Wazoku Crowd Challenge Name: **Reducing Fossil Fuel Dependency of Syrian Irrigation Systems**

Solution: **Using Solar Energy Storage Setup to Reduce Fossil Fuel Dependency of Syrian Irrigation Systems**

Solution Abstract

The use of various alternatives to traditional fossil fuel should provide an affordable and stable energy supply for irrigation systems. However, the use of solar panels is associated with overcoming a number of disadvantages, the main one of which is the complex technical design of the solar panel - current controller - accumulator battery - electric water pump system. Failure of any element will lead to the failure of the entire system and the cessation of water supply to the irrigation system, and repairs may require a long time and the involvement of specialists. Therefore, the development of a simple and reliable system with high maintainability in the field is the main task in the development of an alternative Syrian Irrigation Systems. Obviously, in hot cloudless terrain, the sun is a constant and reliable source of energy. However, the radiant energy of the sun can be used not only for direct generation of electricity using solar panels, but it can also be stored and stored as heat. Everyone knows that if you use lenses and concentrate the sun's rays with lenses, then the temperature in a hot spot can reach 650-800 degrees Celsius. Therefore, it is proposed to use concentrated solar rays to heat a heat accumulator to a temperature of 350-400 degrees Celsius and store energy in this accumulator for using daily and overnight.
To convert the thermal energy of the heat accumulator, it is proposed to use a simple Stirling engine, which converts heat directly into work. In this case, a power of 20-30 kW can be achieved, which is quite enough to pump water from a well into an irrigation system for watering 20-30 hectares of agricultural crops.
Let's consider the proposed system in more detail.

Detailed Description of the Solution

Let us consider the proposed technical solution in more detail. As already mentioned above, it is proposed to store solar energy in a heat accumulator. Its diagram is shown in Fig. 1. The heat accumulator is a steel box filled with two tons of sand. The sand is heated by the sun's rays and acts as a heat accumulator and gives off heat to the Stirling engine cylinder, ensuring its continuous operation both during the day and at night and pumping water from the well to the fields. For this purpose, a frame filled with Fresnel lenses is located in the upper part of the heat accumulator. The sunlight shines from above onto the Fresnel lenses and is concentrated in hot spots on the surface of the sand. In this case, the surface of the sand, for better heat absorption, is covered with sunlight acceptor - a black pigment - iron oxide, which accumulates sunlight well. In this case, the temperature in the hot spots reaches 650-800 degrees Celsius. From the hot spots, the heat spreads deep into the sand volume and heats it to a temperature of 350-400 degrees Celsius. The steel box is insulated from the environment with mineral wool, so heat is not lost. The accumulated heat heats the cylinder of the Stirling engine and thus sets it in motion. And the water pump, which pumps water from the well, is set in motion by the Stirling engine as well.
As mentioned above, Fresnel lenses are proposed to be used as sunlight concentrators. Their appearance is shown in Fig. 2. As we can see, the advantage of such lenses is their flat shape, which allows them to be laid out in an even layer in a frame above the sand surface. At the same time, Fresnel lenses work the same way as regular lenses, effectively concentrating sunlight into a hot spot (Fig. 3). It is necessary to use lenses made of borosilicate glass, since we have high temperatures and polymer lenses are not suitable.

