# Mechanize Solar in Desert

### The Solar/Hydrogen Pathway

There are different methods of reducing $CO_2$, each of which are referred to as a "pathway". Each has their advantages and disadvantages, especially with respect to different geographical regions. For example, Nevada might favor solar; whereas Toronto might favor hydroelectric dams.

One method of reducing $CO_2$ is to generate electricity at a solar farm and use a portion to create hydrogen gas ($H_2$). $H_2$ can later be burned like we burn natural gas ($CH_4$), to create heat and to power vehicles. The big difference is $H_2 + O_2 = H_2O$; and $CH_4 + O_2 = CO_2$. In other words, hydrogen is like natural gas, yet without the $CO_2$ greenhouse gas. Hydrogen can be placed into tanks, which resolves the issue of storage for when the sun is not shining. A variation is to create ammonia ($NH_3$), which is easier to store and transport than $H_2$ gas, yet still burns after being "cracked" into N and $H_3$.

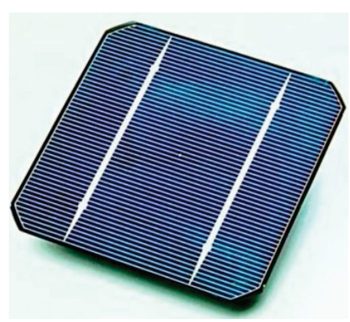
Powering vehicles with hydrogen instead of electricity resolves the following issues: (a) no longer need to obtain significant amounts of EV related rare earth materials at reasonable cost, (b) charging many EV's at one time requires rebuilding the electrical grid between power plant and home, and (c) EV charging is sometimes inconvenient.

The disadvantage of the solar/hydrogen pathway is cost. Generating hydrogen via electricity is expensive. If we could reduce this cost via innovation, then this pathway would be more feasible.

### Covering 25% of Nevada with Solar

The US currently consumes ~4K TWhr of electricity each year. Also, the US burns a similar amount of gasoline in vehicles, and burns a similar amount of natural gas for heat and processing. In other words, if we triple electricity generation from ~4K to ~12 TWhr/yr, and use this for transportation and heat, we could stop burning gasoline and natural gas. And, if electricity was generated without emitting $CO_2$, we could decarbonize the US. If we do the math on how much solar is need for ~12 TWhr/yr, it works out to coating ~25% of Nevada with solar PV material. This is enormous and expensive, and does not resolve the storage problem, yet is one possible decarbonization pathway.

### Solar Cells are Cheap



Let's begin by looking at the cost of an actual solar cell. This is a thin 5" x 5" x 0.01" device that converts light to electricity, and cost approximately $0.12 per watt. If one of these produces electricity for 20 years in a sunny region and you dispose of it after 20 years, the cost for the electricity attributed to the initial cost is $0.005 per KWhr ($0.005 = $0.12 / (0.707*5*365*20/1000)). The average US residence is currently paying approximately 20 times more for generated electricity. In other words, the 0.01 inch thick cell themselves cost less than 5% of the cost of electricity.

## Metal, Glass and Cement

Solar farms place panels above ground and this involves a significant amount of metal and glass, and the occasional cement for foundations. These materials cost money. Yet perhaps more importantly, their fabrication requires heat, and heat requires energy. Steel is fabricated at 2600°F, aluminum at 1200°F, glass at 2600°F, and cement at 2500°F.

## Wind and Snow Drives Material Requirements

Wind pressing on a surface exerts a force and that increases with the square of the velocity. For example, 50mph exerts 11 LBs-per-square foot (psf) and 100mph exerts 44psf. If a 100mph wind presses against a 6 x 6ft surface, for example, then 1800LBs presses against that surface (1800 = 50 x (6 x 6)). Panels are designed to handle snow loads as well. In many cases, weather is not so bad, yet handling the worst storm in 100 years requires a lot of material. In summary, material is heat is energy is $CO_2$.

## Transformational Research

Every now and then a transformational innovation occurs that has a big impact on how we do things. An example is the LED light bulb that replaced the incandescent bulb and caused energy consumption from light to drop 7-fold. Before this occurred, no one could imagine this would happen, yet happen it did.

We will look at placing solar in deserts since this land is plentiful and is free of hailstones. No hailstones means we can work with plastic instead of glass. Products made out of plastic and silicon exist, an example of which is shown below. This Sunpower product is 2mm thick and is just as efficient as your ridged flat solar panel.

