Proposed: # Smart Building Development Center

Creating Free & Open Plug-and-Play Standards that Reduce CO_2
$100M over 5 years

Abstract

We propose the establishment of a Smart Building Development Center (SBDC) that focuses exclusively on the development of interconnection standards that reduce CO_2 emissions.

We are budgeting $100M to be spent over 5 years.

This involves multiple university which focus on their respective strengths.

For a Power Point summary presentation, click here.

Standards

A mechanical, electrical, or communications standard is a document that describes interconnections between components and is accepted by multiple companies and multiple industries.

For example, the mechanical design of the 35mm analog film canister enabled makers of film, and makers of cameras, to coordinate. Without this, revenue would be low given multiple proprietary expensive options for film and cameras.

Standards facilitate interoperability between components sold by multiple companies, which reduces cost via increased competition and commoditization.

There is very little incentive for a company to develop a standard, since the world receives the total benefit, while they receive a small portion of that total. Companies can only afford to focus on activities where they receive most, if not all, benefit.

The federal gov't tends to not fund standards development either, since they delegate to industry to solve this problem.

The proposed center develops standards that are free and open, which means they are not owned by anyone, which facilitates worldwide collaboration and adoption. The world's companies and countries are not interested in being controlled by a private party; therefore, if one really wants to get this done, free and open is a requirement.

No one else focuses on developing plug-and-play standardization, and therefore we would be fulfilling a unique role.

Plug-and-Play Standards Are a Low-Cost Way of Reducing Worldwide CO_2 Emissions

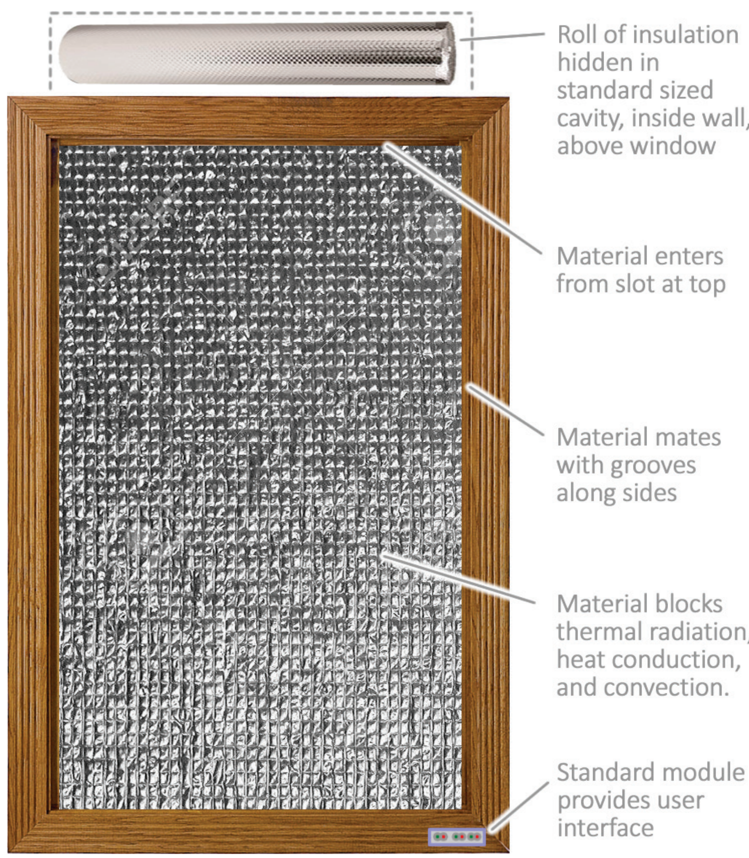
The world's high-carbon infrastructure is currently being replaced with low-carbon infrastructure, and plug-and-Play standardization could potentially reduce the cost of this movement.

We believe that spending money on low-carbon standards is probably the most efficient way of reducing CO_2 emissions, per dollar spent. This is because standards are an amazing force multiplier. Each standard might be utilized millions or even billions of times.

Also, standards development in the United States is one way the US can encourage others to reduce CO_2 emissions. The US can de-carbonize to zero while other countries are less inclined. Yet their CO_2 emissions will ultimately harm the US. Therefore, developing internationally accepted interconnection standards is one way of facilitating CO_2 reduction elsewhere.

Interconnection Standards Enable Us to do Great Things

Interconnection standards enable us to do things we otherwise would not do. Here's an example. Window Thermal Cover. The average American home has an average wall insulation of R16 (amount of insulation). A typical window has an insulation of R3 (1/5th as much). In theory, one could *thermally* turn a window into a wall with a 2 inch thick thermal cover embedded in the wall that slides over when the room is not occupied.



Currently this is not being done since there is no standard way for the device to connect to the building. If we had a standard electrical power plus data connector for a window thermal cover, then one could plug-and-play without needing to hire an engineer, which is costly.

Mechanical components such as motors are often replaced multiple times over a building's life-time. Each manufacturer is not inclined to make a product over this period of time. Therefore, mechanical module standardization is needed to maintain a building over its lifetime (e.g. plug-in module with motor, gear and connector).

Standardization drives down price via commoditization (i.e. multiple companies make the same thing and compete). This helps architects to incorporate low cost components which pay for themselves over a reasonable period of time due to decreased energy costs.

Standardized window thermal cover components would not be expensive relative to the window itself, since the window needs to be resilient against hurricane force winds and rain. Alternatively, an indoor thermal cover is implemented with lightweight Styrofoam-like material that is moved with a small low-cost motor. We currently have two mechanical engineers at Ohio State University working on this. For details, click here.

We Redesign Everything from Scratch Starting with a Blank Piece of Paper

The proposed R&D center does not stop at window thermal covers. It keeps going. How far? All the way.

The center redesigns everything within a building starting with a blank piece of paper. This includes light sockets, light switches, HVAC, radiator valves, vents, dampers, fans, sensors, appliances, solar electronics, power electronics, batteries, and thermal storage.