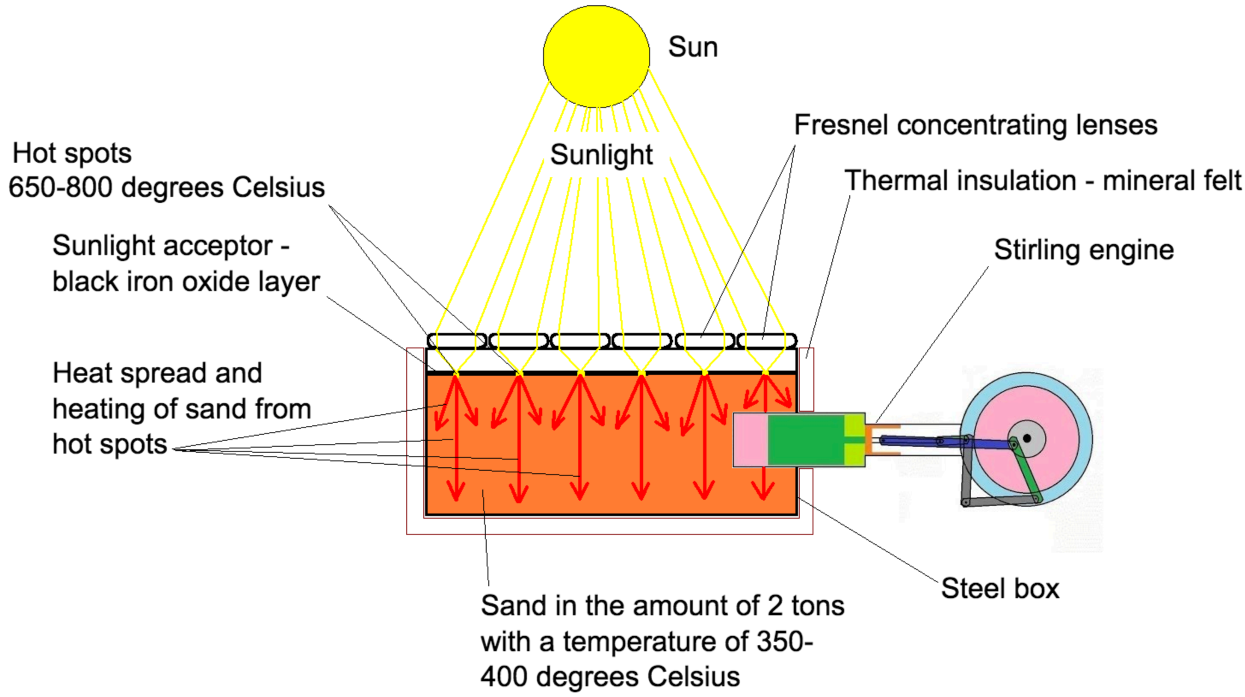

Figure 1. Schematic of heat accumulator with interconnected Stirling engine.

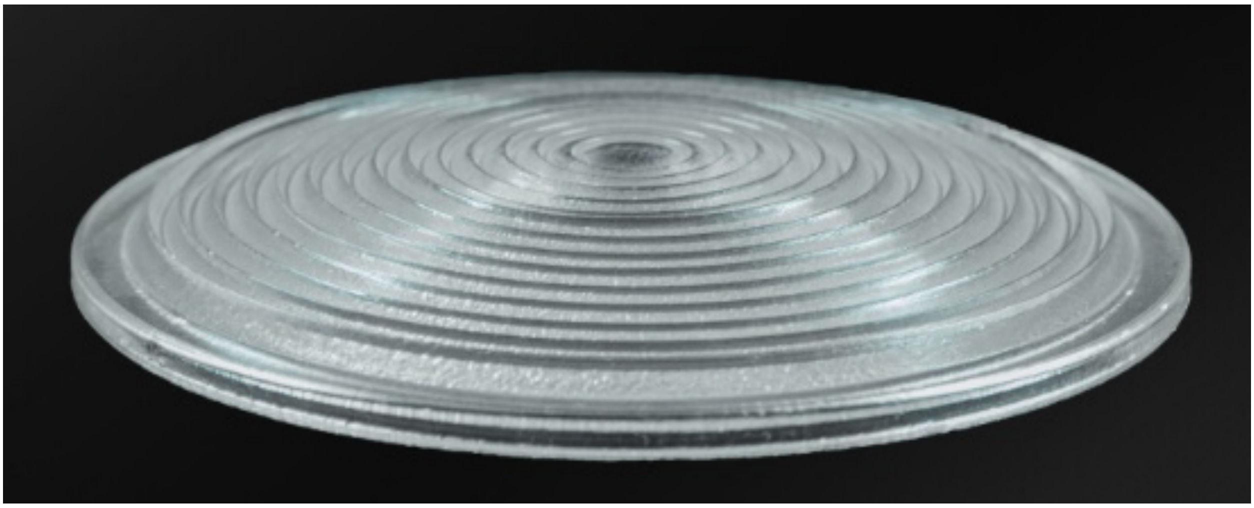

Figure 2. Appearance of Fresnel concentrating lens.

