Apply Solar Skins Direct To Building Surfaces

For several decades engineers have theorized solar skins could wrap building roof and wall surfaces, edge-to-edge, and generate electricity on-site. Below is an illustration of what this might look like. This does not exist, yet is an exciting area of research referred to as "Building Integrated Photovoltaics" (BiPV). This document explores challenges faced by BiPV researchers.

Wrapping with Solar

When building a house, 4 x 8ft sheets of internal drywall panels are typically shipped to a construction site and cut into custom shapes that wrap windows and doors. Architectural software produces a list of custom shapes for builders, who cut and install.

In theory, one could do the same with custom pieces of solar material that attach directly to external plywood. Custom solar would probably be made to order in a factory, shipped in a canister, and installed by a specialized machine.

In this scenario, the solar material is the water barrier. This means that the cost of roof shingles and horizontal side clapboards are being eliminated. If it is cheaper to wrap than not wrap, then everyone would wrap, worldwide. This is a big deal. In order to decarbonize the planet we need to devise green technology that is cheaper than not-green. Solar skins is therefore a potential opportunity of global importance.

So what is the Problem?

The good news is conversion materials (i.e. silicon, thin film) are cheap. And developing mechanical systems to wrap a building cost little. The bad news is developing machines to fabricate and install is expensive. Also multiple complicated machines causes investors to consider this "too big" or "too many moving parts", which it is.

We intend to do implement Phase I, which is to develop the mechanics of wrappings, develop embedded electronics, and *explore* machines that fabricate and install. If Phase I was positive, anyone could continue onto Phase II and fully develop machines that fabricate and install, at a cost of $50M to $300M. In other words, developing a solar skin system would cost little, yet developing machines to implement would cost much more.

Flexible Solar Products Already Exist

Flexible solar products currently exist, an example of which is the SunPower product, pictured below. This involves solar PV cells embedded in flexible ETFE plastic that is 2mm thick. These can be attached to a curved surface, or rolled up and placed into a large canister. In theory, current flexible silicon solar products could be made larger, in custom shapes, and installed on building surfaces.

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

Implementing solar skins directly to building surfaces would require machines that fabricate, install and maintain. Developing these machines might cost hundreds of millions of dollars. If one company developed one machine, then revenue would be zero in the absence of other machines (e.g. installation machine is not useful without material fabrication machine). This is commonly referred to as a "chicken and egg" problem. In theory, one company could develop multiple machines from scratch, yet almost all companies are reluctant to engage in an expensive, complex, and risky venture of this magnitude.

Our strategy is to develop initial technology that is used by others, and move the world closer to a final system.

R&D Challenge #2: Coordinating Multiple Companies with Standards

In theory, government and/or foundation money could design a system and propose interconnection standards that coordinate multiple companies. If there is a standard way to place rollable material into a canister, then a company that makes the fabrication machine could coordinate with a different company that makes the installation machine.

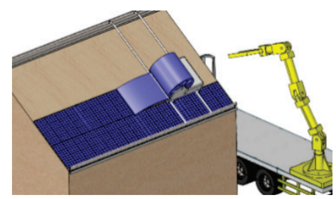
Twenty years ago, 35mm analog film was stored in a canister, pictured to the right (for younger readers). The dimensions of the film and canister were standardized and this enabled makers of cameras and makers of film processing machines to coordinate. One could apply the same principle to solar skins.