We refer to each of these as a "device" and we embed a $3 microcontroller into each. Then, we connect them together with an additional data wire that is routed alongside power wires.

This might sound daunting; however, we have a special trick, so to speak. Our prototypes use the same microcontroller within each device (i.e. the Xmc4200). This means that engineers can borrow much of their design from someone else, and focus on what is unique about their device. This also means they can borrow software, which helps them move quickly.

Common Software Is Placed Onto All Devices

If one is frying an egg while a light bulb and occupancy detector are above their head, we would like for the occupancy detector to send a message to the bulb and tell it to turn on if not already on. We would like for this to occur without relying on the cable that goes down the hall, the controller electronics at the end of the hall, the electronics in the basement, the cable modem, the internet, Alexa, Amazon, etc.

This is what we call "local intelligence". We need for devices that are physically close to each other to do as much as possible, without requiring additional resources. This is needed to support fault tolerance, which means that if something is amiss, disruption throughout the building is minimized.

There is only one way to do this, which is to supply the software that is placed onto all devices. The only way to get the world to agree to this is to make this free and open, which means anyone can use it at no cost. Also, there is one more requirement. Quality. If the software is difficult to read or buggy, it will be ignored. So, the onus is on the engineers to do quality work.

There are existing networking protocols that define how devices interact, yet they do not include software that facilitates an encompassing system. Our approach is unique, and we believe this is what is needed to get this done.

We call this system "BuildingBus" and the software that is installed on the devices is called the "BuildingBus Framework". In summary, any device can send a message to any other device, any device can read or write any register within any other device, any device can receive a library that contains information about other devices, any device can monitor sensors from any other device in pseudo real-time, and any device can send a command to any other device.

We currently have 15 students working on this at UMass Amherst. Click here to download framework source code and click here for documentation.

Communication Must Be Reliable

When one turns on a physical wall light switch, the communication between this switch and the bulb is operational better than 99.999% of the time. This is a subtle point that gets little attention, yet is important.

In order for our system to be accepted, we need a similar level of reliability in our communication. This is far from wireless or power-line communication, which fails 1% to 10% of the time (e.g. due to dead zone, crowded spectrum, bad signal to noise, antenna too small, etc).

Our solution is to add an additional data wire that is routed along with power wires. We are currently developing a new physical layer standard with the following characteristics:

supports CANbus (wire-AND), tree topology wiring (not daisy chain, no termination), short circuit protection to 220VAC, device transmitters only needs 10's of milliwatts to transmit, and devices sleep when not in use. We currently have one student at UMass Amherst working on this. For a simulation, click here.

More Thermal Control

Standards can help reduce energy consumed to heat and cool buildings. For example, if you are in your office on the second floor, the office is warm, and the basement is cool, then you could move air from basement to office, instead of turning on the central HAVC. Doing this requires low cost and reliable motorized fans and dampers within ducts, and at vent openings. These would be connected to the BuildingBus network and provide more control over air.

Motorized dampers could also be helpful if the central HVAC is turned on. For example, rooms not being used could be turned off and the system instead could focus on rooms used by occupants.

We currently have four mechanical engineers at Utah State University that are working on motorized dampers and fans in ducts, and at vent openings. For details, click here.

More Energy Control

Within a building one has multiple producers and multiple consumers of energy. For example, the HVAC system and the oven are big consumers; and the solar panels and grid power are big suppliers. If large consumers and suppliers communicate they can often figure out how to process energy more efficiently. For example, an HVAC with a variable speed motor might prefer to receive DC voltage from solar panels, as opposed to moving the solar power through a DC-to-AC converter, followed by an AC-to-DC converter. Currently, each manufacturer has their own communication system. It is our intent to propose free and open standards that coordinate consumers and suppliers of energy within a building, to reduce energy consumption.

Solar Direct To Building Surfaces

There is a term called "BiPV" which refers to "Building Integrated Photovoltaics". This involves placing solar material, such as silicon, directly onto building surfaces such as plywood. This includes roof and wall, potentially edge-to-edge.

BiPV has been worked on for many years by many people, yet we do not see it. We believe this is due to the fact that installing BiPV probably requires specialized machines that cost 10's to 100's of millions of dollars to develop. This includes machines that fabricate, install, maintain, and disassemble large pieces of solar material.

We believe the next step is for us to develop a BiPV system yet not develop the machines (revenue is $0), propose mechanical interconnection standards, and then let industry move forward from there after multiple companies are coordinated (so that one company does not need to do everything).

Twenty years ago, 35mm analog film was stored in a canister. The dimensions of the film and canister were standardized and this enabled makers of cameras and makers of film processing machines to coordinate. We need to do the same with BiPV.

We currently have five students at UMass Amherst, five students at UMass Lowell, and five students at Ohio State working on this. For details, click here.

Solar Direct To Soil

In theory, one could coat 25% of Nevada with solar and create enough energy to decarbonize the entire United States. We would still need to resolve other issues such as storage (i.e. how to store energy when the sun goes down) and limited rare earth materials used in electrical vehicle batteries. Currently electric vehicles consume 50% of world's cobalt production and it is unclear how we could move completely over to EV. Coating land with solar could potentially be performed with farm-like equipment that works with large pieces of solar. Coordinating multiple companies that work on this would require mechanical, electrical, and communications systems; similar to what we intend to do with BiPV.

It's Too Big

Perhaps by now you are thinking, "Many of these things are big, perhaps too big". This is true. And that is why many of these issues have not been resolved. They are too big. Too big for one company. We aim to move them forward to the point of prototypes and proposed standards, as an intermediate step before companies move them forward. We aim to tackle things that, on the surface, appear too big, yet are manageable if approached with this intermediate step.