Now let's estimate the cost of manufacturing a heat accumulator. First of all, it should be noted that there is no need to follow strict drawings. The volume of the heat accumulator is about 1.5 m^3 to accommodate about 2 tons of sand. The metal box itself can be made of any suitable metal - for example, old fuel or oil barrels. The most expensive part is the Fresnel lenses. It is assumed that 100 Fresnel lenses with a diameter of 150 mm will be used for one heat accumulator. The cost of one Fresnel lens is about $3 from the supplier from reference [1]. Thus, the cost of 100 Fresnel lenses will be $300. Fresnel lenses should be installed in a frame of 10 by 10 lenses. Thus, the size of the heat accumulator will be 1.5 by 1.5 meters, in length and width, and its height is 1 meter. It is simply installed on the ground without a foundation. In this case, it is first necessary to lay thermal insulation (Fig. 1). The best option is to use mineral wool or felt. It is also possible to use construction waste mineral felt or slag to reduce the cost of the heat accumulator. Also, the steel box should be insulated from the sides by covering with felt or filling with slag. The cost of the steel box itself, made from waste, can be estimated at $100 including sand, thermal insulation and small amount of black iron oxide which is used as sunlight acceptor (Fig. 1).

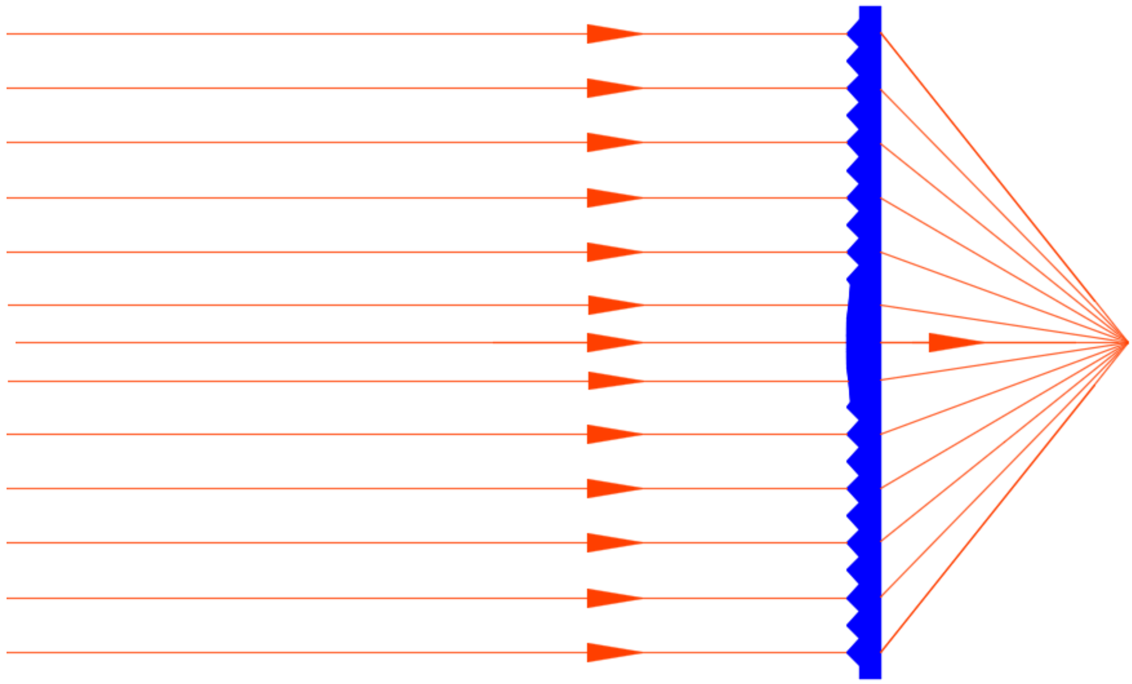

Figure 3. Sunlight collection with Fresnel lens.

Thus, the total cost of the heat accumulator will be about $400-500.

Now let's look at what the Stirling engine is, which is proposed to be used for pumping water from a well to the fields.

