, build/install, operate, and maintain/repair as much as they can on their own. Simplicity over sophistication.
- Rühstaller wants to design systems such that they create an **engaging customer experience**, showcasing Rühstaller as a sustainable brewery and adding to the Rühstaller story.
- Rühstaller is frustrated with the difficulty of finding capable, reliable, and hard-working employees and would like to avoid the need to have to hire any additional staff. Ideal solutions would be passive systems which **minimize labor time** for operations and maintenance.
- The new facility is a clean blank slate and Rühstaller has stated they want to **take advantage of this brief opportunity** to design it sustainably from the start and avoid expensive retrofits later. So, our project should focus on those solutions which would be best built or installed before or during the initial construction.

Project Scope

Due to the limited time and resources available to our team, we were unable to adequately address the full Master Plan as outlined above and narrowed our project scope to focus on specific elements of the Master Plan to investigate at greater depth.

Based on the project objectives stated above, the current resources being allocated towards the Master Plan outside of this project,[3] the areas of expertise of our team, and feedback provided by Rühstaller, we have determined that this project will focus on the following elements of the Master Plan:

- Renewable Energy Generation,
- Process Heating and Cooling,
- Water Resources and Wastewater Management[4], and
- Organic Waste Management.

Conversely, the following elements, as outlined in the background section above, were ultimately not included in our project scope:

- Hop-Kiln Energy Sourcing
- Packaging Design and Waste,
- CO2 Capture and Reuse,
- Agroecology,
- Efficient Buildings, and
- Sustainable Shipping.

[3] Another student team from the ABT 212 001: A Path to Zero Net Energy! Course is doing a project concurrently to ours that is focused on hop-kiln energy sourcing.
[4] One member of our team left the team and project in the middle of the term and so we had to adjust our scope. As a result, we did not fully address the water and wastewater component of this project.

Research Questions

Energy Questions:

- How much of Rühstaller's electricity demand can be met using renewable energy produced onsite? What would it take for Rühstaller to go off-grid and cut the cord with PG&E?
- What is the energy generation potential of Rühstaller's biomass and wastewater? How much of Rühstaller's potential propane usage can they avoid, and what would it take?
- How can Rühstaller shift their power loads to better align with variable renewable supply availability, and what would it take?
- How can Rühstaller store excess energy from non-dispatchable resources in a dispatchable form? What other dispatchable resources can they utilize to fill the remaining gaps between supply and demand?

Water questions:

- How much of Rühstaller's potable water needs can be met with rainwater, and what would it take?
- How much of Rühstaller's non-potable water needs can be met with wastewater reuse, and what would it take?[5]

Methodology

Constraints and Limitations

One limiting factor was the fact that the facility is still in the planning phase; it doesn't exist yet, so any quantitative analysis relied on assumptions and general data from the brewing industry. This is partly what makes it an exciting project; because it hasn't been built yet, Ruhstaller can install innovative, cutting-edge technologies that other breweries may have avoided because they require special equipment or expensive retrofits.

However, the theoretical nature of this operation makes it difficult to provide reliable estimates for capacity requirements, cost, and ROI, so what estimates we have should be taken with a grain of salt. The primary purpose of our analysis is to illustrate the theoretical feasibility of different options so that we can recommend whether an idea is worth pursuing, at which point Ruhstaller should contact contractors directly for specific designs and cost estimates.

Procedure

We started by studying the general brewing process to ensure we had an in-depth understanding of what resources are needed at each phase, and what waste will be generated. We expanded this analysis to encompass all the operations that will take place at Ruhstaller's new location: growing, harvesting, processing, and storing hops; brewing, packaging, and distributing beer; maintaining a taproom for

[5] One member of our team left the team and project in the middle of the term and so we had to adjust our scope. As a result, we did not answer this question.

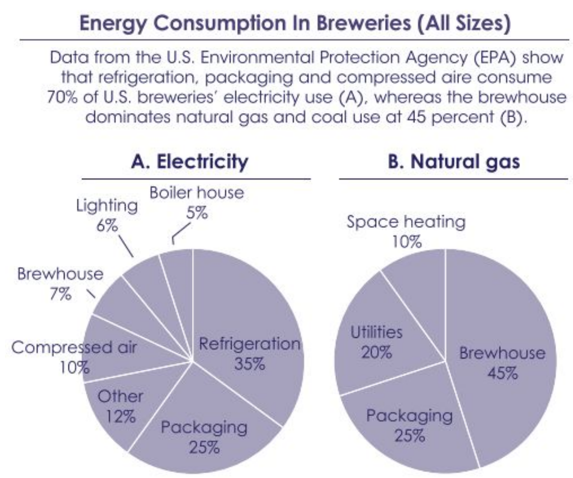
customers; and cultivating the walnut orchard. We identified the inputs and outputs at each step based on interviews with the Ruhstaller crew, supplemented by informational graphics and videos.[6]

Our methodology relied on close communication with our client. We met in person on approximately a biweekly basis, during which time we discussed everything from JE and Xo's philosophy on living in harmony with nature to the technical specs of their water pump. We determined their criteria for which technologies would be a good fit, and brainstormed ideas about potential energy, waste, and water solutions. After meeting, we did further background research based on technical papers, brewery case studies, and speaking directly with suppliers, to refine the ideas and determine whether they were worth pursuing.

Analysis

Electricity and Heat

We used data from the Brewers Association (BA) Energy Manual to estimate Rühstaller's annual electricity and heat demand.



According to the BA, a brewery's average electricity consumption is between 12-22 kWh per barrel of beer produced, and thermal demand is estimated to be 1.3 - 1.5 therms per barrel. We assumed Ruhstaller will be using 22 kWh/barrel since it is a smaller brewery; according to BA, the lower end of the spectrum tends to reflect larger breweries that can take advantage of economies of scale and more efficient processes. Ruhstaller is planning to start by producing 4,000 barrels a year, eventually ramping up to 10,000, so under a business-as-usual scenario we expect their peak consumption to be around 220 MWh/year.

To model how much of their electricity demand could be met by solar, we calculated different scenarios based on what energy usage could feasibly be allocated to daytime hours with mild behavior modifications. The three scenarios were:

1) Assuming all packaging can take place when solar is available, all compressed air, 5 of 7% of the brewhouse electricity, and 65% of refrigeration use solar
2) Assuming 80% of packaging, all compressed air, 50% of brewhouse electricity, and 50% of refrigeration use solar
3) Assuming all packaging, half of other, all compressed air, all brewhouse, half of lighting, half of boiler house, and 70% of refrigeration use solar.

The annual demand for solar capacity was then calculated using the following equation, assuming 3608 sunny hours per year:[7]

[6] Example: First We Feast, 2014
[7] Current Results, n.d.

*[Total annual demand (kWh)] * [% met by solar] / [# sunny hours per year]*

Under scenario 3, which assumes the highest percentage of solar utilization, the max system size is 48 kW. The full results are included in the Appendix. This does not include the water pump, or a solar-powered hop kiln dryer. It should also be noted that this is on an annual basis, rather than reflecting peak demand. The system is therefore likely to have a higher capacity requirement, unless Ruhstaller is able to lower the energy intensity of their beer.

To calculate the potential supply of solar PV, we used NREL's PV Watts Calculator, which simulates the solar energy resource availability for a given location based on latitude and longitude. The results model a 70-kW array on west-facing roof for solar. Wind supply was modeled for a 50 kW turbine with 45m hub height using NREL's System Advisor Model (SAM).