R&D Challenge #3: Securing Material to Building via Brackets that Control Water

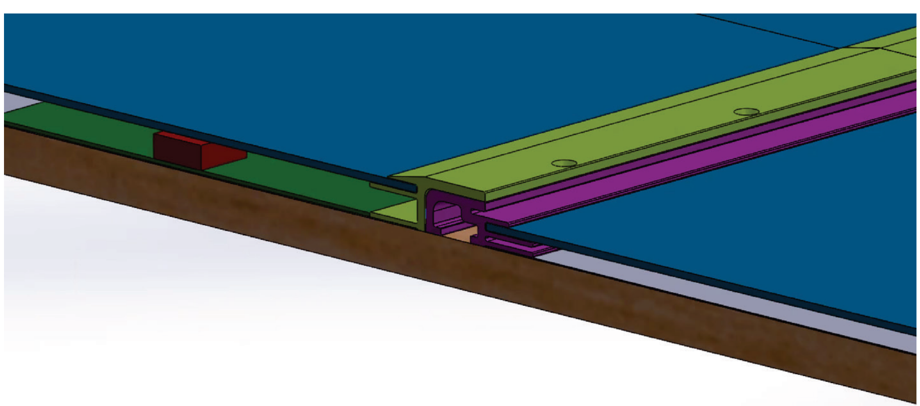
We are looking at attaching solar material directly to plywood roof and wall surfaces, without an underlying water barrier. The solar material is the barrier. Custom solar skins would need to support disassembly and replacement, since a building might last five times longer than a set of skin. In other words, gluing solar direct to plywood is not feasible.

If you look carefully at most buildings, you will see overlapping components on both roof and wall surfaces. These exist to control rain water. Water is sneaky. If it can work its way into a building, it tends to do so, especially over time. Overlapping surfaces is an important technique for controlling water.

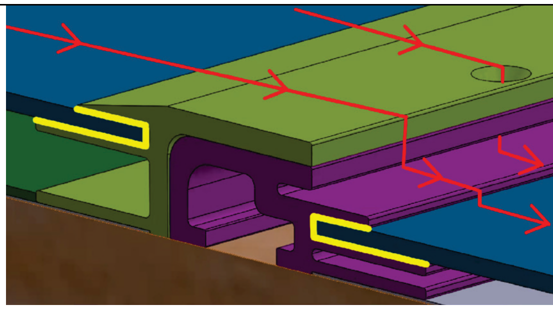
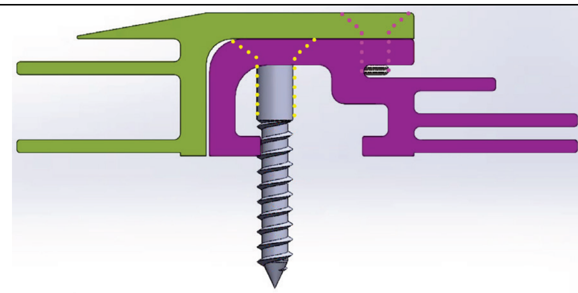
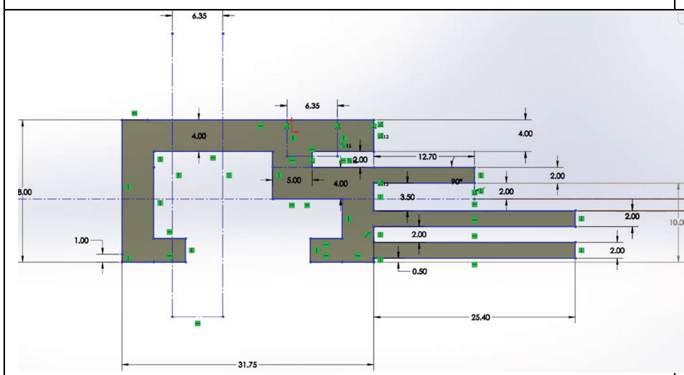
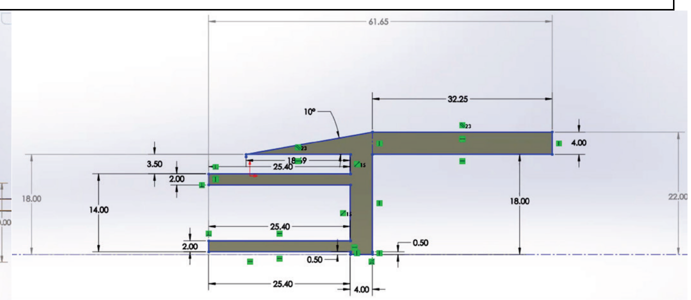
If one has a plywood roof that is 15m wide x 10m high, for example, they might place five overlapping strips of material directly onto plywood, where each strip is 15meter wide x 2meter high.