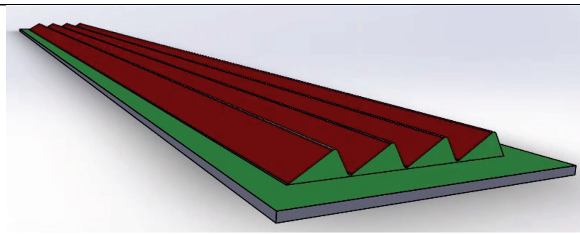

## Rollable Solar


In theory, one could make large pieces of flexible solar in the ~2m x ~100m size range, roll them up (e.g. ~2.5m diameter), and place them into a canister for transport. This is similar to what we did with analog film -- pictured to the right for younger readers.

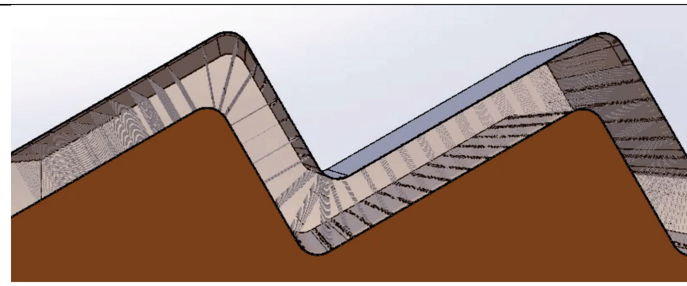
### Solar Direct to Soil

The soil could be shaped with earth moving equipment as needed. For example, one could create rows that point toward sun. To hold the top solar layer in place, a flat underground anchoring layer, ~0.3m below ground, could attach to the above layer via many ~1.5mm diameter metal links. The below ground anchoring layer might be wire mesh embedded in plastic as well. Wire mesh is only ~0.25Kg per square meter (1.5mm diameter, 2.5cm squares, steel), it cost little (e.g. \$0.50/$m^2$), and is very strong. In other words, strength would probably not be an issue. Wind creates pressure which applies a force on the top solar layer. This system would transfer that load to the weight of the soil between the two layers. The good news is this might reduce cost and reduce material usage. The bad news is multiple R&D challenges, as discussed below.

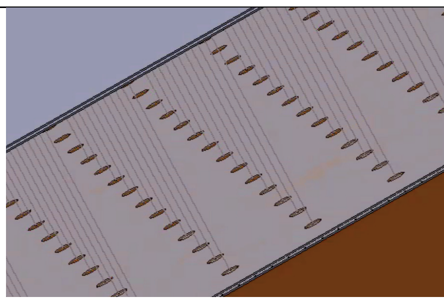
One possible approach is detailed below.



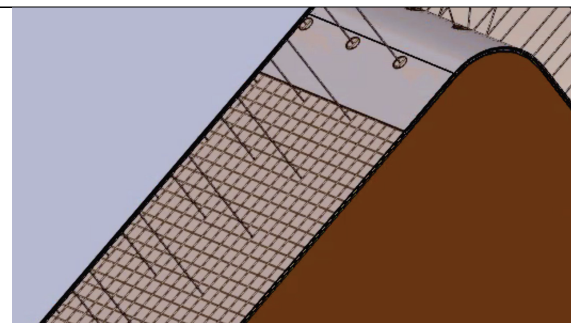
*Multiple rows of flexible solar material are placed directly onto soil (e.g. 2m x 100m per row, shown in red). Entire bed is covered with solid material to control soil erosion from rain and wind. Skirt along outer perimeter (green) controls erosion near rows.*



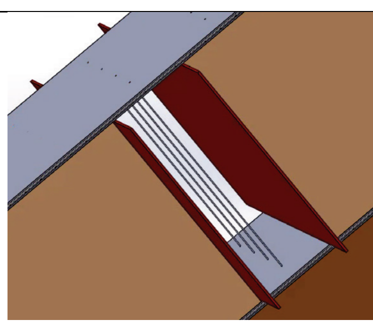
*Metal links connect above-ground solar layer to below-ground anchoring layer. Silicon solar cells are embedded in plastic on top layer, similar to existing flexible solar products. Not shown is soil between two layers.*