To estimate the payback period and savings-to-investment ratio for PV and solar thermal, we used NREL's FEMP screening map. The calculations for solar thermal assumed an 83% boiler efficiency rate based on the spec sheet JE was provided by Bay City Boiler & Engineering Co., Inc, and a fuel cost of $2.70/therm based on Energy Information Administration data for LPG.[8] The full reports from the simulations are available in the appendix.

Waste-to-Energy

In assessing an on-site anaerobic digester, we estimated the biogas production potential of Rühstaller's waste biomass. We were not able to get sufficient data to estimate the production potential of hop vines and leaves or wastewater, so our results only report estimates for spent grain. From our review of literature we made the following assumptions:[9]

- 20 kg of wet (80% moisture content) spent grain are produced per 100 L of brewed beer
- 1 kg of dry spent grain can produce between .06 - .236 normal cubic meters of biomethane in an anaerobic digester

We then converted this into an equivalent amount in gallons of propane to compare to their estimated heating needs.

Water

Local precipitation data was acquired from yourweatherservice.com.[10] Rühstaller's potential rainwater supply was estimated according to the following equation.

<u>Rainfall Catchment Equation</u>

Catchment Area (ft^2) x Event Rainfall Depth (in) x 0.623 Conversion Factor = Gal of Rainwater Collected

The brewery's water demand was estimated based on industry data from the BA Water and Wastewater Manual.

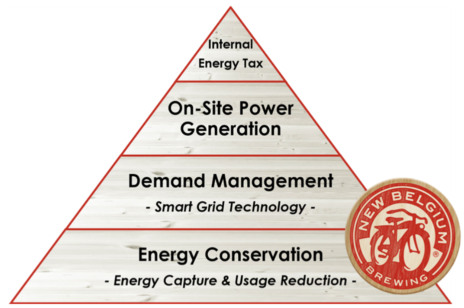
[8] EIA, 2019
[9] Bochmann, Drosg, & Fuchs, 2015; Ivanova et al., 2017; Lynch, Steffen, & Arendt, 2016; Panjičko et al., 2017; Weber & Stadlbauer, 2017
[10] US Climate Data, n.d.

Prior Art/Literature Review

This section describes the different sources we used to inform our analysis and recommendations, and can serve as a reference point if our client wishes to go more in-depth on their own research.

Case Studies

Perhaps due to the common cultural thread that ties microbreweries to environmentally conscious customers, case studies for sustainable and even off-grid breweries at various scales are easy to find. During our initial research, we perused success stories and reports from other breweries to get a sense of what was possible and being done already. Breweries we included during this phase of our project included Goat House (Folsom, CA), Sierra Nevada (Chico, CA), and New Belgium (Fort Collins, CO). We also found examples of truly off-grid breweries, such as Big Thorn Farm and Brewery in Illinois, which is powered through a small solar PV system, 12V marine batteries, propane.[11]



In all cases, the general approach is the same: maximize efficiency, install onsite renewables where appropriate, shut down non-critical loads during peak demand (mainly for larger breweries), and send spent grain offsite to feed cattle. Sierra Nevada and Goat House may be of special interest to Ruhstaller as both grow hops as part of their operations.

As we refined our scope and ideas, we investigated whether specific technologies had ever been used successfully in a brewery setting before, and searched intentionally for solutions to specific challenges. During this phase, we drilled deeper into solar thermal[12] and innovative ways of processing organic waste.

Brewers Association

The Brewers Association (BA) is an American trade group for brewers, suppliers, distributors, and craft beer retailers. They provide information about best practices, government affairs and advocacy, business tools, and resource management. Their "Energy Usage, GHG Reduction, Efficiency and Load Management Manual" was effectively our bible throughout this process, and we recommend that Ruhstaller continue to circle back to this document. It covers everything from electricity and natural gas consumption, to regulatory- and non-regulatory drivers for implementing sustainability practices, to case studies highlighting best practices.

Having an in-depth background on where energy is used in the brewing process and what other breweries are doing was extremely helpful in making suggestions and inspiring ideas for further research. We also

[11] Johnson, 2018
[12] BINE Informationdienst, n.d.

used this information to develop our supply and demand profiles. They have similar manuals on waste and water, but we did not have access to them.

The Brewers Association also offers Craft Beer Research and Service Grants, stating the following as funding priorities for sustainability projects:

- Increase the usage efficiency of energy, water and other natural resources
- Protect the long-term viability of watersheds in which we operate
- Identify and implement more sustainable growing practices
- Identify and implement more sustainable packaging options
- Evaluate the feasibility and effectiveness of less hazardous chemicals and / or process alternatives

If Ruhstaller is interested in turning any of their sustainability initiatives into a research venture, they could partner with UC Davis and apply for funding. BA's website includes past grant awards for examples, and grant guidelines are included in the Appendix of this report.

Technical Papers

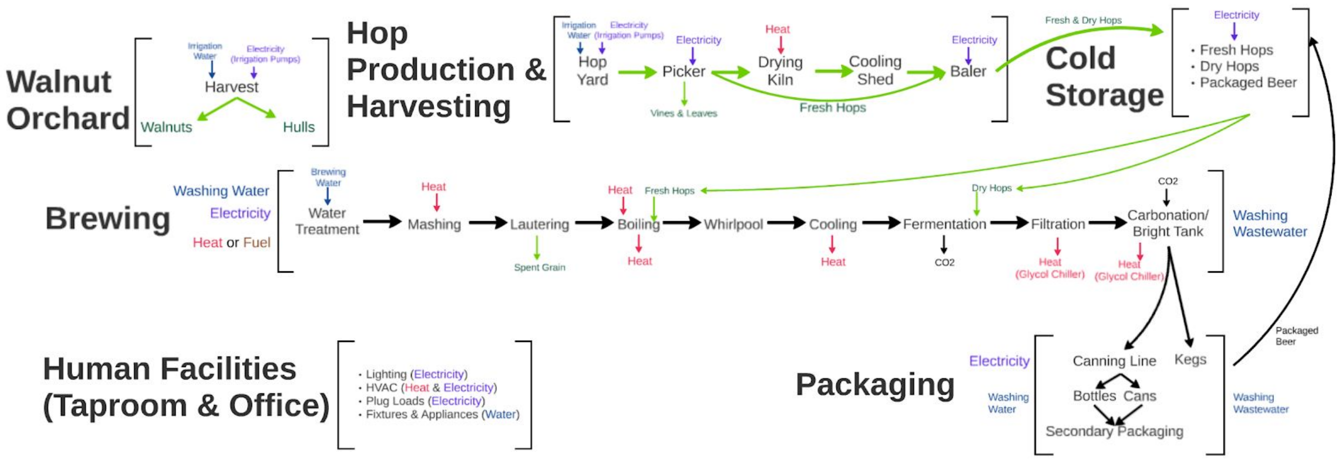
Technical papers were used during this project to complement and verify the information we learned from case studies and the BA, as well as to explore more innovative ideas that aren't commonly implemented at breweries in the US. There have been a number of studies published on energy usage and LCA of the brewing process,[13] wastewater treatment and anaerobic digestion in breweries, and utilizing solar thermal during the brewing process.[14]

We also relied on journal articles to learn about the viability of a few more creative storage technologies, such as small-scale compressed air and micro pumped hydro.[15] Small-scale compressed air is scientifically possible, but still in the research stage. Micro pumped hydro has been shown to be unfeasible economically.