Below is an example of an overlapping horizontal joint. In the illustration at the beginning of this chapter, these are shown as horizontal light gray rails between horizontal 2m wide solar strips. The lower extruded aluminum rail (violet) attaches to plywood via screws, and the upper rail (light green) attaches to the lower via bolts. Flexible solar ~2mm thick (blue) attaches to rails via adhesive. A PCB (green) is embedded in the material, and in this design, supports electronic components 1cm tall (red). A lower layer of thin sheet metal (gray) presses against plywood, provides strength, and provides a fire barrier. Not shown is honeycomb plastic between the lower metal layer and upper solar layer. This fills empty space around PCB. Under the solar material is plywood (brown).

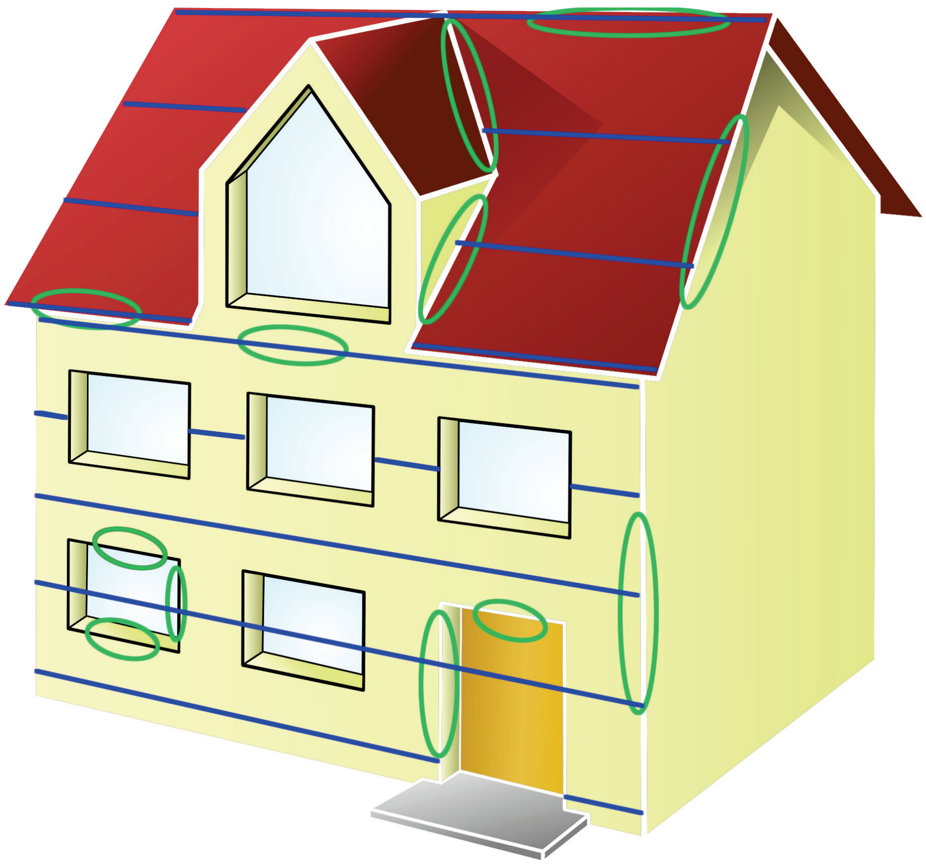


The following illustrations provide more detail:

 *Rain water (red) flows across overlapping surfaces. Adhesive (yellow) bonds flexible solar material to metal rails.*	 *Wood screws secure lower metal rail to plywood (dotted yellow) and bolt secures top rail to lower rail (dotted violet).*
 *Lower metal bracket.*	 *Upper metal bracket.*

Designing Multiple Brackets

The above bracket applies to horizontal seams; however, to fully wrap a house, one would need about a dozen different *types* of brackets, illustrated below with green circles. For example, one would need a bracket at window vertical edge. Blue lines in below illustration shows how one might wrap features on roof and wall surfaces. A factory would fabricate custom shapes since one cannot cut solar in the field.