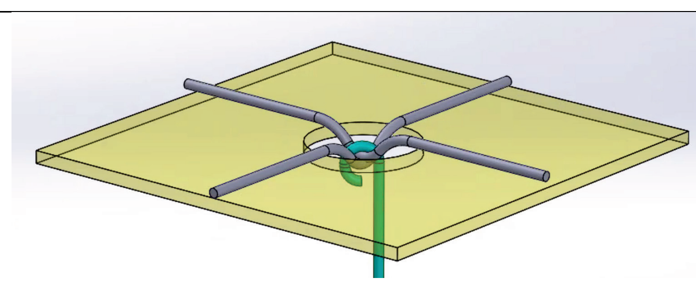
*Vertical metal links connect above-ground solar layer to below ground anchoring layer. Load is transferred to the weight of the soil (not shown) between two layers. This keeps top layer in place when wind creates negative pressure.*



*Both above-ground solar layer and below-ground anchoring layer consists of flat plastic with embedded wire mesh (e.g. 1x1 inch metal squares). In above illustration, soil and top surface of anchoring layer are not shown allowing one to view metal mesh.*



*Installation machine uses retaining plates, shown in red, to control soil between top layer and below-ground anchor layer while a mechanism between plates (not shown) installs vertical metal links. The retaining plates move as the installation machine moves. Machine unrolls both layers, places soil in between, and connects them together via metal links.*



*Hooks in vertical metal links connect to wire mesh embedded in both top and bottom layers.*

### R&D Challenge #1: It's Too Big

The primary challenge with solar-direct-to-soil is one would need complex machines to fabricate, install, and maintain; and developing those is expensive. It is our intent to do Phase I research, which covers everything except costly machine design.

### R&D Challenge #2: Erosion Due To Wind and Rain

Wind and rain could potentially move soil under and around the solar material. To mitigate, one could place flat material between solar rows and around the solar bed to control erosion. One might drain rain water into soil, in-place, in troughs between rows. However, it is not clear how much erosion one might experience after several decades of desert-like 10 inches rain-per-year.

Surviving many decades of wind and rain is a challenge for researchers. The good news is simulators can help predict how soil behaves given various designs and conditions.

### R&D Challenge #3: Solar Efficiency Degradation

The amount of electricity collected by a silicon solar cell decreases with time, and is typically 0.5% per year. It is not clear how, if any, this is effected by storing cells in a curved state. Curved storage has not be studied.

All solar cells are not the same. There are different thickness, different doping, different metal patterns on top and bottom surfaces, and different ways to join multiple cells via metal clips. And storing in a curved state might affect each differently.

When solar is placed directly onto a roof with insulation under the solar, all heat must dissipate from the top surface. This causes the solar cells to run hotter than the case where the back surface is exposed to free air. Tesla solar roof is an example of this. The back surface of their tiles are not exposed to atmosphere. In the case of flexible solar direct to soil, soil conducts heat and 5m underground it is cool; therefore, solar direct to solar would probably run cooler than some of the warmer above-ground alternatives. Research is needed to better understand thermal effects of solar on soil, and with respect to the different types of solar cells.

When wind buffets a surface, it could potentially vibrate. Anchor links attached to the bottom surface of flexible solar on soil might vibrate and affect solar cells. Research is needed to ensure that solar cells do not degrade due to mechanical stress.

### R&D Challenge #4: Reduce cost and Reduce Material Requirements

In order for this to be popular, it would need to be less costly and require less material, than the traditional solar farm.

### Design Problem

Assignment for researchers:

> *Develop multiple methods for covering large amounts of desert land with photovoltaic solar where material usage is dramatically reduced relative to traditional solar farm (e.g. aluminum, glass, cement) and labor cost is reduced via mechanization. Assume $100M to $1B is available to develop*

*complicated machines that fabricate, install and maintain. Propose standards that define how components plug-and-play together, including mechanics, electronics, and communications. Do all development except full design of machines.*

## Summary

Many challenges face researchers working on solar direct to soil. However, this could potentially provide enough energy to power our civilization, at reasonable cost, and with low material requirements. We still need to solve the problem of storage, which entails dealing with energy requirements after sunset. If the world developed a lower cost method of converting electricity to hydrogen gas, we could solve our storage problem.

The good news is researchers can explore different methods of placing solar on land without spending much money. The bad news is most concepts require multiple machines and these are costly to develop.

Investors tend to avoid projects that are "too big"; therefore, if this is going to move forward, an organization like ours needs to move this forward until not too big for investors.

## See Also

For an example of free and open solar direct to soil research, click here.