Results and Discussion

Inputs and Outputs Throughout Onsite Operations

[13] Koroneos, Roumbas, Gabari, Papagiannidou, & Moussiopoulos, 2005
[14] Mauthner, Hubmann, Brunner, & Fink, 2014; Schmitt, Lauterbach, Dittmar, & Vajen, n.d;
[15] CHEN, L., ZHENG, T., MEI, S., XUE, X., LIU, B., & LU, Q. (2016)



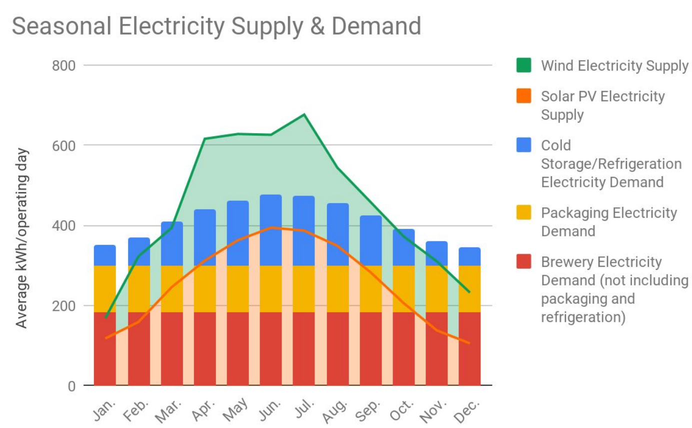
The process diagram above details the material and energy flows throughout the diverse activities that will be taking place on Ruhstaller's new property. The key takeaways are that a significant amount of **organic waste** will be generated from the walnut orchard, hop production, and the brewing process; **heat** is both consumed and produced at different phases throughout the brewing process; **electricity** is mainly consumed for cooling, packaging, and pumping; and **water** will be required for irrigation, washing, and to make the beer.

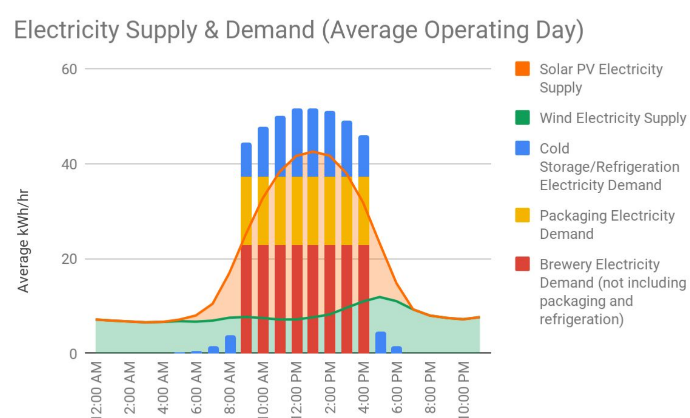
Supply and Demand Profiles

Electricity

The electricity supply and demand profiles show that wind and solar can meet a significant part of Rühstaller's electricity demand, but not all of it always. For better or worse, they will need to maintain their connection with PG&E, especially since they are not interested in batteries as a storage option. Note that these profiles do not include potential electricity demand from well pumping, irrigation pumping, the hop-picker, or the hop-baler.

Most of our conversations have been focused on solar PV since it is more predictable, and we were not able to find a local example of small-scale wind. However, a combination of both would provide Ruhstaller with more consistent renewable electricity. A small wind turbine could provide the electricity for the 24/7 cooling required at a brewery. Further





information on both options is provided in the menu of options.

Ruhstaller will be able to apply a 26% tax credit to any renewable energy system if it is installed by 2021, including solar thermal.[16]

Heat and Fuel

We estimate Rühstaller's heating demand for hop-drying to be about 1,000 gallons of propane, while demand for brewing and packaging is about 8,000 gallons of propane, totaling 9,000 gallons per year. This does not include demand for heating the tap room or other space heating.

Meanwhile, we estimate they will generate about 25,000 kg (or 55,000 lbs or 25 metric tons) of spent grain per year and this can generate the biomethane equivalent of about anywhere between 590 to 2,300 gallons of propane through anaerobic digestion. This is a significant amount, but not enough to completely replace propane. There is additional biomethane potential in their hop vines and leaves as well as their wastewater, but we were not able to estimate these amounts.

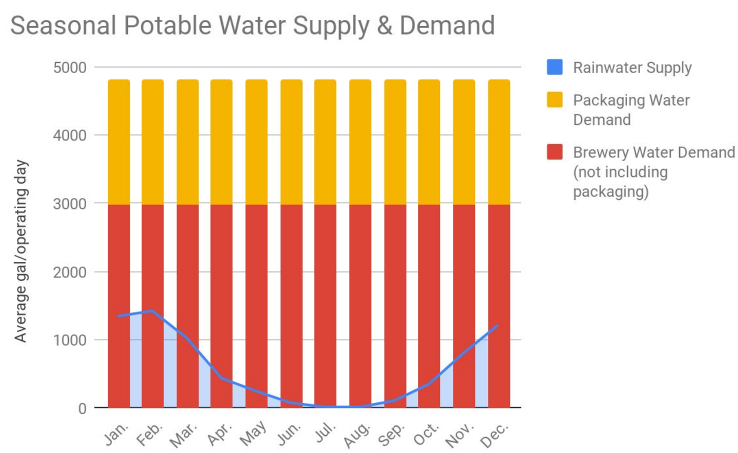
Boilers do exist which can run on both propane and natural gas (i.e., biomethane), but not simultaneously. In the model we found, there are 2 valves but only one should be open at a time while in use.

If Rühstaller wants to utilize biogas in their boiler, but does not want a dual-fuel boiler, they could consider switching to a natural gas boiler. If the biogas supply is insufficient, containerized natural gas may be an option to supplement (this does exist in some markets).

Potable Water

Rainwater can meet about 12% of Rühstaller's annual potable water demand (30% in February), but they will still need to rely heavily on groundwater throughout the year.

A major benefit is that the rainy winter months are also when there is the least sun for solar power. So, taking advantage of the rainwater would reduce the electricity demand from pumping from their wells when there is less solar power available.



Menu of Options

The complete "menu of options" provided as an attachment includes (1) brewery case studies (pilot studies or applied and proven at commercial production-scale), (2) identified contractors, vendors, and service providers, (3) guidance documents, (4) personal contacts (smart people who can answer more of your questions), (5) funding sources & incentives (grants, rebates, and more), and (6) other notes about the specific application of the technology in a brewery setting.

[16] Because they are not connected to a natural gas line, they will not be able to take advantage of California solar thermal tax incentives that are utility-driven.

The following technologies, processes, and practices are ones which we still believe have potential to be a good fit for Rühstaller:

- **Wind Turbines & Rooftop Solar PV** - Wind and solar can meet a significant part of Rühstaller's electricity demand, but not all of it always. Invest in those resources, but without electric storage Rühstaller must maintain its grid connection.
- **Reduce Propane with Rooftop Solar Thermal Heat Generation** - Can be used to either:
  - preheat water (for hot water heater or steam boiler),
  - create superheated water, or
  - create steam.