How to Create a Standard

To create a standard, one must first design, prototype, and demonstrate a system. Then, one can propose how the various elements interconnect. To gain adoption, one can provide all material to all parties, free of charge. Without this last point, others will resist being controlled by a private entity.

A standards body, such as IEEE, contacts members and asks if they would be interested in participating in meetings that develop the proposed standard. If there is interest, the materials are reworked to the satisfaction of the majority of the participants. It is our intent to do the initial work for a standards body. If they assemble before our materials are produced, they will not have time to figure out what to do in a few hour meeting.

Where the Money Goes

The center establishes a board that reviews proposals from university researchers, decides who to fund, and then manages the awards.

The center focuses exclusively on developing interconnection standards that reduce CO_2 emissions. All recipients are under contract to make produced materials free and open, to encourage adoption (no IP, no patents). This includes software, simulations, analysis, mechanical drawings, and documentation.

Our role is to coordinate multiple companies, multiple industries, and multiple countries. We do this by taking a break from creating propriety IP, and instead focus on producing free and open materials to reduce CO_2.

Suggested Research Topics

The R&D Center suggests research topics, and researchers are welcome to propose their own. The following pages contain suggested topics that would be seriously considered for funding by the center, provided the applicant's proposal was reasonable.

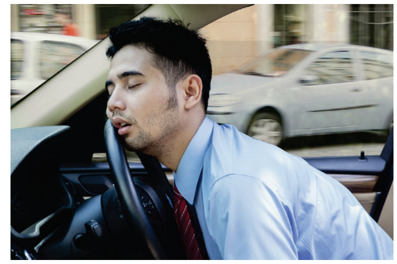
Topic 1a) Develop Standard Electrical Vehicle Battery

Currently, the world has a mechanical and electrical standard that defines the 9V battery; and this enables one to power small appliances at low cost.

In theory, one could have a standardized car battery that looks similar to the Tesla battery, yet is used by all cars. The standard would define the mechanics (e.g. height, length, and width), electrical connections, and communication between battery and car. One could potentially swap out and replace with a fresh battery in under one minute.

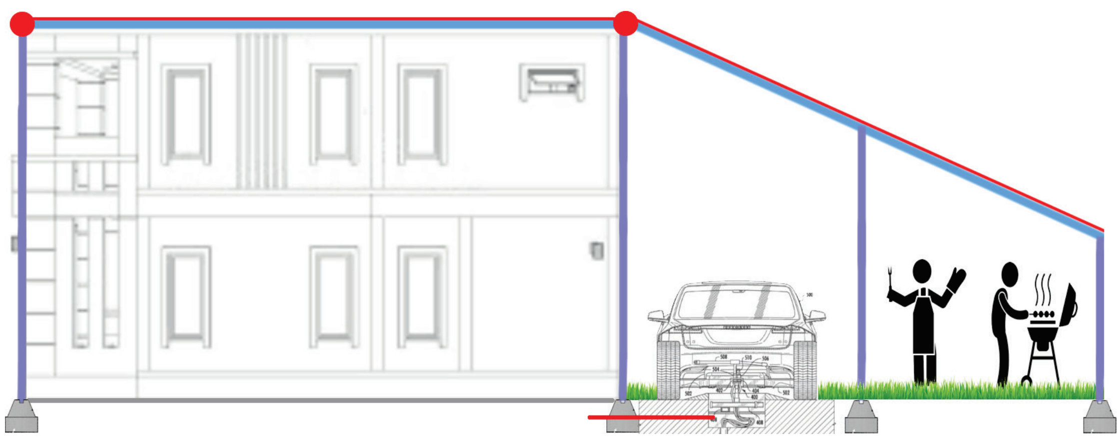
What might the world do with such a standard?

- Create market for companies that manufacture standard EV batteries; which reduces cost through competition and commoditization.
- Driver visits ~~gas~~ swap station, swaps out battery, pays for electricity consumed and wear inflicted on battery, and goes -- instead of catching nap at charging station.



- Home includes chamber in driveway that houses standard batteries. One owns multiple batteries, solar charges during day, batteries power house at night, and one swaps with car as needed.

Researchers develop standard mechanical and electrical battery system, communication system between battery and charger, and communication system between car and battery swap station. Car companies are invited to participate with things like company-paid engineer on sabbatical who works side-by-side with MA funded engineers. All work is free and open, to support collaboration and adoption by multiple companies.



Topic 1b) Develop Standards that Better Coordinate the Charging of Electric Vehicles

Many world leaders are advocating we decarbonize over the next 20 to 40 years. This means we will probably need to power vehicles with electricity and/or hydrogen gas, instead of gasoline. A big challenge with electric vehicles is they consume much electricity when charging. The electrical grid might support charging a few cars at night on one street. However, it will not support simultaneously charging a car at each house. Electrical wires on the street telephone pole, and those that route to the neighborhood, are not large enough. Subsequently, converting transportation from gas to electric involves a costly upgrade of the electrical grid.

In theory, it is possible to position charging stations throughout a community -- to places like office parking lots, street parking meters, and homeowner's property edge.

Researchers propose standard electrical connectors, communication systems between car and charger, communication systems between grid and car display panel (tell me where I can charge and give me price), browser/smart phone user interface, and payment system interface.

Researchers might propose a new electrical connector that is potentially used by all manufacturers, with adaptors that affix to existing hardware.

Researchers might also propose standards that support radio communication between a common server and each car, and between that server and each charger. This would use very little radio spectrum since messages are short. Gov't or electric companies might be willing to pay for the server and radio spectrum, since it helps to distribute grid load.

Currently, there are several different systems and connectors that support charging and communication. Many are proprietary and are not recognized by multiple companies. For example, Tesla is not interested in talking to Ford, and vice versa. Researchers look at unifying suppliers and consumers with free and open software and standards.

