**KADMON** *(1470 words + 286 numbers in tables)*

**Project concept.** KADMON **conveys the energy of light** to the land and people of Fly Ranch in the most direct way. Exploring ‘light’ took us to physical, human, and metaphysical realms; symbolically hinting to concepts of light in Western and Eastern cultures. Thus the project became a multilayered message in itself, a hub of energy and meanings.

KADMON assumes **no single identity** but connects to the cultural landscape of the land and people, their history and knowledge, as well to the heritage of guests and residents. All cultures have a myth of the beginning of time and light, the evergreen story always in front of us independent of our differences.

KADMON attempts to explore past the colloquial notion of sustainability into **deep ecology:** a wisdom of humility and receptiveness. It calls for transformative collaboration between people and projects and for contemplation within.

Physically KADMON receives, concentrates, stores and transmits solar energy directly converted into high temperature heat for several projects. It is able to fully cover energy needs of the ONION banya and further provide for a communal bakery/kitchen, heating and agricultural projects. It employs an open-interface concept for future projects and the energy hub can be easily scaled up. Thus KADMON targets topics of ‘shelter’ and ‘energy’.

On the human level, KADMON collects sunlight and warmth for gatherings in the Vessels. The versatile structure is set up to operate year long for many years.

At the core, KADMON speaks to our desire of alchemy and meaning. KADMON means ‘primordial’ and invites us to explore the connection between light and time through the notion of timelessness, immediacy and radiance.

Beyond Fly Ranch, we hope to demonstrate the ethical use of technology: making us more human. In many traditions, food, water and steam heated by the celestial light were believed to be medicinal. Enabling this efficiently and artfully will inspire others. Finally, we believe that the Gerlach community and beyond would benefit from a multipurpose communal space attracting guests.

**Vessels.** The communal spaces of KADMON are called ‘Vessels’: four dome-shaped structures partly interconnected, open but sealable, heated using the accumulated energy. The amphitheatre-like design of the central Vessel accommodates larger gatherings of 70 ppl, allowing the space to be used in a versatile manner, but guarding the sanctity of the light infused space. Two adjacent spaces provide for smaller groups up to 10-15 ppl each. Another detached Vessel takes the next step of separation and privacy. Uses are multifold: conferencing, lecture, theatre or concert, reading, or even sleeping or stargazing. As a vehicle of transformation, KADMON invites us to recognize the sacred in everyday life.

KADMON is a harmony of opposites: Vessels shaped as moving rocks or the pulsating chambers of the heart, solid but changing shape due to ellipsoid geometry; topped by bright moving Spheres looking still from afar. The central Vessel deploys reflective lamellas to maintain a core of bright light in the center of the space.

The Vessels are semi-translucent spaces, covered by a double PE+PVC membrane on steel frames. The central Vessel measures 15х15х9m, adjacent heated Vessels are 9x6x3.5m and 7x5x3.5m, the standalone Vessel measures 6.4x4.3x3.5m. Resilient structure makes Vessels operational all year round. Three of the Vessels host spherical reflectors at 4.8m height, supported by additional frame and foundation.

**Basic technology.** KADMON heat generation deploys concentrated solar power technology with heat storage (CSP/HS): the most efficient high-temperature heat technology for the environment of Fly Ranch with conversion efficiency of 60-80%. A properly insulated heat capacitor exceeds 95% efficiency for multi day storage, making KADMON a reliable source of heat independent of weather. For high-temperature heat generation, CSP/HS outperforms PV+Li-Ion in terms of cost, lifecycle, environmental impact:

|  |  |  |
| --- | --- | --- |
| HTH generation, Fly Ranch | LCOE, c/kWh | Social cost of carbon (@$50-$100/ton), c/kWh |
| Wood | 6.8 | 1.80-3.60 |
| Propane | 8.9 | 1.17-2.34 |
| PV Solar (20 kWt mixed, +1.5h battery) | 13.7 | 0.23-0.46 |
| PV Solar (15 kWt mixed, +4h battery) | 28.5 | 0.45-0.90 |
| PV Solar (solo array, 6 kWt + heat storage) | 10.5 | 0.10-0.20 |
| **Concentrated solar thermal (20 kWt mixed use)** | **13.6** | **0.05-0.10** |

Basic technology for CSP is off-patent and widely used. Most engineering systems are available at the needed scale. We purposefully suggest to apply CSP in a novel way:

* proving efficiency and scalability of a small scale CSP/HS;
* heat-as-a-service: pre-installing heat/steam circuit integration in capacitors;
* setting a precedent of running a banya (sauna) fully solar;
* creating unique aesthetics of spherical reflectors.