  This can also be coupled with a "thermal Battery" for dual-purpose water and heat storage.
- **Waste Heat Recovery** - Recover waste heat from throughout the brewing process (boiler or other). Also, if a solar PV system is installed, it can be designed as a "hybrid solar collector" - harvesting heat from the PV panels themselves and increasing the efficiency of the PV system by keeping it cool.
- **Supply-Driven Production** - "If the sun ain't shining and the wind ain't blowin, we ain't brewing..."
- **Rainwater Capture for Potable Use** - Rainwater can meet about 12% of expected annual potable water demand (30% in February), but will still need to rely heavily on groundwater. Rainy winter months are also when there's the least sun for solar power to pump from wells.
- **Biomass to Biogas** - Future partnership with the UC Davis Renewable Energy Anaerobic Digester (READ).

As JE learned at the UC Davis School of Management, "if you have an idea, kill it fast. If you can't kill it, it's a good idea." We discussed the following ideas with the Ruhstaller team, and ultimately *do not* recommend they pursue them:

- ❖ **Gasification** - More ideal at larger scale.
- ❖ **Battery Electric Storage (Second-Life EV Batteries)** - JE concerned about short-term nature of system, but may be an option in the future if they want to truly "cut the cord" .
- ❖ **Hydrothermal Liquefaction** - Unproven.
- ❖ **Microbial Fuel Cells** - Newer tech, apparently failing at other breweries.
- ❖ **Biofiltro** - Too expensive, but may be necessary if the operation is discharging more than 1,000,000 gallons of water per year.
- ❖ **Pumped-Storage in Water Tower** (for night-time irrigation or electricity via hydropower turbine) - Outrageous volume required.
- ❖ **Electric Boiler** - Not powerful enough. Need faster ramp-up time.
- ❖ **On-Site Anaerobic Digestion** - Too sensitive to manage and operate.

Recommendations & Conclusions

There is no silver-bullet solution or one-size-fits-all approach to sustainability. It requires a diverse portfolio of technologies, processes, and practices arranged and integrated in the right way, and continually monitored and managed through an iterative process of designing, testing, learning, and improving. Below is a strategy for Rühstaller to get started on that sustainability journey.

Energy Strategy

Conserve First - The cheapest kWh is the one you never use. A common theme throughout the various case studies and guidance manuals we reviewed is the importance of first reducing the expected energy demand of the brewery, *then* looking to meet that with alternative energy sources. This philosophy has been echoed by numerous guest speakers throughout our Path to Zero Net Energy course. For a brewery, one way of achieving this is by harvesting and utilizing waste heat generated during the brewing process by installing heat exchangers and thermal storage tanks. The BA manual has detailed information regarding equipment efficiency and harvesting waste heat.

Ruhstaller can also minimize their energy demand by incorporating daylighting into their building design, using LED light bulbs, capturing rainwater to limit the need for groundwater pumping, and investing in high-quality insulation for their refrigeration units.

Continue to Explore Solar Thermal - There are two potential ways to incorporate solar thermal into the brewing process, and both should be incorporated into the brewery's design during the planning phase to avoid expensive retrofits later.

The first and easiest is to use standard flat-plate solar water heaters to provide hot water for consumable purposes: namely, pre-heating water before it goes into the mashtun, cleaning bottles and equipment, and washing glasses in the tap room. A similar project was implemented at Lucky Labrador Brewery in Portland, with a calculated cost savings of $179,450 over a 25-year period for a system feeding a 900-gallon hot water storage tank.[17] Under this scenario, a propane boiler would still be required to boil the wort. Since Ruhstaller will only brew two-to-three times a week, extra storage capacity will be required.

The more advanced option is to replace the propane boiler entirely. Commercially available technologies exist that can heat water up to 300F (ErgSol) and even generate steam (Artic Solar). A system that operates on pressurized hot water like ErgSol's would be more efficient, but require brewing equipment with heat exchangers that can use hot water instead of steam. These systems have an added benefit of providing cooling, minimizing the need to draw electricity from the grid at night.

Monitor Energy Consumption - To ensure that they are on track to meet their sustainability goals, Ruhstaller should keep careful track of their energy consumption. One easy way to achieve this is to set up a simple Excel spreadsheet where staff can enter the monthly production, propane consumption, and electricity use (taken from PG&E bill), then calculate the energy intensity of their beer. Not only will this provide useful information as they expand their operations, by making this information visible it can also serve as a way to educate and involve their customers. The BA example is provided in the Appendix.

Install Onsite Renewables - As noted above, solar PV and wind are both good options for Ruhstaller, and they are already working with a local provider to get a cost estimate and system design. However, we recommend they prioritize efficiency and solar thermal first, since these considerations need to be factored into the system design *before* the brewery is built. The primary time constraint for onsite renewable electricity is the diminishing federal incentive, which will decline each year starting in 2019. Rühstaller can maximize their use of solar by making behavioral modifications such as only brewing during the day,

[17] Heliodyne Inc., n.d.

pumping water during the daytime to store and use at night, and compressing air for cleaning and packaging during the day.

Waste-to-Energy

Though we've essentially "killed" the idea of on-site anaerobic digestion (due to the complexity of managing and operating a system), the UC Davis Renewable Energy Anaerobic Digester (READ) is less than 4 miles away and we believe this could be a great partnership opportunity. READ is in the midst of a recovery and ramp up after the previous owners went bankrupt and sold the facility to UC Davis. It remains to be seen whether the new management can turn it into a functional, reliable operation. Their standard tip fee is currently $62/ton, but they've also stated that this is negotiable in some cases. It is possible that Rühstaller can negotiate a better rate because of how clean their waste material is (no packaging or other contaminants).

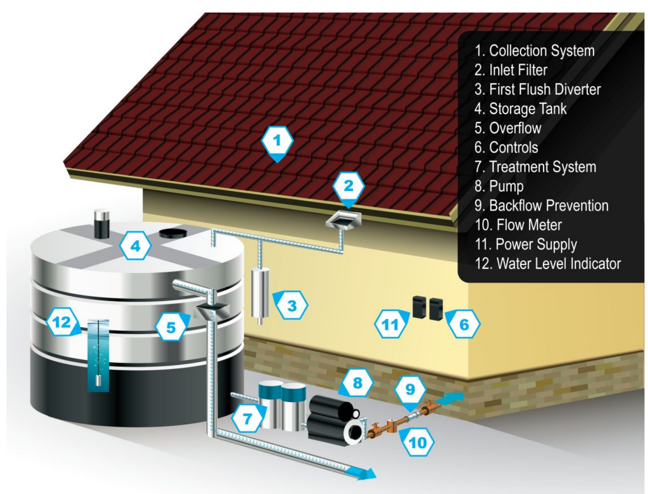
READ is currently producing in a day the amount of fuel (biomethane) that Ruhstaller needs in a year (about 9000 therms). In the future, this could be an affordable source of renewable fuel to displace propane and generate heat and/or power.

Until then, however, keep it simple and just send your spent grain to nearby livestock farms as is common practice in the brewery industry.

Rühstaller should also stay aware of any potential impacts that AB 1826 (Mandatory Commercial Organics Recycling) and the Organic Waste Reduction Goals of SB 1383 (Short-Lived Climate Pollutants) might have on them and their organic waste management requirements in the near future. Additionally, these policies may result in a reduction in the cost of off-site hauling.

Water Strategy

Install a rainwater catchment system (rooftop and/or bioswale). This will meet 12% of Rühstaller's expected annual potable water demand. A major benefit is that rainwater supply will primarily be in the winter months when there is less sun and thus less solar power available for pumping from wells.