An example project is a Website (server computer) that coordinates charging stations and cars. Owners of charging stations register, specify their location, and communicate their pricing model. Charging station constantly reports status (e.g. car is charging, solar electricity is available), price and source of electricity (e.g. solar, wind). Cars interact with website to identify reasonable charging options. System supports homeowners who charge cars at property edge. Researchers look at how to verify source of electricity and allow it to influence price (which might require standards that define how solar panels talk to charging hardware). Researchers do not implement the actual system, and instead create a prototype that demonstrates concepts and tests proposed standards. Deployment is a later step, which might involve a national gov't. All source code is given away for free, enabling others to build on the effort, and encouraging adoption by industry and gov't.

Topic 2a) Create website that Manages *Investments* in Solar Farms and Wind Farms

Researchers create a website that supports investors who fund portions of solar farms. Researchers propose standard ways for solar electronics to communicate with the common website (server computer). This allows the website to periodically receive information, including power generated, wind speed, and degradation of components. Energy output results in dividends to investors, degradation of components results in investment value reduction.

Hardware suppliers register at website and enter product prices and specifications. Installation and maintenance companies register and quote prices. Website coordinates the various parties, including routing dividend money to investors and trading of portions.

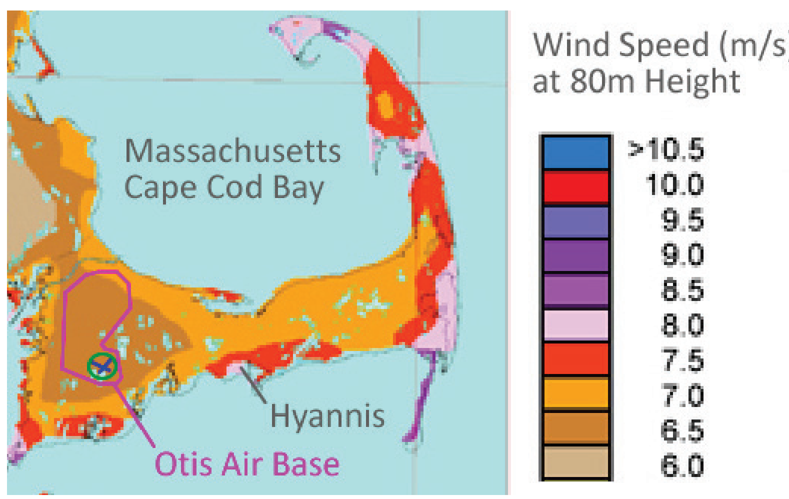
Tracking component degradation and faults creates incentive for suppliers to not reduce cost at a sacrifice to quality. This is a big problem for owners who are trying to get through multiple decades of ownership w/o premature failures.

Researchers do the same thing for wind farms.

Researchers do not implement the actual system, and instead create a prototype that demonstrates concepts and tests proposed communication standards. Deployment is a later step, which might involve a US Gov't agency. All source code is given away for free, enabling others to build on this work, and encouraging adoption by industry and gov't.

Topic 2b) Build Wind Farm Development Website

Researchers build an online website that designs and monitors wind farms. It supports any size, ranging from one small windmill to many large windmills in an array.



Owners of *existing* windmills and wind farms can register with the website (server computer), specify location, and specify size. Optionally, they maintain a constant connection and periodically report things like wind speed and energy output.

Manufacturers of wind products (e.g. turbines) register and enter product prices and specifications.

Organizations with wind data (e.g. NOAA) register and provide maps that show wind speeds at various locations. Also, developers of wind maps are given access to real-time wind and energy data from existing installations.

Researchers propose standard communication protocols between map makers and website, and between windmills and website.

Also, anyone can register and design a wind farm. Designers specify things like location, wind turbine hardware, height above ground and number of turbines; and the website responds with a report that estimates cost and energy production.

Researchers do not implement the actual system, and instead create a prototype that demonstrates concepts and tests proposed communication standards. Deployment is a later step, which might involve a national gov't. All source code is given away for free, enabling others to build on this work, and encouraging adoption by industry and gov't.

Topic 2c) Develop Central Reporting Website That Implements Wind & Solar Project Transparency

Decarbonization is expensive and political support for spending vast sums does not exist. Therefore; now is a good time to develop, reduce cost, build and improve prototypes.

In theory, society might want to build a prototype, incur a variety of faults, make sure the engineering community is aware of the faults, have them fixed, produce a better prototype, and go through several cycles. However; suppliers, buyers, and owners tend to not want to openly discuss faults; for a variety of reasons. This reduces the improvement rate, since secrecy causes engineers to not learn from past experiences.

In this initiative, researchers create a website that controls technical and cost transparency for wind and solar farms. Technical transparency involves publically reporting technical performance (e.g. wind speed, electricity produced) and technical faults (e.g. turbine bearing failed). Cost transparency is when project cost components are made public.

Transparency is not always resisted. For example, gov't leaders, investors, and electric companies may at times desire transparency.

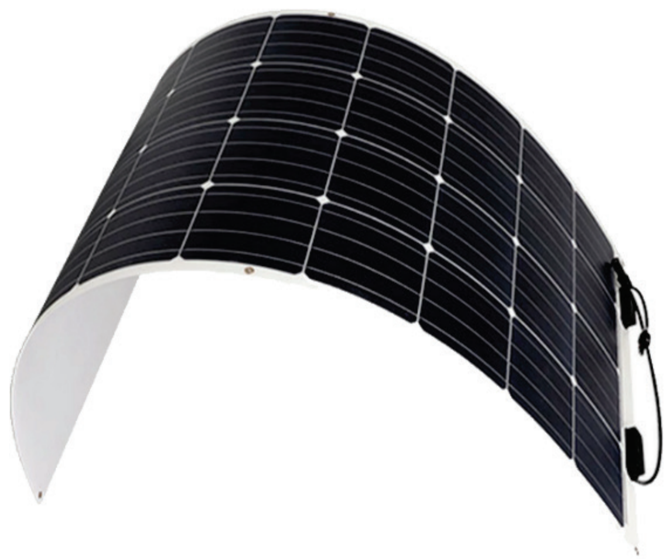
In the previous topic, researchers develop a website that communicates with wind and solar farms in a standardized manner. In this initiative, researchers add features that enable a higher authority to manage both cost and technical transparency. For example, the owner of a windmill might be required by the federal gov't to upload for public viewing PDF files describing each technical fault (e.g. bearing failure).