**Reflectors.** Placed above the Vessels, the 2.65m inner diameter Spheres are dual axis tracker-enabled Fresnel reflectors able to concentrate 80x-100x suns to heat an inflammable heat transfer fluid (HTF). Reflector is a sphere made of coaxial aluminum ring-shaped mirrors, total weight of 350-400 kg, net weight about 70 kg.

The reflectors are balanced, allowing the tracking system to operate under 20Wt. Compared with parabolic systems, ring shaped lamellas decrease wind and snow load, simplifying the support system. Lamellas can be shaped differently while maintaining optical properties.

**Controls, heat capacitors and heat distribution circuits.** There is a technical compartment in the standalone Vessel for controls and pumps. HTF heat exchanger distributes the harvested heat into 400-600l insulated tanks filled with scrap glass and sand or salt. The secondary heat circuit distributes HTF to desired applications. We specifically designed the system to fully substitute the need for propane for steam generation for the ONION banya, occasional floor heating and cooking/baking, however other projects can plug in as well for both high-temperature (300-350c) and low-temperature heat. Estimates for pumping and type/amount of HTF would need to be adjusted in that case.

There are various widely available HTFs for CSP applications; we envision using a non-flammable low-viscosity HTF as the project is small scale and in direct proximity to shelter.

**System inputs and outputs.** KADMON generates around 20 MWh usable heat energy p/a, peak power 20 kWt. ONION Banya requires about 55 kWh per session, heated Vessels about 3 kWt each:

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Month | CSP harvest kWh/m2 per day | Full system harvest, KWh per day | Generated useful thermal energy, kWh per day | Energy coverage for 1/daily ONION banya |
| Jan | 2934.6 | 46.7 | 32.7 | 59% |
| Feb | 3566.7 | 56.8 | 39.8 | 72% |
| Mar | 4912.1 | 78.2 | 54.8 | 99% |
| Apr | 5337.0 | 85.0 | 59.5 | 107% |
| May | 5858.0 | 93.3 | 65.3 | 118% |
| Jun | 6385.1 | 101.7 | 71.2 | 128% |
| Jul | 6884.7 | 109.7 | 76.8 | 138% |
| Aug | 7004.4 | 111.6 | 78.1 | 141% |
| Sep | 6803.7 | 108.4 | 75.9 | 137% |
| Oct | 5620.5 | 89.5 | 62.7 | 113% |
| Nov | 3616.2 | 57.6 | 40.3 | 73% |
| Dec | 2840.1 | 45.2 | 31.7 | 57% |

The heat capacitor can be built to separately produce high- and low-temperature heat, depending on applications.

The outer surface of the Vessels is over 300m2 of waterproof membranes, and could optionally harvest rainwater and dew.

Major system input is electricity for pumps, trackers and light, total estimate 4 kWh per day of operation, no power needed in idle state. We expect to provide electricity with auxiliary solar panels already at Fly Ranch or from future projects.

**Materials.** Local stone, concrete, steel and membranes are used for the Vessels; aluminum and steel for Spheres; scrap glass, local sand and salt for heat capacitors. Membranes and aluminum for reflectors can be manufactured locally or abroad. Most of the structure can be assembled on site; no large-scale shipment is needed. All materials but HTF are estimated to last for 15+ years.

**Maintenance.** KADMON requires simple maintenance with minimal replaceable parts. Every 3 months HTF levels need to be checked, as well as reflectors’ traction motors and moving parts. Reflective surfaces should be cleaned of dust every 1-3 months using steam cleaner (reusing the generated steam) or self-cleaning electrodynamic film.

**Safety.** The Vessels and Spheres are estimated to be stable enough under the climate conditions of Fly Ranch. Main risk to mitigate is fire safety. Most system components are sealed and designed for HTF, except for heat receptors in reflectors. The HTF used in the system is a non-flammable composite. The Vessels’ membranes are fire retardant, additionally protected by steel funnels under reflectors. Exits from the Vessels are designed to allow people to leave the space fast enough in case of emergency.