Rühstaller should also stay aware of any potential impacts that the CA Sustainable Groundwater Management Act (implemented by the Solano Groundwater Sustainability Agency) might have on them and their water usage in the near future. It's very possible that there may at some point be fees charged for excessive groundwater pumping.

References

American Brewers Association. (2018). *Energy Usage, GHG Reduction, Efficiency and Load Management Manual*. Retrieved from https://www.brewersassociation.org/attachments/0001/1530/Sustainability_Energy_Manual.pdf

BINE Informationdienst. (n.d.). *Hofmühl brewery in Eichstätt*. Retrieved from www.bine.info

Bochmann, G., Drosg, B., & Fuchs, W. (2015). Anaerobic digestion of thermal pretreated brewers' spent grains. *Environmental Progress & Sustainable Energy*, *34*(4), 1092–1096. https://doi.org/10.1002/ep.12110

Brewers Association. (2013). *Water and Wastewater: Treatment/Volume Reduction Manual Energy Usage*. Retrieved from https://www.brewersassociation.org/attachments/0001/1517/Sustainability_-_Water_Wastewater.pdf

Current Results. (n.d.). Average Annual Sunshine in US Cities. Retrieved June 11, 2019, from https://www.currentresults.com/Weather/US/average-annual-sunshine-by-city.php

EIA. (2019). Weekly Heating Oil and Propane Prices (October - March). Retrieved June 11, 2019, from http://www.eia.gov/dnav/pet/pet_pri_wfr_dcus_nus_m.htm

First We Feast. (2014). Learn the Step-by-Step Process Of Brewing Beer, Explained in Animated GIFs | First We Feast. Retrieved June 11, 2019, from https://firstwefeast.com/drink/learn-how-to-brew-beer-with-these-fun-animated-gifs

GoatHouse Brewering Co. (n.d.). GoatHouse Brewing. Retrieved June 11, 2019, from https://www.goathousebrewing.com/

Heliodyne Inc. (n.d.). *CASE STUDY: LUCKY LABRADOR BREWERY*. Retrieved from www.heliodyne.com

Ivanova, K., Denkova, R., Kostov, G., Petrova, T., Bakalov, I., Ruscova, M., & Penov, N. (2017). Extrusion of brewers' spent grains and application in the production of functional food. Characteristics of spent grains and optimization of extrusion. *Journal of the Institute of Brewing*, *123*(4), 544–552. https://doi.org/10.1002/jib.448

Johnson, R. (2018). Their Illinois Farm Brewery is Totally Off-the-Grid. Retrieved April 26, 2019, from https://www.craftbeer.com/featured-brewery/big-thorn-the-illinois-farm-brewery-runs-that-on-solar-power

Koroneos, C., Roumbas, G., Gabari, Z., Papagiannidou, E., & Moussiopoulos, N. (2005). Life cycle assessment of beer production in Greece. *Journal of Cleaner Production*, *13*(4), 433–439. https://doi.org/10.1016/J.JCLEPRO.2003.09.010

Lynch, K. M., Steffen, E. J., & Arendt, E. K. (2016). Brewers' spent grain: a review with an emphasis on food and health. *Journal of the Institute of Brewing*, *122*(4), 553–568. https://doi.org/10.1002/jib.363

Mauthner, F., Hubmann, M., Brunner, C., & Fink, C. (2014). Manufacture of Malt and Beer with Low Temperature Solar Process Heat. *Energy Procedia*, *48*, 1188–1193. https://doi.org/10.1016/J.EGYPRO.2014.02.134

National Renewable Energy Lab. (n.d.-a). FEMP Screening Map. Retrieved June 4, 2019, from https://maps.nrel.gov/femp/?aL=8YxuAg%255Bv%255D%3Dt&bL=clight&cE=0&lR=0&mC=40.21244%2C-91.625976&zL=4

National Renewable Energy Lab. (n.d.-b). PVWatts Calculator. Retrieved June 11, 2019, from https://pvwatts.nrel.gov/

National Renewable Energy Laboratory. (n.d.). Wind Power - System Advisor Model (SAM). Retrieved June 11, 2019, from https://sam.nrel.gov/wind.html

New Belgium Brewing. (n.d.). Living Our Values Everyday - Sustainability. Retrieved April 26, 2019, from https://www.newbelgium.com/sustainability/

Panjičko, M., Zupančič, G. D., Fanedl, L., Logar, R. M., Tišma, M., & Zelić, B. (2017). Biogas production from brewery spent grain as a mono-substrate in a two-stage process composed of solid-state anaerobic digestion and granular biomass reactors. *Journal of Cleaner Production*, *166*, 519–529. https://doi.org/10.1016/J.JCLEPRO.2017.07.197

Schmitt, B., Lauterbach, C., Dittmar, M., & Vajen, K. (n.d.). *Guideline for the utilization of solar heat in breweries*. Retrieved from http://solar-publikationen.umwelt-uni-kassel.de/uploads/2012_EuroSun_Schmitt_Leitfaden.pdf

Sierra Nevada Brewing Co. (2015). *Biennial Sustainability Report*. Retrieved from https://drive.google.com/drive/u/0/folders/1_465xxutYnO_0ckZvJtYvRvX9jMMmc0N

U.S. Climate Data. (n.d.). Climate California - temperature, rainfall and average. Retrieved June 11, 2019, from https://www.usclimatedata.com/climate/california/united-states/3174

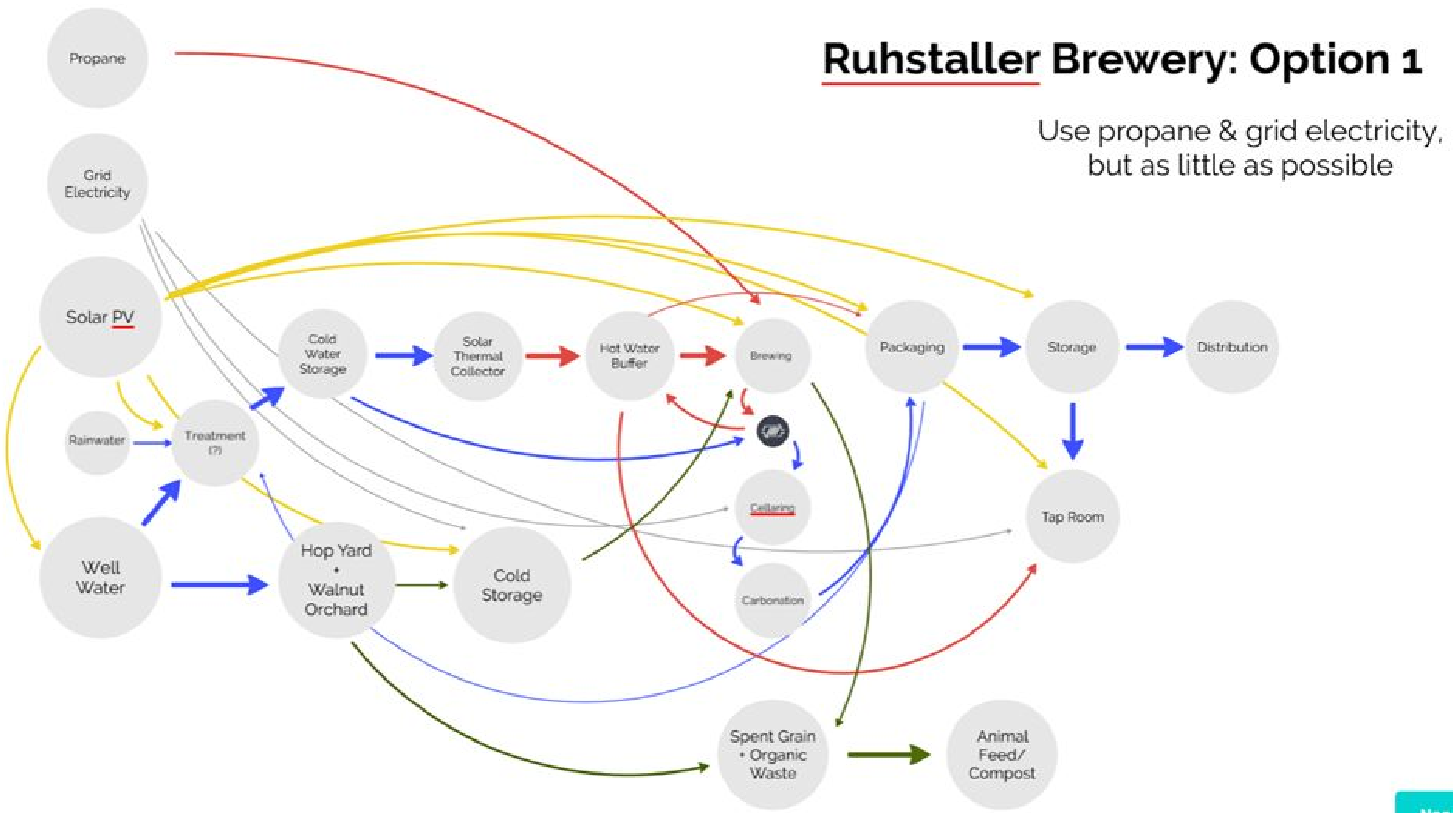
Weber, B., & Stadlbauer, E. A. (2017). Sustainable paths for managing solid and liquid waste from distilleries and breweries. *Journal of Cleaner Production*, *149*, 38–48. https://doi.org/10.1016/j.jclepro.2017.02.054