Small Flat, Large Flat, or Large Rollable?

Instead of large rollable, researchers can explore covering a roof with small flat non-rollable custom pieces that assemble like a puzzle and wrap features such as windows, doors and chimneys. In theory, a factory could stack custom pieces in the small 1 x 1.5m size range into a container, transport, and install via specialized machine. Alternatively, a worker could handle pieces due to their manageable size and weight. A flat non-rollable system might include 3.2mm thick tempered glass to resist hailstones.

One disadvantage of small flat vs. large rollable, is small flat needs to control water at vertical seams. A potential remedy is overlapping vertical ribs, similar to what one does with a metal ribbed roof on a commercial building. Yet many vertical seams, over many years, might be prone to reliability problems. And ribs tend to bend after being pressed on by things like tree branches.

Another disadvantage of small flat is it entails an electrical connector at each piece, and this is less reliable than solder joints embedded in large rollable. Also, with many connectors, one tends to reduce the number of wires within each connector, which reduces the number of power conversion options. From a power conversion perspective, large rollable is very different from small flat, the details of which are beyond the scope of this discussion.

Alternatively, one might look at large custom flat that drop in via crane, similar to corrugated steel panels on commercial buildings, pictured here.

In summary, there are a variety of approaches, all of which deserve exploration by researchers.

Embedded Electronics Optional

In some cases, one might place power conversion electronics inside a building, such as under a roof in the attic. However, this is not always convenient. For example, a wall surface without access from inside the building might not support cabling to solar. Subsequently, one might have a ~1cm thick layer between solar cells and plywood, for electronics and cables, as illustrated above.

Seven Parameters that Characterize a Solar Skin System

There are many different types of solar skin systems, where each are characterized by seven parameters: type of building, new construction or existing, roof or wall or both, topology (large rollable, large flat, small flat), embedded electronics or not, 3mm flat glass or plastic cover, and silicon or thin film PV.

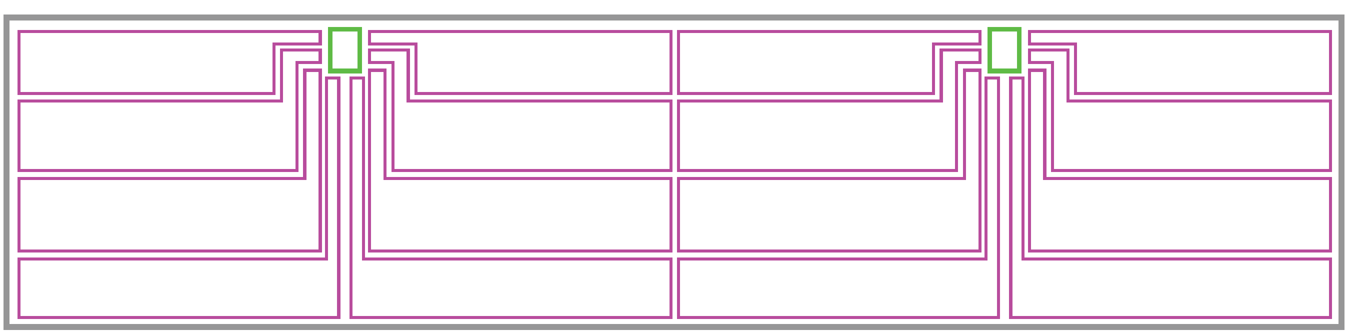
Solar Skin Mechanical System Involves Mounting Brackets and Material In-between

Mounting brackets would need to be standardized in order to coordinate machines from different companies that fabricate and install. This would be similar to 35mm analog film cartridges that coordinated cameras and film companies. There is no business model that supports the development of such brackets; therefore, an organization like ours would need to step up to move this forward. The good news is developing brackets, defining material between them, and building simple prototypes is cheap. The bad news is developing machines that fabricate and install is costly. Yet you need step #1 before step #2.

We intend to design multiple solar skins systems. For each, one needs to specify the above seven parameters (e.g. large rollable, large flat, or small flat) and be prepared to spend $1M to $10M. If free and open, others can easily build on one's work, including a standards body. This would not be enough money for machines, yet would move the world closer to a complete systems.