**Cost assessment.** Conceptual cost estimate for KADMON is 250-400k USD, including contingency and overhead:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Material & Direct Labor estimate | m/m2/m3 | ft/ft2/cu.ya/ton | USD per unit | Material | USD per unit | Labor | Total |
| **Construction** |  |  |  |  |  |  |  |
| Steel pipe 2in | 322 | 1063 | 7 | 7,438 | 5 | 5,313 | 12,751 |
| Steel pipe 1.5in | 634 | 2092 | 6 | 12,553 | 4 | 8,369 | 20,922 |
| Steel pipe 3.5in | 365 | 1205 | 15 | 18,068 | 8 | 9,034 | 27,101 |
| Membrane (SF 502 S2 / W96 / Airtex / PE+PVC) | 704 | 7040 | 3 | 21,120 | 3 | 21,120 | 42,240 |
| Concrete foundation | 10 | 11 | 120 | 1,370 | 7 | 80 | 1,449 |
| Amphiteatre step stones 1ft (per ton) | 10 | 15 | 500 | 7,345 | 500 | 7,345 | 14,690 |
| Other foundation boulders (per ton) | 48 | 71 | 100 | 7,051 | 50 | 3,526 | 10,577 |
| Safety steel panels | 67 | 670 | 4 | 2,680 | 6 | 4,020 | 6,700 |
| Wooden deck | 62 | 620 | 25 | 15,500 | 5 | 3,100 | 18,600 |
| Hydronic floor heating | 70 | 700 | 10 | 7,000 | 3 | 2,100 | 9,100 |
| **TOTAL, USD** |  |  |  | **100,125** |  | **64,006** | **164,131** |
|  |  |  |  |  |  |  |  |
| **Solar & Engineering** |  |  |  |  |  |  |  |
| Reflectors and supports | 3 |  | 6000 | 18,000 | 1500 | 4,500 | 16,500 |
| Pumps and controls | 1 |  | 15000 | 15,000 | 5000 | 5,000 | 20,000 |
| Heat storage | 1 |  | 1000 | 1,000 | 1000 | 1,000 | 2,000 |
| Tubes | 40 |  | 40 | 1,600 | 50 | 2,000 | 3,600 |
| HTF | 1 |  | 1000 | 1,000 |  | 0 | 1,000 |
| **TOTAL, USD** |  |  |  | **36,600** |  | **12,500** | **49,100** |
|  |  |  |  |  |  |  |  |
| **Prototype (1 Vessel + Reflector + engineering)** |  |  |  |  |  |  |  |
| Construction |  |  |  | 18,625 |  | 12,381 | 31,006 |
| Engineering |  |  |  | 25,620 |  | 8,750 | 34,370 |
| **TOTAL, USD** |  |  |  | **42,045** |  | **21,131** | **65,376** |

**Prototype.** The simplest prototype would prove the path from gathering light to generating steam in the banya, as well creating a prototype of the communal space. Building the separate Vessel with 1 Sphere (6.5 kWt peak) and most of the engineering including the ONION steam circuit would achieve that. The overall budget for the prototype (ex design and shipment) would range between 55-75k USD. The project could be executed within 2021, as most systems and materials are available off-the-shelf.

**> Environmental assessment** *(202 words)*

**Overall.** KADMON is designed not only to reduce human impact on environment, but to showcase carbon-negative technologies applied in a novel way. The project produces no waste and requires no consumables.

**Carbon footprint.** By deploying a heat capacitor, carbon footprint of the system per kWh generated is expected to be better than that of any PV system using battery. KADMON would require additional source of electricity which is outside of the scope of the project, expecting a collaboration with a sustainable power generation project.

**Other emissions.** Reflectors, motors and pumps emit no light or noise, except for Vessels lighting throughout night and sky reflected in the Spheres.

**Wildlife impact.** Reflectors are positioned high enough to prevent all wildlife but birds to access them. Studies show that small scale CSPs rarely harm birds, as opposed to heliostat-based CSPs. KADMON’s reflectors’ frame additionally prevents avian contact with the heat receiver.

**Life cycle impact.** We mostly avoid using rare earth materials or materials with complicated logistics chains, except for motors, controls, pumps and specialty tubes. Heat capacitors reuse waste glass. All materials can be reused or safely utilized once decommissioned. There are no possible pollutants except for HTF liquid/oil for the case of disaster.