Requirements are stipulated either by government law or contract. For example, a federal gov't might require that wind turbines > 1MW publically report electricity production. This website provides a centralized place to report; and is therefore a tool used by higher authorities to manage transparency.

Researchers create control panels where Federal Gov't, State Gov't, and Electric Companies specify which information is made public; to help inforce their laws and contracts.

Researchers do not implement the actual system, and instead create a prototype that demonstrates concepts and tests proposed communication standards. Deployment is a later step, which might involve national governments. All source code is given away for free, enabling others to build on this work, and encouraging adoption by industry and governments.

Topic 3a) Develop Free & Open Electronics System Embedded in Rollable Solar Material



In theory, one could have an electrical and mechanical standard that defines a roll of solar material with embedded electronics.

This would be similar to the 35mm film canister, yet larger. A canister of rolled solar material might be 6 ft in diameter x 6 ft wide, and contain a piece of material that is 6 x 150 ft when flat. This approximate size fits into a shipping container or a large truck.

Small flexible solar products already exist, as pictured above (e.g. 5 x 2 ft). These are often made of plastic and silicon, and are approximately 0.1" thick. Big rolled solar does not exist since it would require specialized machines to handle it, these machines do not exists, and the material is useless without the machines. Researchers who develop the material, and standards that define it, in theory, could change this. This initiative focuses on packaging and installation, and therefore supports all forms of conversion material, including silicon and thin-film.

What could one do with this material? One could cut into smaller custom pieces and place them directly onto plywood roof and wall; or place directly onto land formed by specialized machines. If one does the math on energy, they can see we need to move beyond 3 x 5 ft panels handled by workers, and think about larger solar handled by machines.

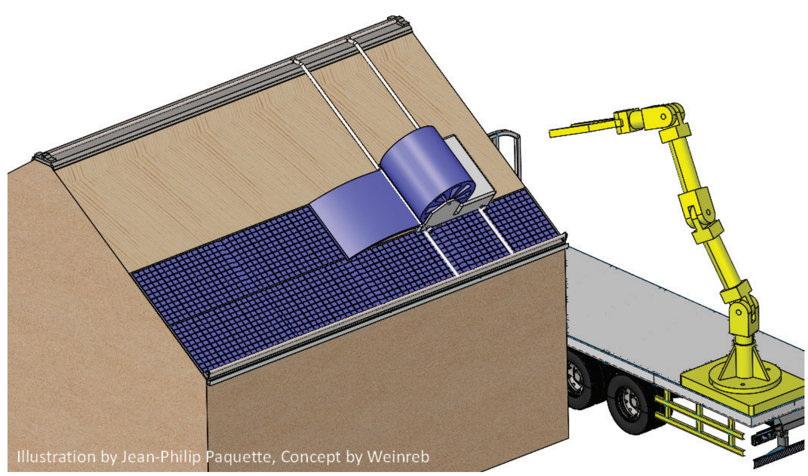
Researchers develop embedded electronics, produce free and open reference designs, and propose communications protocols that support interoperability between electronics provided by different manufacturers. All produced materials are free and open, to support collaboration and enable others to build on this work.

For ideas on how researchers might tackle big rolled solar, click here.

Topic 3b) Develop Mechanical System for Mounting Rollable Solar directly onto Building Roof and Wall Surfaces (BiPV)

This is similar to the previous topic, yet mechanical engineers devise a system for mounting rollable solar with embedded electronics directly onto building surfaces, such as plywood. This includes both roof and wall surfaces for commercial and residential buildings.

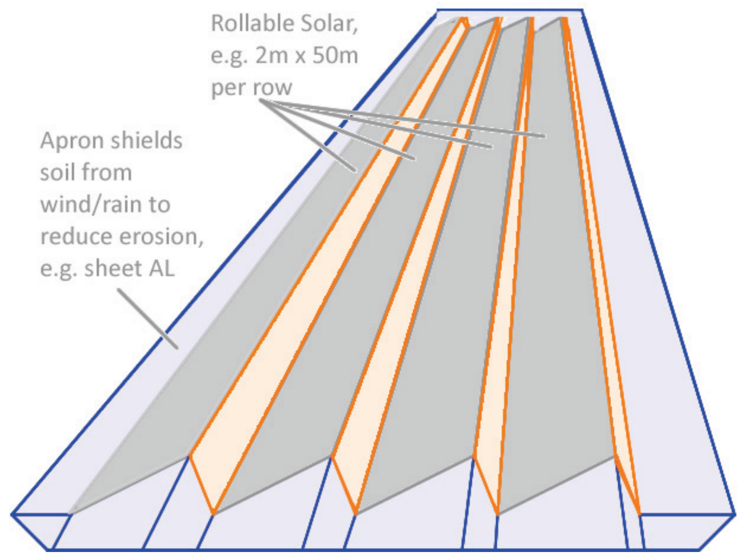
For example, if one has a plywood roof that is 40ft wide x 30ft high, they might place five overlapping strips of material directly onto plywood, where each strip is 40ft wide x ~6ft high. Horizontal metal rails might secure material at overlap positions, and vertical batons might help resist movement during high winds, as illustrated above.



Researchers develop a durable mechanical system; design a canister that holds material during transportation; explore machines that transport, install, and clean; and propose mechanical standards that coordinate multiple suppliers. All produced materials are free and open, to support collaboration and enable others to build on this work.