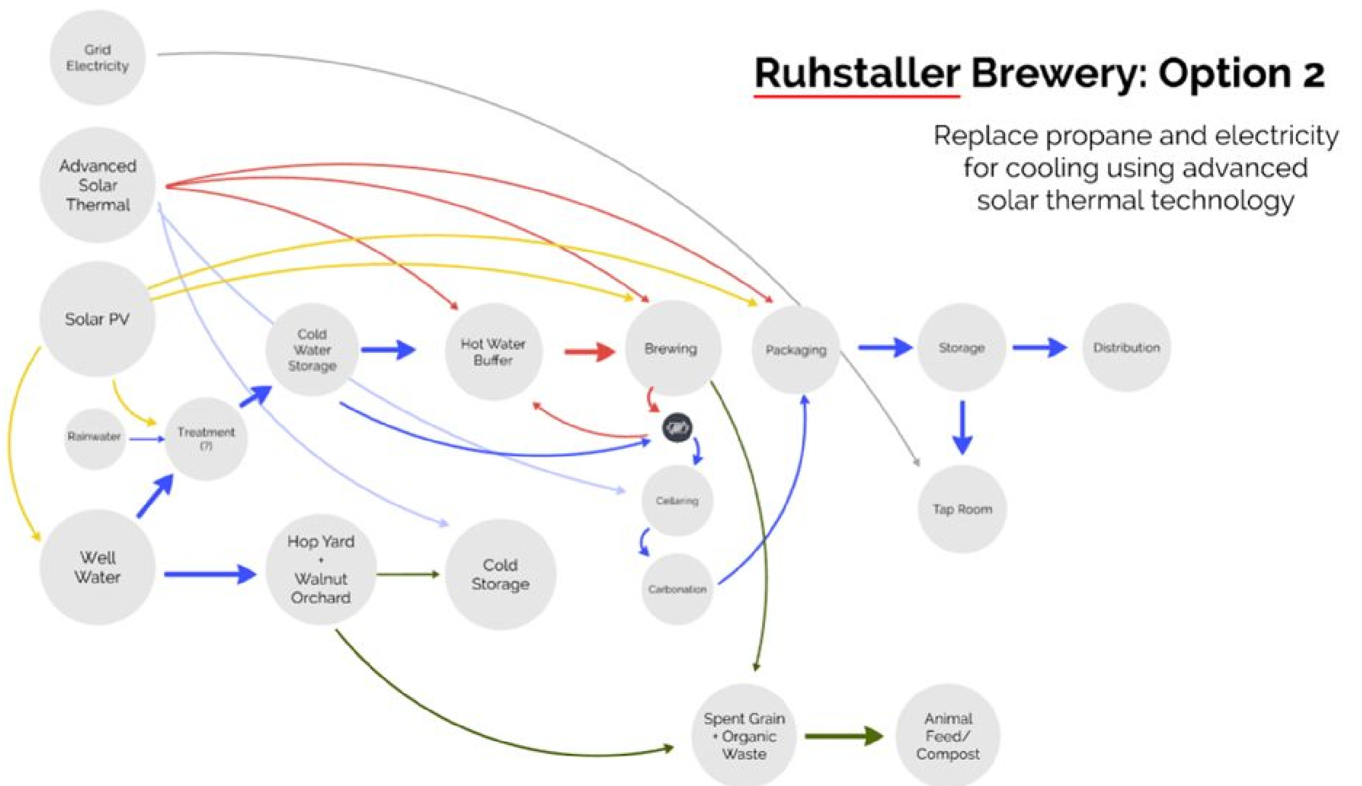
V Malakhova, Dina & A Egorova, Maria & I Prokudina, Ljuba & Netrusov, Alexander & Tsavkelova, Elena. (2015). The biotransformation of brewer's spent grain into biogas by anaerobic microbial communities. World journal of microbiology & biotechnology. 31. 10.1007/s11274-015-1951-x.