Stirling engine works according to thermodynamic Stirling cycle. The Stirling cycle (Fig. 4) consists of four phases and is divided by two transition phases: heating, expansion, transition to a cold source, cooling, compression and transition to a heat source. Thus, when moving from a warm source to a cold source, the gas in the cylinder expands and contracts. At the same time, the pressure changes, due to which useful work can be obtained. Heating and cooling of the working fluid (sections 4 and 2) is performed by the displacer.

Ideally, the amount of heat given off and taken away by the displacer is the same. Useful work is performed only due to isotherms, i.e. it depends on the difference in temperatures of the heater and cooler, as in the Carnot cycle.

When implementing a Stirling engine in our conditions, the main thing is the simplicity and cheapness of the design. Therefore, we will use the simplest β-type Stirling engine. Its working cycle is shown in Fig. 5.

1. An external heat source heats the gas at the bottom of the heat exchange cylinder. The pressure created pushes the working piston up (the displacement piston does not fit tightly to the walls).
2. The flywheel pushes the displacement piston down, thereby moving the heated air from the bottom to the cooling chamber.
3. The air cools and compresses, the working piston moves down.
4. The displacement piston rises up, thereby moving the cooled air to the bottom. And the cycle repeats.

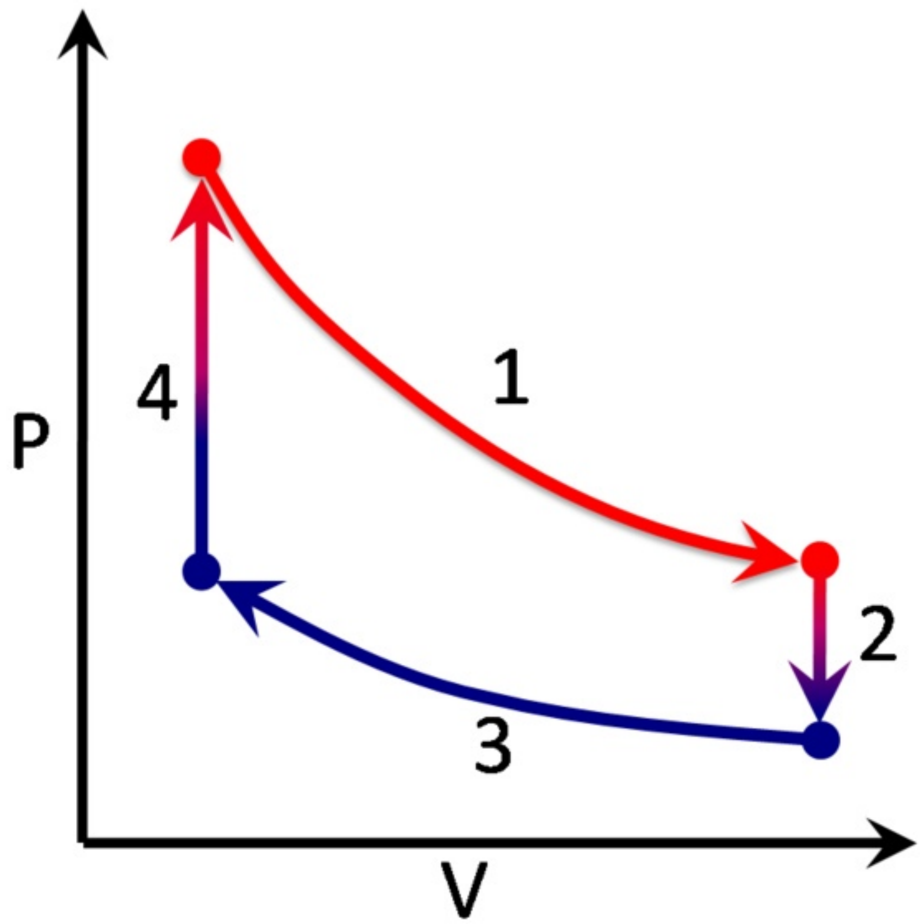

Figure 4. Thermodynamic Stirling cycle.

