Catenary Kitchen

**Narrative, Technologies, Input/Outputs, and Materials**

In this landscape with a dearth of trees, a designer interested in using local materials lacks one of the most obvious and commonly used tensile materials in construction, wood. Cultures from the dawn of permanent settlement on have encountered a lack of forest cover whether through natural circumstance or by their own landscape degradation, and long before modern materials their longest lasting solution was the compressive arch.

As we the designers observe the impacts of industrialised society, we find that most modern materials have secondary impacts and emissions as well as sourcing ethics issues. The amount of CO2 that is emitted in the production of concrete and steel, on average one and two tons respectively per ton produced, causes us to look to reduce the use of these as much as possible in our efforts to enclose space.

While tensile solutions reign in terms of material efficiency, developments in the arch continued well into the early period of architectural modernism especially in Catalonia where designers like Antoni Gaudi and builders like Raphael Guastavino learned and improved on a long and well developed masonry tradition. You likely know of the celebrated architect Gaudi and his opus, the Sagrada Familia that refined the shape of the arch into a catenary, a perfect reflection of the shape of chains hanging down under various loads.

Less common is the knowledge that Guastavino and his descendants are responsible for vaulting many if not most of the grand projects of the late nineteenth and early twentieth century in eastern North America. His secret was patenting some of the techniques he was taught in Catalonia, namely vaulting without the need for a supporting formwork and accomplished this cost saving measure by vaulting first from the corners of the space using light, often hollow bricks and a fast setting mortar before adding other more permanent structural courses above and a decorative course below.

We chose a combination of these two ideas to enclose a space that starts with a low roof that you can step on covering a cistern. As the roof sweeps gently upward it provides the space to contain a system of equipment designed to provide power through the dual means of batteries and combustible hydrogen fuel. We have no need for the form of the resulting structure to adhere to what is presented. Instead, the form should respond to the needs and desires of the community and it should grow larger as the uses it supports do. This way each successive course of bricks becomes a decision on how fast to expand (or contract) the width and height of the structure, which way to turn it, and when. Its narrow and low base should serve as a wellspring of energy for buildings in the form of electricity, heat, cooking power, and refrigeration and be located wherever the community wants to collocate other projects like food production, housing. In our modeling we felt drawn to the Geyser and to the Setting sun in colder months. We oriented the tail due north and maintained a gentle slope, so the walls of the building are accessible from above.

No iteration of the building is intended to stay bare. Instead, as the building is built the complex sides are intended to provide varying levels of solar exposure and wind protection for existing and future needs, like for the location of the 2m x 3.3m of solar panel for the proposed hearth system, or to provide varying levels of sun/water/surface area/shade to complement a diversity of food choices and strategies. Another desire of the designers not flushed out in the design is to eventually see the structure partially buried with arable soil so as to begin integrating the structure more completely into the landscape, or alternatively to intensify and optimise food production around the structure. These adjacent use aspects of the project are inspirational and not covered any further within the scope of this submission.

Instead we are focused only on initially building the structure only so big as to enclose our prototype technological process and a small, sheltered area in which to cook and provide refrigeration. Depending on available funds, this could mean the construction of a reduced or slightly modified set of the technologies shown.

The system we have organised consists of a minimum of 4 standard solar panels and a small chemical battery storage unit. These power a 1HP motor which drives a water pump that brings the water pressure up to 700 BAR because it is more efficient to compress water than hydrogen. Electrolysis is then conducted on the water. This level of compression results in about 200 kWh fitting in 5 m3 of tank. For a system of this size, half the hydrogen in pressure or volume, or even less should be sufficient to provide a large amount of on demand energy. The design also stores the oxygen in order to reintroduce it in combustion to avoid the production of nitrous oxides. For cooking a gas stove is modified for use with hydrogen fuel while a turbine is modified to produce electrical power, a by product of which is heat. Alternative to a turbine, a fuel cell could be used instead, providing for a more efficient electric energy transfer if the heat is not a desirable by-product; however, this type of transfer is more likely to occur in the cold months of the year or at night when extra heat may useful. Finally, the system powers a refrigerator for keeping food and for freezing water.

This design has the primary purpose of supporting cooking and food storage throughout the year as well as providing a reservoir of potential energy that can be balanced between both electrical and combustible form. With high pressure tanks, the system could also be used to fuel hydrogen powered vehicles.