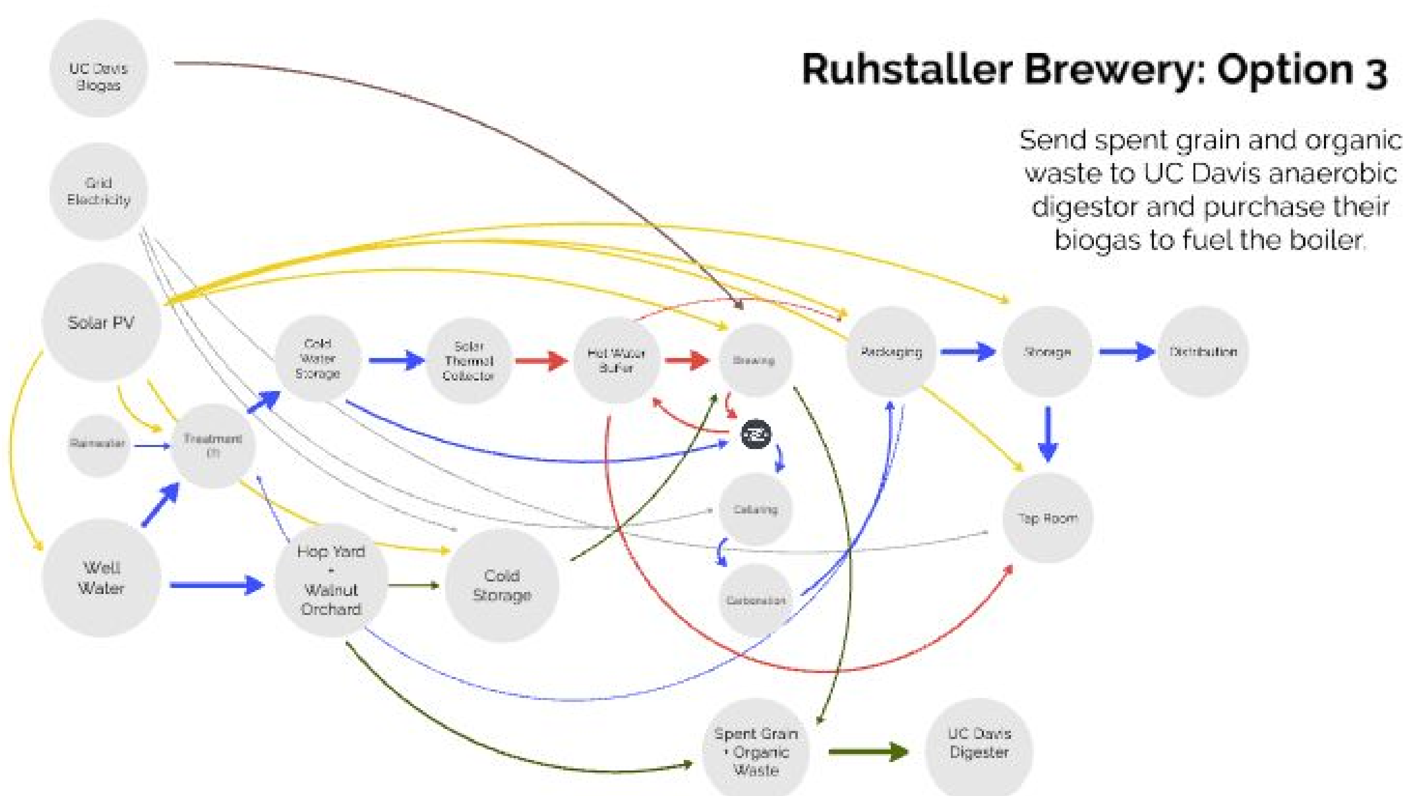
Appendix

1. Conceptual Sustainable Brewery Designs

In order to help our client visualize the process, we made conceptual designs incorporating the technologies we discussed throughout the quarter. The first option represents a system where waste heat recovery, water reuse, and conventional solar hot water are used to minimize fossil fuel use. In the second option, advanced solar thermal replaces propane and minimizes grid reliance for cooling. In Option 3, Ruhstaller sends organic waste to the UC Davis Anaerobic Digester, and uses their biogas to fuel their boiler. Solar thermal is still incorporated to pre-heat process and cleaning water.




Ruhstaller Brewery: Option 2
Replace propane and electricity for cooling using advanced solar thermal technology
Grid Electricity
Advanced Solar Thermal
Solar PV
Rainwater
Treatment (?)
Well Water
Cold Water Storage
Hot Water Buffer
Brewing
Packaging
Storage
Distribution
Tap Room
Cellaring
Carbonation
Hop Yard + Walnut Orchard
Cold Storage
Spent Grain + Organic Waste
Animal Feed/ Compost


Ruhstaller Brewery: Option 3
Send spent grain and organic waste to UC Davis anaerobic digestor and purchase their biogas to fuel the boiler.
UC Davis Biogas
Grid Electricity
Solar PV
Rainwater
Treatment (?)
Well Water
Cold Water Storage
Solar Thermal Collector
Hot Water Buffer
Brewing
Packaging
Storage
Distribution
Tap Room
Cellaring
Carbonation
Hop Yard + Walnut Orchard
Cold Storage
Spent Grain + Organic Waste
UC Davis Digester

2. Solar capacity requirement based on annual output

Electricity demand (kWh/bbl)	Annual output (bbl/yr)	Total annual demand (kWh/yr)	% met by solar	Annual System Requirement (kWH)	Capacity Requirement (kW)
22	4000	88000	0.6275	55220	15.30
22	6000	132000	0.6275	82830	22.96
22	8000	176000	0.6275	110440	30.61
22	10000	220000	0.6275	138050	38.26
22	4000	88000	0.51	44880	12.44
22	6000	132000	0.51	67320	18.66
22	8000	176000	0.51	89760	24.88
22	10000	220000	0.51	112200	31.10
22	4000	88000	0.78	68640	19.02
22	6000	132000	0.78	102960	28.54
22	8000	176000	0.78	137280	38.05
22	10000	220000	0.78	171600	47.56

3. Complete NREL FEMP pre-screening report

Ruhstaller Hop Farm & Brewery (Lat: 38.486920, Lon: -121.837006) Thu May 30 2019

Introduction

This renewable energy (RE) pre-screening assessment tool (http://maps.nrel.gov/femp (http://maps.nrel.gov/femp)) was funded by and conducted on behalf of the U.S. Department of Energy's (DOE's) Federal Energy Management Program (FEMP) in support of U.S. Federal agencies' use of renewable energy technologies in accordance with the Energy Policy Act of 2005 (EPAct 2005), Executive Order (EO) 13423 and the Energy Independence and Security Act of 2007 (EISA 2007).

The objective of this analysis is to provide a high-level assessment of the expected economic performance of commercially available renewable energy technologies. These results provide a basis for determining whether further investigation of the feasibility of any technology is warranted.

Pre-screening Inputs and Results

A summary of the technology calculation inputs are presented in Table 2. Default values are italicized, and user-speci ed values are in bold. Default values are drawn from geospatial databases (renewable resource values, annual electricity rate) and from values reported by FEMP in the “Distributed Generation Renewable Energy Estimate of Costs” page (http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html (http://www.nrel.gov/analysis/tech_lcoe_re_cost_est.html)).

Table 1. Input Performance and Cost Functions

PV Inputs

Annual Elec. Rate ($/kWh)	.26
System Size (kW)	50
System Cost ($/kW)	3463
Present Worth (years)	34.426
Solar Resource (kWh/m2/day)	5.8
Annual Elec Delivered (kWh/yr)	1820.32
Fixed O&M ($)	19

SHW Inputs

Annual Natural Gas Rate ($/therm)	2.7
Natural Gas Efficiency Rate (0-100%)	80
System Cost ($/kW)	162
Present Worth (years)	34.426
Solar Resource (kWh/m2/day)	5.8
Annual NG Delivered (therm/yr)	157.40
Fixed O&M (0-100%)	0.5

The economic analysis assumes that the renewable energy technologies are purchased directly and are owned and operated by the site. There are other procurement options for renewable energy, such as Power Purchase Agreements (PPA) and Energy Services Agreements (ESA), whereby the renewable energy systems are owned and operated by a third party who sells the renewable energy to the end-user; in this case, the federal agency. These alternative nance options allow for non tax-paying entities to bene t from available tax credits and accelerated depreciation schedules that would otherwise not apply. As a result, alternatively nanced projects can sometimes yield a lower cost of renewable energy depending on the project size and the available tax credits and incentives. If the results from this analysis show promise for a particular technology, it is recommended to investigate the alternative nance options as part the procurement strategy.