R&D Challenge #4: Developing Cost Effective and Long Lasting Electronics

In the below illustration we show one large piece of rollable solar with PCB's in green color. In this concept, each PCB maintains *eight* 300W power converters, where each 300W region of solar is shown in violet. These PCBs are connected together with multiple wire cable that joins via solder joints instead of connectors. Having this kind of access to solar cells, with more than 2-wires between PCB's, is different from the traditional 2-wires at each 1 x 1.5m panel. Figuring out how to combine power in a cost effective and reliable manner is a challenge for electrical engineers. It is our intent to develop and propose interconnection standards for electronics to help coordinate multiple companies.



R&D Challenge #6: Mitigating Fire and Safety Risks

Obviously, one does not want to burn the house down or electrocute the neighbor walking the dog.

To reduce fire risk, electronics can be designed to not produce excess heat upon component failure, and a thermal barrier can be placed at plywood.

If solar on wall is on ground floor or close to open window, one would need to limit voltage to avoid shock hazard. This would be necessary since cover surface could potentially fail and expose electrical contacts. Placing multiple power converters on one PCB, described above, could help limit voltages to an acceptable level.

R&D Challenge #5: Coordinating Architectural Data

Custom pieces that wrap building features requires the coordination of architectural software, servers that maintain architectural drawings, building owners, and factories that make custom solar pieces. Software that coordinates does not exist. To move this forward, we intend to implement a complete system in software, build prototypes (servers, user interface, database), and make source code available free and open to enable others to build on this work. Also, we intend to propose standard communication protocols that coordinate the various components.

The placement of windows and doors might only be accurate to +-1cm relative to drawings. Subsequently, one would need photography, video and/or laser scanning to improve accuracy.

R&D Challenge #6: Surviving Hailstones

A 2cm diameter ball of hail ice traveling at 100kph can damage silicon PV solar cells; however, thin film photovoltaic conversion material, such as CIGS, are more resilient. Silicon PV has higher conversion efficiency and less efficiency degradation over time, relative to CIGS, and is therefore more popular. However, BiPV researchers are not connected to any one conversion technology, since they are focused on the mechanics of wrapping and installing of *any* material.

Silicon solar cells on roof surfaces are typically protected by flat tempered glass 3.2mm thick. This glass cannot roll or bend. However, vertical walls do not take direct hailstone strikes, and are therefore safe with silicon solar cells embedded in flexible plastic such as ETFE. In other words, with today's conversion materials, one might look at covering vertical walls with ~2m diameter rollable silicon, and look at covering hailstone-proof roof surfaces with something like rollable CIGS or flat 3.2mm glass over silicon.

Also, researchers could try to develop a rollable silicon solution that resists hailstones, yet it is not clear this is possible. Sunpower Corporation is probably the leader in this field; however, their silicon still breaks when hit with a hailstone.

Design Problem

Assignment for researchers:

> *Develop multiple methods of covering building roof and wall surfaces (e.g. direct to plywood), edge-to-edge, where parts and labor costs are less than traditional treatments (e.g. shingles, side clapboards). Explore multiple solar skins systems, where each is characterized by above seven parameters. Assume $100M to $1B is available to develop complicated machines that fabricate,*

install and maintain. Assumptions: architectural software generates list of custom shapes that wrap building features, custom shapes are fabricated in factory, and installation is automated via specialized machine. Propose standards that define how components plug-and-play together, including mechanics, electronics, and communications. Do all development except full design of machines.

Summary

BiPV researchers face many challenges in devising a system that supports solar skins mounted directly onto building surfaces at a cost lower than non-solar coverings. The primary challenge is the high development cost of machines that fabricate and install. However, researchers can design much of the system before spending big money on machines. This includes developing brackets and material that wraps buildings; and proposing free and open mechanical interconnection standards that coordinate multiple companies. It is unlikely a company would fund free and open development; therefore, to move this forward, an organization like ours is needed.

See Also

For an example of free and open solar skins research, click here.