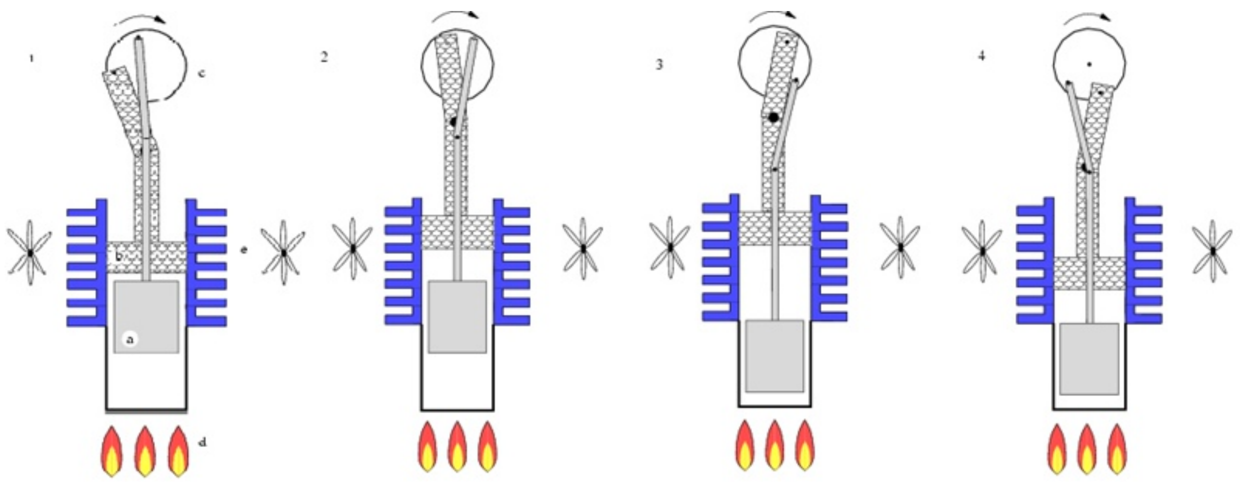

Figure 5. Working cycle of the β-type Stirling engine: a — displacement piston; b — working piston; c — flywheel; d — fire (heating area); e — cooling fins (cooling area).

In a Stirling machine, the movement of the working piston is shifted by 90° relative to the movement of the displacer piston. Depending on the sign of this shift, the machine can be an engine or a heat pump. At a shift of 0°, the machine does not produce any useful work. [2]

As mentioned above, such an engine can be easily assembled from improvised means - pipe cuttings, pieces of metal, parts from car engines. At the same time, the cost of the assembled engine will be minimal. However, it is necessary to provide some calculations that will set the necessary parameters and dimensions of the assembled Stirling engine.

The required shaft speed is 1200 rpm;

Manufacturing quality: handicraft, from improvised means;

Air temperature in the heater: 350 degrees Celsius (equal to the temperature of heat accumulator);

Air temperature in the refrigerator: 65 degrees Celsius;

Diameter of the working piston: 300 mm;

Stroke of the working piston: 1 m;

Average air pressure in the cycle: 2 bar

Estimated engine power: 20 kW

This will be quite enough to pump water from a well 100+ m deep for the irrigation system of fields.

The proposed design is extremely simple. The working small prototype of the proposed design is shown in Fig. 6 and can be purchased on Amazon according to reference [3]. It is proposed to implement the same design only on a larger scale as a big device.
Let's try estimate the cost of such a Stirling engine made from metal waste. It can be estimated at $300-400.

Thus, the total cost of the heat accumulator and the Stirling engine will be $700-900, which fully satisfies the necessary Technical Requirements.

In this case, it is proposed to connect the water pump directly to the Stirling engine. This will make it possible to completely avoid breakdowns of electrical parts, because they are absent in this device. This device is completely mechanical and can be easily repaired with improvised tools even by an unskilled worker. This device is cheap and reliable and can be easily implemented within a few months.

The proposed technical solution can be attributed to TRL = 6, because there is a laboratory prototype (Fig. 6). In addition, Stirling engines have been studied sufficiently, so this solution can be implemented immediately. The novelty of the proposed solution lies in the combination of the widely known and simple in design Stirling engine with a heat accumulator of an original design. In principle, if necessary, round-the-clock operation of such a system without stopping is possible, since the heat in the accumulator can be stored for several days.