Once this purpose has been met, the design is able to expand to provide proper enclosure for cooking, eating, warmth, and eventually for group activities as the enclosed space eventually grows to full size and begins to support ancillary projects on the site.

The system’s two main inputs are water and solar energy, and the three main outputs are water, electrical energy, and thermal energy. It is possible to output trace amounts of nitrous oxide but by keeping the oxygen as well as the hydrogen from electrolysis, this is nearly zero.

Another stream that comes from use of the system is food waste. The system does not produce it directly, instead, the food waste is generated through use of the facilities. It is a larger aspiration of the project to support food networks and regeneration, however, they are outside of the scope of this submission.

The primary material used in the design is earth dug from the immediate area of the building. This will be mixed with a clay binder, If available on site, or less than 10% plaster of Paris or Portland cement. The bricks will be formed or pressed in such a way as to have coffering or material otherwise scalloped of thinned out to reduce weight and material. The prototype section will be about 3 metres by 5 or six metres total in size. The full building if completed in the same form as portrayed would be up to 14 metres by 40 metres at its widest dimensions.

**Conceptual Cost Estimate**

Hydrogen and Oxygen tank: 4000 USD

10 kWh chemical battery: 2500 USD

~2 kW of solar panels: 6000 USD

Turbine: 2000 USD

700 Bar water pump: 1000 USD

1hp Motor: 150 USD

Fridge: 500 USD

Stove: 500 USD

Portland Cement: 150 USD

Brick Form: 50

Pipes and Fittings: 300 USD

**Total: 17 150 USD**

**On-Site Strategy**

Our strategy is to bring with us some preliminary work on forming strong and light bricks from various materials while trying to minimize the environmental costs of the ingredients.

Once on site we will confirm our initial explorations with the local soil and then begin forming bricks to be sun dried as we dig out a pit within our foundation for a cistern.

We will then prepare the cistern walls and provide load bearing surfaces for installing both the equipment and the arch. We may need to dig foundations or decide to hammer short piles to support the catenary arch over the equipment. Foundations and cistern walls will be made using bricks or rammed earth in order to maximise the use of the underlying soil itself as the substrate for reinforcement.

Once the floor is prepared, we will begin vaulting, increasing in height and width from a small base to encompass the equipment. We will run a pipe from the nearest appropriate water source. We will then install the equipment, ending with the appliances on the large opening side of the vault, recessed enough to protect the appliances from the elements. Any further enclosure of space will proceed from there.

**Environmental Impact Assessment**

The environmental impact of the project can be broken down into three portions for simplicity: construction impacts, operational life impacts, and decommissioning impacts.

Because of the superior strength and permanence of Portland cement, the designers have identified a need of up to 10% binder in their construction material. While this represents a 90% reduction in CO2 impact as opposed to more liberal use of cement mixtures, this is the main Impact of the structural solution on the environment.

The equipment used to create the described system is made of a complex set of components. While this assessment will not identify all specifics, many of these components could have adversely impacted the environment in their production. The solar panels for example, would have required a number of rare earth elements to create, likely at least partially coming from areas with ongoing environmental degradation as a result of extraction. It is important to consider using parts that are long lived and highly repairable. Replacing repairable components leads to a much higher operational life impact than necessary.

The impact on the landscape exists but is mitigated by the fact that the site is already a disturbed area. An opportunity exists to create a positive impact by integrating the building into the environment over time and allowing the natural environment (or human cultivation) to grow over the building’s sloping faces.

A potential negative impact is leaking or leeching, or other transfer of chemicals related to the battery or solar panels. Some of the elements in these systems can be harmful and good maintenance and inspection is required to minimize impacts.

The facility can be used as a source of power for fuels and other vehicles. It should be noted that there are possible environmental impacts from increased and repeated operation of motorized vehicles. While these vehicles would not emit GHG, they can still give off particles like rubber, metals, paints, fluids, and oils. These will not disappear with green fuels.

Once the equipment in the facility is decommissioned, it needs to be appropriately handled and recycled in order to minimize both the impacts of waste on the environment as well as the impact of mining virgin materials when unnecessary.

The structure, once ultimately demolished, should not negatively impact the area. It should only be noticeable by some small bits of old cement scattered around the demolition.