For each technology, three result parameters are calculated: savings-to-investment ratio (SIR), payback period, and the LCOE needed to reach a SIR = 1. These values are reported in Table 1, and provide different ways of gauging the economic viability of the technology relative to the input parameters. For SIR, values below 1 are uneconomic, and values of 1 and above are economic. For payback period, values above the assumed present worth value are uneconomic (will take longer than the desired investment period to pay back investment cost), and values at or below the assumed present worth value are economic. The electricity rate for SIR = 1 is a calculation of the levelized cost of energy (LCOE) needed to reach economic viability, and is compared to the annual electricity rate assumed in the analysis.

Table 2. Calculated results of the economic analysis by technology

	PV	SHW	Reference Value
SIR	3.96	77.05	1
Payback Period (years)	7.6	0.4	34.4
Electricity Rate for SIR=1 ($/kWh)	0.07	0.04	0.09

The pre-screening results for Ruhstaller Hop Farm & Brewery (Lat: 38.486920, Lon: -121.837006) are represented graphically in Figure 1 for the electricity rate to reach SIR = 1. The vertical bars represent ranges of levelized cost of energy (LCOE) for each technology necessary to reach a SIR of 1, based on varying the system cost +/- 25%. By comparing the calculated value to the assumed electricity rate of the site, the assessment of the economic viability of that technology can be seen.

If the site electricity rate falls below the technology's vertical bar centerpoint, the technology assessment result is uneconomic using the current assumptions; if the site electricity rate is above the centerpoint, the technology result is economic using the current assumptions. The vertical bar gives a sense of the impact of system cost change by technology on the comparative results.

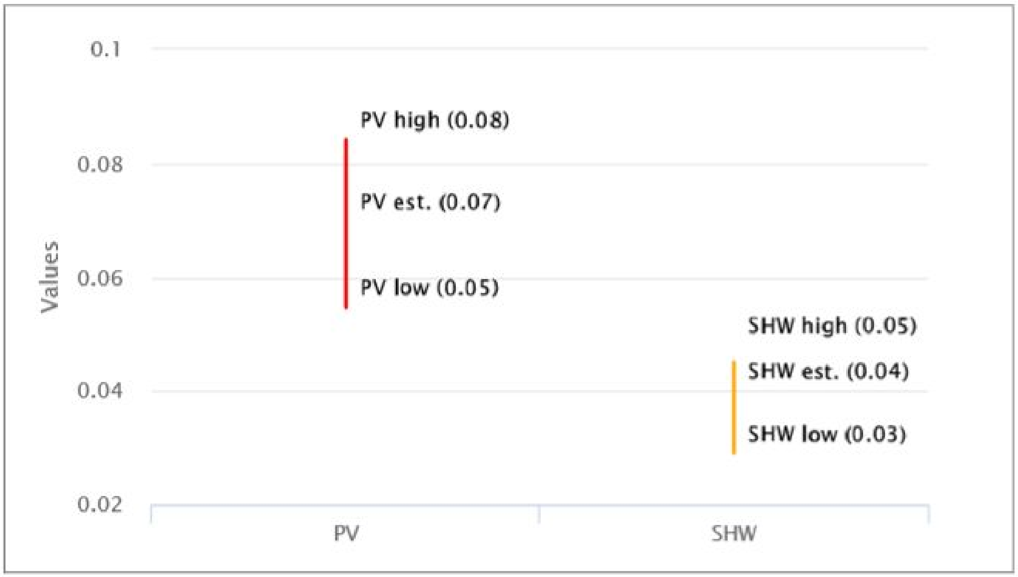


Figure 1. Chart of Expected Ranges of LCOE

Supporting Information

Context: Renewable Energy Project Cycle

Figure 2 illustrates the renewable energy project development cycle and the stage when the pre- screening analysis is performed. The pre-screening is the rst due diligence step in development of a RE project. The planning phase involves progressive levels of analysis that support decisions on whether to expend further resources on RE project feasibility investigation or project development.

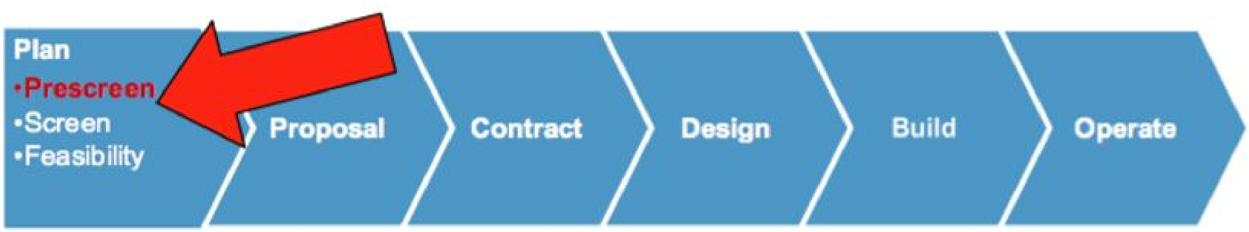


Figure 2. Renewable Energy Project Process

Methodology

The calculations are based on a simpli ed economic formula that is manipulated to solve for SIR, payback period, and the electricity rate to achieve a SIR of 1. While there are some minor variations for some technologies, broadly they follow this format:

SIR = (Annual Elec Delivered [kWh]* Present worth [yrs] * annual average electricity rate [$/kwh]) / (System Cost [$] + (Lifetime O&M [$]))

Payback Period = (System Cost [$] + Annual O&M [$]) / (annual average electricity rate [$/kWh] * Annual Elec Delivered [kWh])

(Electricity Rate for SIR = 1) = (System Cost [$] + Lifetime O&M [$]) / (Annual Elec Delivered [kWh] * Present worth [yrs])

If incentive values are entered by the user, site-based values are subtracted from the system cost, and production based incentives are subtracted from electricity rate.

Further Information

The results of this report can be used to gain support for investment in further analysis. Additionally, FEMP offers limited support services to Federal agencies for renewable energy project development. Please visit the FEMP website (www.eere.energy.gov/femp (www.eere.energy.gov/femp)) for more information.

For questions about the results, methodology or assumptions used to generate this report or to discuss options for further assistance regarding renewable energy project development, please contact:

Email: fempta@ee.doe.gov

4. Sample energy tracking sheet

Tracking example

The example in Section 2.2 established an average energy intensity ratio of 58kWh/BBL using the short-term goal of 4.5% reduction. A new monthly target can be established and used to track progress towards the goal.

FY2012

Item	January	February	March	April	May	June	July	August	Septem-ber	November	December	Totals
Electircal kWh	40,000	45,000	39,000	39,500	50,000	50,000	40,000	35,000	40,000	42,000	30,000	450,500
Fuel kWh	90,000	92,000	80,000	75,000	72,000	73,000	72,000	65,000	67,000	75,000	85,000	846,000
Total Energy kWh	130,000	137,000	119,000	114,500	122,000	123,000	112,000	100,000	107,000	117,000	115,000	1,296,500
Barrels Produced	2,000	2,200	1,800	2,000	2,500	2,500	2,000	1,800	2,000	2,100	1,600	22,500
Energy Intensity KPI (kWh/BBLs produced)	65	62	66	57	49	49	56	56	54	56	72	58

FY2013

Item	January	February	March	April	May	June	July	August	Septem-ber	November	December	Totals
Electircal kWh												
Fuel kWh												
Total Energy kWh												
Barrels Produced												
Energy Intensity KPI (kWh/BBLs produced) Actual												
Energy Intensity KPI (kWh/BBLs produced) Monthly Target	62	59	63	55	47	47	53	53	51	53	69	55

Source: BA Energy Guide