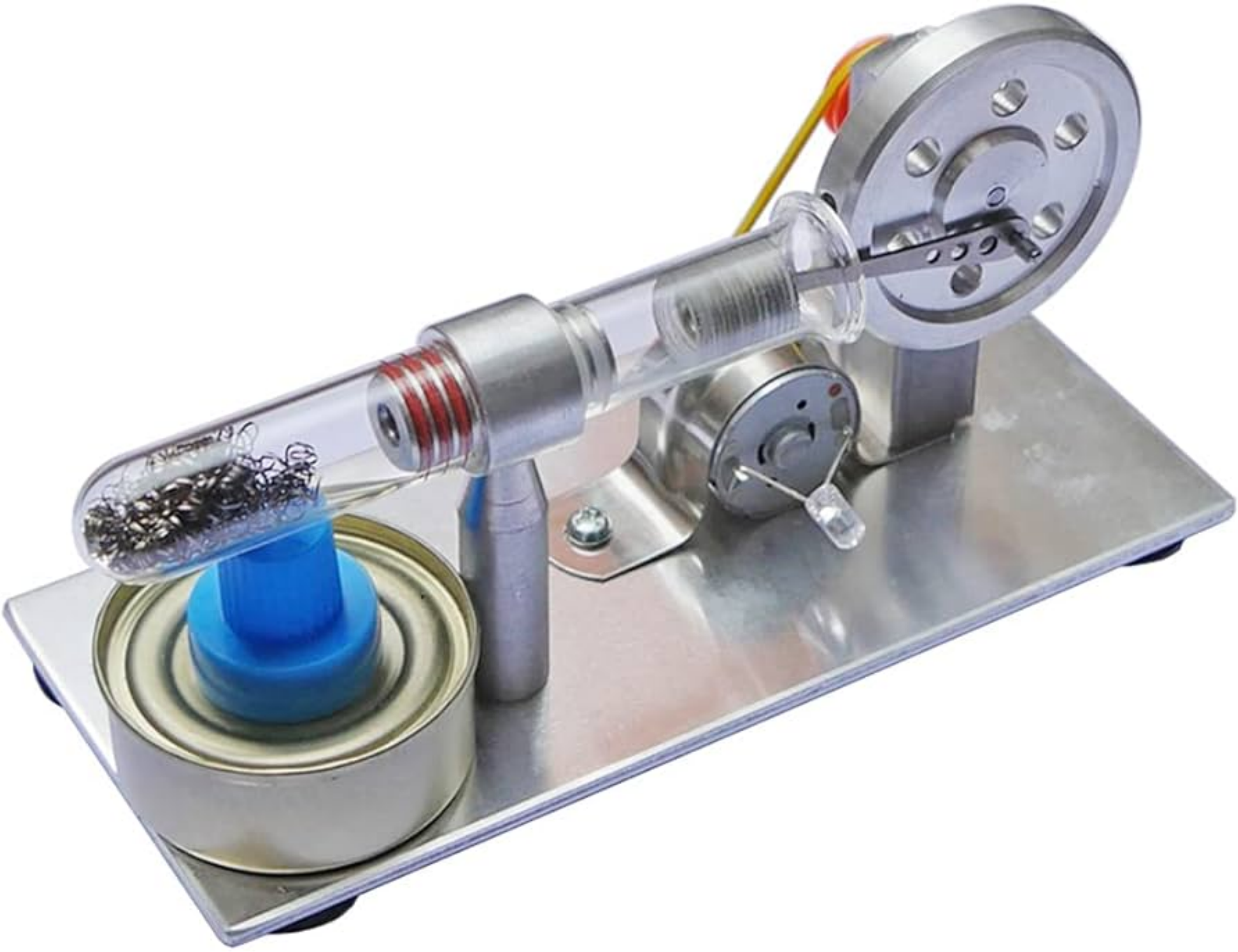

Figure 6. Small prototype of the proposed Stirling engine for irrigation system.

Conclusion

It was proposed to use the energy of the sun, stored as heat in a heat accumulator of an original design together with the well-known Stirling engine as a mechanical drive for a pump for pumping water from a depth of 100+ m to the fields for an irrigation system for watering 20-30 hectares of agricultural crops. The cost of such a system is **$700-900**, power is equal to **20 kW** and this system can be easily implemented within few months. It uses the energy of the sun and thus it reduces fossil fuel dependency of Syrian irrigation systems.

References

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