Topic 3c) Develop Mechanical System for Mounting Rollable Solar Directly onto Land

Researchers develop a method for mounting rollable solar material with embedded electronics directly onto soil, on land, without framing, to create a cost-reduced method of high-volume installation via automated machinery.



For example, a road roller might prepare rows of soil at a ~30° angle pointed toward the sun; while a different machine unrolls material onto soil, as illustrated here (e.g. 6 x 150 ft per strip).

One might have an anchoring layer (e.g. steel mesh on 1cm matrix) ~1 ft below ground that connects to top solar layer via steel rods. Engineers using software simulate how the system behaves over 30 years given wind, rain, erosion and other environmental conditions; and devise a system that works well.

Researchers develop a durable mechanical design; design a canister that holds material during transportation; explore machines that transport, install, and clean; and propose mechanical standards that coordinate multiple suppliers. All produced materials are free and open, to support collaboration and enable others to build on this work.

Topic 3d) Develop Tools and Standards that Support Rollable Solar on Building Surfaces

Researchers develop architectural tools and propose standards that support rollable solar material mounted directly onto building surfaces.

Achieving building net-zero often requires high ratios of solar PV to floor space. A ratio of one square foot of solar for each square foot of floor space is illustrated here. Currently, this is expensive. In this initiative, we rethink solar installation and packaging, and work toward significant cost reduction. For ideas on how researchers might tackle this, click here.

Researchers develop architectural software modules that define PV shapes and placement, propose data standards that describe custom shapes for factory and installation machines, and propose changes to building codes.

All produced materials are free and open, to support collaboration and enable others to build on this work.

Topic 3e) Develop Standards That Supports Plug-in Modules under Large Angled Roofs

A high ratio of solar-to-floor-space might result in more indoor space under a large angled roof (e.g. 40 x 30 ft roof at 30° angle pointed toward the sun). Researchers design physical modules that install under angled roofs, including things like large deep drawers, deep cabinets that fit triangle shape, bathtub, bed with low headroom above feet, closet with triangle shape, and desk. Researchers assume each is a factory-made module that drops-in via crane, to reduce cost. Also, researchers propose mechanical standards that support fitting these together and securing to framing (e.g. standard widths and lengths affix to standard sized rails attached to framing). Electrical engineers propose standards that define ports which provide electricity and reliable wired communication to each module. This includes defining electrical power/data connectors, and communication protocols for a PCB within each module.

All produced materials are free and open, to support collaboration, adoption, and enable others to build on this work.

Topic 4a) Develop Residential Energy Core System

Let's make the following assumptions about a theoretical two story residential home with basement:

- A tank of water in the basement stores heat and/or cold. For example, one might heat water during the day via solar, and use that heat in the evening.

- A ground source supplies cold to the house via pipes that route to underground ~58°F soil. This significantly reduces both cooling *and* heating energy consumption via a [Ground Source Heat Pump] (GSHP).
- All energy intensive hardware is physically consolidated into 3 small utility rooms that are stacked on top of each other. One accesses each via a door.
- Energy intensive appliances back up against utility room wall. This includes oven, washer/dryer, dish washer, and refrigerator. Researchers consider standardized ports that integrate appliances with utility room. Interface includes things like electrical power, wired Ethernet, domestic hot/cold water, 58°F ground source water, thermal storage water, and heat pump airflow.
- Faucets, drains, air vents and HVAC radiators share wall with utility area.
- Stacked utility rooms contain: heat pump, water thermal storage tank, domestic hot water tank, ducts and pipes, electrical wiring, internet modem and Ethernet router. Air ducts and HVAC piping are kept short since they are consolidated into a small space; reducing energy loss.
- Fully loaded modular utility rooms, held together with metal or wood framing, drop in via crane.

We are increasing complexity, which typically increases costs. However, if modules are mass produced in a factory, additional cost is reduced. Yet by how much? Researchers explore the various possibilities, and their costs.

Researchers design examples of how Home Energy Cores might be implemented and propose mechanical, electrical, communications, and piping standards that define how the various pieces might fit together in a plug-and-play manner.

All communication is ≥99.999% reliable; which means no wireless and no power line communication.

All work is free and open, to support collaboration and adoption, and to assist others that want to build on this effort.

Topic 4b) Integrate Appliances with Heat Pump, Thermal Storage and Ground Source

In the previous initiative, architects connect energy intensive appliances (e.g. dish washer, refrigerator) with a Home Energy Core (i.e. utility rooms with heat pump, thermal storage water, ground source, etc.).

Researchers develop prototype appliances that integrate appliances with resources within the core. For example, one might interface refrigerator to 58°F ground source, or connect stored hot water to dish washer via heat exchanger; both of which would reduce CO_2 emissions.

All work is free and open, to support collaboration and adoption of standards, and to assist others who want to build on this effort, to reduce worldwide carbon emissions.

Topic 5a) Better Connect Federal Grant Applicants to Large Private Funds

There is a movement for large foundations to join the fight against climate change. An example is the $10B Bezos Earth Fund. Also, there exists a variety of USA Gov't offices that review, accept, fund and manage grants. For example, the US Dept. of Energy has both a Solar PV Research and Grid Modernization office.

Many of the newer private funds do not have the staff, the experience, or the computer systems that typically reside at a US Gov't office, many of which have been operating for decades. In some cases, gov't offices are comfortable sharing information with select individuals and organizations.

Massachusetts offers to pay gov't software developers to add a user interface to their computer systems that enables large private fund managers, of their choosing, to interact with existing proposals on file with their office. Added features include log in, viewing proposals, offering to fund proposals directly without gov't involvement, and offering to fund proposals managed by a gov't office augmented by a small management fee. We want Jeff Bezos to read a proposal on file, click a button, go to bed, and sleep well knowing it is being taken care of by the United States of America.

Topic 5b) Develop Website that Manages a Decarbonization Research Fund

Researchers develop a website that manages research funds, such as what we have here. The website displays research topics and allows entities to donate money to each, with conditions. For example, a wealthy UCB alumni donates $1M to Topic 2b and specifies that 100% goes to UCB researchers. Or a state donates money toward various topics and specifies that ≥ 66% go toward in-state researchers.

The system might support both Large and Small donations. For example, Large might be ≥ $1M, maintain donation in an independent bank account, allow donor to view proposals before releasing funds, and allow donor to repatriate funds at any time. This additional control increases comfort, which encourages participation.

A management committee decides on the list of topics shown at the website, who reviews proposals for each topic, and who manages each grant.

Researchers register, upload their proposals, interact with reviewers, and interact with grant managers.

Other big funds (e.g. Bezos, Gates, etc.) are allowed to view proposals registered at the website, provided author specified they can be shared.

All produced materials and source code are free and open, to support collaboration, adoption, and enable others to build on this work.

This means that anyone can copy this website and deploy their own versions. For example, UCB might deploy a version with UCB professors on their management committee, control the topics, and use it to encourage alumni to support UCB researchers.

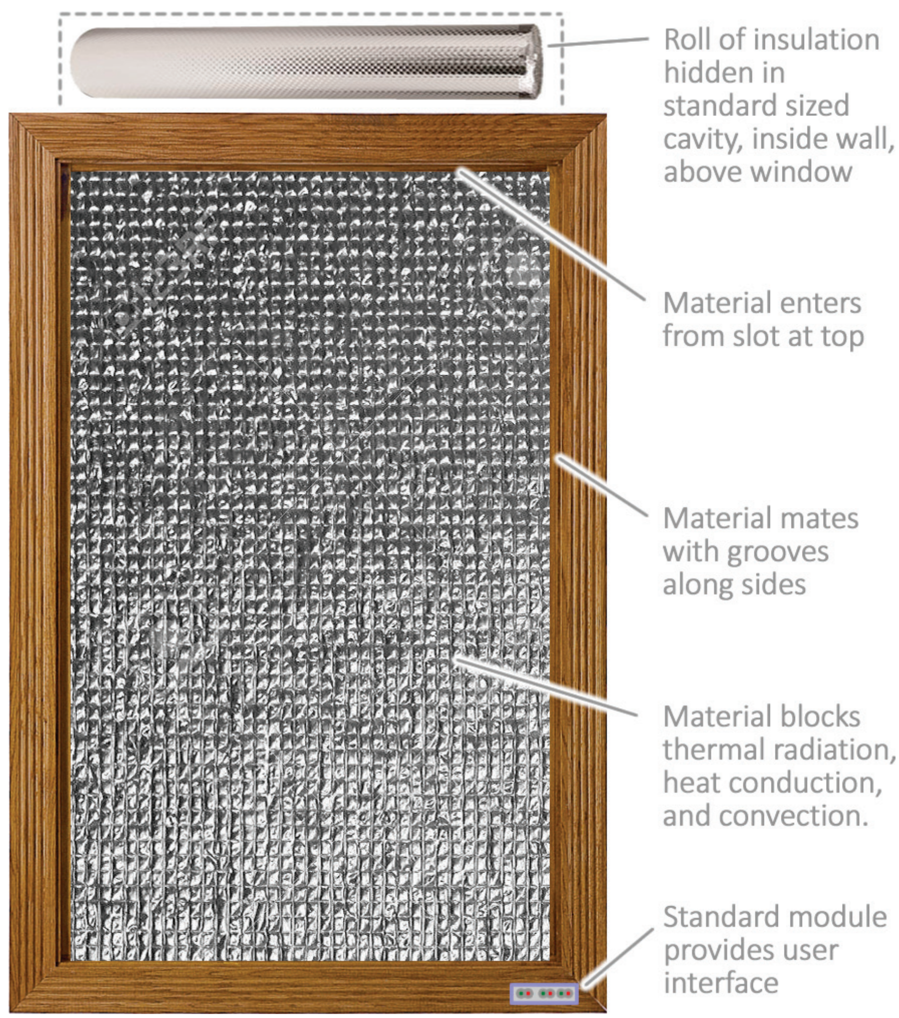
Topic 6a) Develop Standards that Support Motorized Windows

Much energy is lost through wall windows.

In theory, one could have motorized rolled thermal covers deploy over a window when the room is unoccupied. Products such as these *do* exist. Yet they do not sell well since there is no standard way to attach to a building, which dramatically increases cost.

Also, the components are not standardized modules, which means the building degrades over time when a module fails and a replacement is not available.

Much of this could be changed with standardized plug-and-play modules that support motorized windows.



There is a technique called "passive heating" which involves allowing the sun to enter the building and heat the floor.

However, windows leak heat when the sun is not shinning. Motorized thermal covers enable one to toggle between letting sun in and blocking heat loss; making passive heating much more feasible.

Lights saw a transformational improvement when we moved from incandescent to LED. We have not yet seen a transformational improvement with windows. Perhaps this is it?

All devices must be 99.999% reliable, which entails no wireless, no power line communication, and no batteries. For ideas on how researchers might tackle windows with motors, click here.

Topic 7a) Reduce cost of Installing a Ground Source

If one circulates ~58°F ground water through a heating/air conditioning heat pump, instead of outside air, they can reduce space heating/cooling energy consumption approximately 2 to 1. The problem is it is expensive to install underground piping through which one circulates water. The aim of this project is to reduce the cost of installing this pipe. Researchers design machines that utilize an independent drilling mechanism that worms its way into the ground instead of the traditional method of drilling (e.g. rotate heavy pipe that traverses entire length of drill hole with ~10,000 Kg of downward pressure). Researcher are not responsible for building the actual machine, and instead work with computer simulators to design a system "on paper" that works reasonably well. All designs, simulation files, reports and calculations are free and open; allowing others to build on this work. For ideas on how this might work, click here.

Topic 8a) Create CO_2-Reduction-Per-Dollar Website

There are many things that private individuals, small companies, large companies, power companies, state gov't and federal gov't can do to reduce CO_2 (six groups). Researchers produce lists for each of these groups that shows CO_2-reduction-per-dollar for a variety of activities, sorted, with highest reduction at the top.

This is based on past data, and not projections of future costs (which are sometimes later found to be inaccurate). For example, if MA built a solar farm last year for $1M, then one item on the list might be to build more of these, using this $1M value.

The list might show solar farms in rural areas with cheap land, low labor cost, and existing power wires to be more reduction per dollar than solar farms on expensive land near a large city and far from power wires. The natural inclination is for a city to focus on their own electricity, yet this list might show there is more reduction-per-dollar if they focus on someone else's electricity.

In another example, the data might show solar above parking lots as having relatively low reduction-per-dollar due to the cost of heavy structures that support high wind loads.

Researchers produce a website that displays the lists, and supports drilling down to receive more information. This provides an easy tool for decision makers who are not comfortable with dense technical reports. The website assumes the reader is not an engineer or scientist.

Communities are looking at spending money to reduce carbon emissions, and this tool would help them spend wisely.

Topic 9a) Study Methods for Increasing Safety at Existing Nuclear Power Plants

Researchers consider ways of making existing nuclear power plants safer; including proposing new safety standards.

For example, a researcher might propose that a nuclear reactor is to be capable of emergency shutdown to a cooled state (which might take 48hrs) with no human intervention under difficult conditions that include hurricane, tornado, 100m tsunami wave, 20m of floodwater, truck bomb explosion, light airplane attack, rogue operator, no operator, and armed insurgents. Also, it might state that all infrastructure within the hardened system is assumed to be intact (i.e. within 1m thick cement containment building).

Currently, reactor buildings utilize batteries that often do not contain enough power to circulate coolant for the required shut-down period. Subsequently, many reactors are dependent on infrastructure outside the 1m thick walls to turn off.

Given proposed safety standards, researchers look at what can be done to upgrade existing plants to meet new standard. For example, one might place 1m thick bunkers adjacent to the containment building with diesel generators to provide power for several days while the reactor cools. Researchers do rough designs and cost estimates of upgrades.

There are currently ~100 nuclear reactors in the USA and a radiation release might spread to MA. Subsequently, we would prefer they be a safer.

US nuclear power plants had many safety studies back in 1990s under the IPE (Individual Plant Examination) programs using Probabilistic Risk Assessment (PRA) methodology. First the PRA experts identified possible initiating events leading to nuclear accidents which include small and large Loss of Coolant Accident events (LOCA), Loss of Residual

Heat Exchange, Loss of offsite power, earthquakes, and a few other events. Then PRA examined the plant safety system responses and failure probabilities to develop an event tree to fully understand the survivability of the plants and possible additional counter-measures. Researchers consider building on this work.

This is a paper-only exercise. All documentation, calculations and cost models are free and open; which enables others to build on this work.

Topic 9c) Develop NRC Program That Maintains and Manages Standard Designs of Safer Nuclear Power Plants

The US Nuclear Regulatory Commission (NRC) regulates existing nuclear power plants, in addition to overseeing new construction. Currently, there exist little political support for building new plants; however, as the concern over climate change increases, and the cost of deep decarbonization becomes more apparent, we can expect interest in safer nuclear power to increase.

Currently, the cost of building a new plant is high due to an arduous design verification and approval process. In this initiative, we design on paper a new division of the NRC which develops standard *safer* nuclear power plants. Safer, in many cases, entails moderator molecules that are mixed into nuclear fuel and prevent melt-down. This division commissions firms to design reactors. Subsequently, the NRC owns and controls all IP, including software, mechanical designs, reports, test data, etc. When first utilized, these undergo the same verification and approval process as private firms. Yet after successful completion of one plant, the division makes the standard design available to others, to copy and deploy within a stream-lined approval process, reducing the time and cost associated with building a new safer nuclear power plant.

Researchers publish a report that describes this new NRC division. Researchers do not design power plants and do not create the actual NRC division. This is a paper-only exercise. All documentation, calculations and cost models are free and open; which enables others to build on this work.

Topic 10a) Design 10 TWhr/yr Solar PV Farm that Produces Hydrogen Gas

Instead of each state generating its own carbon-free energy, which is disruptive and confusing, one might look at a federal program that generates everyone's carbon-free energy. For example, one possible USA decarbonization path is to cover 25% of Nevada with solar PV (74K km^2 land, 37K km^2 PV) and then use the electricity to make H_2 gas. This gas could then be transported throughout America to power vehicles, heat homes, and generate more electricity. The electricity generated would be ~3 times more than what America currently generates since this system would be replacing energy we currently obtain from burning natural gas, coal, oil, and gasoline (10.4K vs 3.8K TWhr/yr). The solar parts and labor might cost ~$3.7T ($150B/yr over 25yrs, $0.50/Watt, 7.4TW capacity). However, this does not include the following costs: electrolysis to make H_2 (currently costly), transportation of H_2, maintenance of solar, and land. This solves the following problems: US decarbonization, energy storage (H_2 is storage), limited rare earth metals for many EV batteries (cars run on H_2), significant electrical grid expansion (no longer needed), and disruption to communities from locally based wind/solar/nuclear. The disadvantage is cost -- consumers might see a doubling of energy prices, which is politically unacceptable at this time. In order for this concept to be viable, researchers would need to reduce the cost of electrolysis. Mechanized rollable solar, direct to soil, described earlier in this document, could potentially play a key role in this effort.

In this initiative, researchers design a 10 TWhr/yr solar farm that produces hydrogen via electrolysis. Researchers produce drawings and spreadsheets that calculate a variety of issues, including energy production and costs. Researchers are not responsible for deployment. This is a paper-only exercise. All spreadsheets and documents are free and open, enabling others to build on this work.