

[American Chemical Society AMA] Hi! I am Amanda Morris, an Assistant Professor of Energy Chemistry at Virginia Tech. The Solar Solution! I am here to discuss methods to make solar energy competitive —

Amanda Morris¹ and r/Science AMAs¹

¹Affiliation not available

April 17, 2023

Abstract

Hi Reddit! I am a Professor of Chemistry at Virginia Tech. I was hired as an Energy chemist and my research focuses of solar energy harvesting and storage. At Virginia Tech, I am affiliated with the Center for Energy Harvesting Materials ([link](#)), the Sustainable Energy Thrust of the Institute for Critical Technology and Applied Science ([link](#)), and the Macromolecules and Interfaces Institute ([link](#)). With the American Chemical Society, I serve as an ACS Expert in the field of sustainable energy. In one and a half hours enough solar energy hits the earth surface to power human civilization for an entire year. Remaining challenges that limit the wide-spread use of solar energy are the development of economical solar harvesting materials and advances in energy storage. Along those lines, my research group focuses on two next generation solar cell architectures — quantum dot sensitized solar cells and hybrid bulk heterojunction solar cells. Both of these architectures use inexpensive, nanocrystalline titanium dioxide as the bulk of the solar cell. Therefore, these cells can theoretically be made for a fraction of the cost of a silicon solar cell. Even if the cost of the solar module is reduced, there is still the issue of the intermittent nature of the sun. So in addition to research on photovoltaics, my research group explores methods to store solar energy in chemical bonds. Nature's photosynthetic system — a complex assembly of light harvesting arrays, electron transfer relays, and catalytic centers — achieves just that using energy from the sun to convert water and carbon dioxide into sugars (our stored fuel!). In our lab, we try to mimic the photosynthetic system with metal organic framework arrays. Metal organic frameworks are porous networks of inorganic clusters and organic ligands. The function of the framework (light harvesting, catalytic, etc) can be tuned by the type of clusters and organic molecules incorporated. We are interested in the guiding principles behind efficient light harvesting, energy transfer, electron transport, and catalysis in these arrays. Check out our recent publications in the areas discussed above: <http://pubs.acs.org/doi/abs/10.1021/ja410684q> <http://pubs.acs.org/doi/abs/10.1021/jacs.5b03071> <http://pubs.acs.org/doi/abs/10.1021/am500101u> So feel free to ask me anything about next generation solar cells including dye-sensitized solar cells, quantum dot sensitized solar cells, bulk heterojunction solar cells, and hybrid bulk heterojunctions solar cells, artificial photosynthesis, water oxidation, carbon dioxide reduction, metal organic frameworks, and chemistry. I would welcome discuss around the economic outlook for solar energy. Additionally, I would be happy to answer steps we all can take to reduce our carbon footprint and the role solar energy can play in our own households. Lastly, I am open to discussions around academic career paths and diversity in science. I will return at 11 am ET to answer your questions. [EDIT] I am here with members of my team (Dr. William Maza, Spencer Ahrenholtz (PhD Candidate), Andrew Haring (PhD Candidate). We are ready to answer your questions! AMA! [EDIT] Signing off now (12:15 PM ET). I will try to return to continue the discussions that have started. Thank you for participating! [EDIT] Back on (3:30 PM ET) to try to answer some more questions! Glad to see the discussions kept going! [EDIT] Signing off again (5:18 PM ET). I hope to come back again to answer the remaining questions! [EDIT] I will keep returning to answer any more questions that pop up! Thank you for a stimulating discussion! Signing off (11:30 PM ET)

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ABSTRACT

Hi Reddit! I am a Professor of Chemistry at Virginia Tech. I was hired as an Energy chemist and my research focuses of solar energy harvesting and storage. At Virginia Tech, I am affiliated with the Center for Energy Harvesting Materials ([link](#)), the Sustainable Energy Thrust of the Institute for Critical Technology and Applied Science ([link](#)), and the Macromolecules and Interfaces Institute ([link](#)). With the American Chemical Society, I serve as an ACS Expert in the field of sustainable energy.

In one and a half hours enough solar energy hits the earth surface to power human civilization for an entire year. Remaining challenges that limit the wide-spread use of solar energy are the development of economical solar harvesting materials and advances in energy storage. Along those lines, my research group focuses on two next generation solar cell architectures – quantum dot sensitized solar cells and hybrid bulk heterojunction solar cells. Both of these architectures use inexpensive, nanocrystalline titanium dioxide as the bulk of the solar cell. Therefore, these cells can theoretically be made for a fraction of the cost of a silicon solar cell. Even if the cost of the solar module is reduced, there is still the issue of the intermittent nature of the sun.

So in addition to research on photovoltaics, my research group explores methods to store solar energy in chemical bonds. Nature's photosynthetic system — a complex assembly of light harvesting arrays, electron transfer relays, and catalytic centers — achieves just that using energy from the sun to convert water and carbon dioxide into sugars (our stored fuel!). In our lab, we try to mimic the photosynthetic system with metal organic framework arrays. Metal organic frameworks are porous networks of inorganic clusters and organic ligands. The function of the framework (light harvesting, catalytic, etc) can be tuned by the type of clusters and organic molecules incorporated. We are interested in the guiding principles behind efficient light harvesting, energy transfer, electron transport, and catalysis in these arrays. Check out our recent publications in the areas discussed above:

<http://pubs.acs.org/doi/abs/10.1021/ja410684q>

<http://pubs.acs.org/doi/abs/10.1021/jacs.5b03071>

<http://pubs.acs.org/doi/abs/10.1021/am500101u>

So feel free to ask me anything about next generation solar cells including dye-sensitized solar cells, quantum dot sensitized solar cells, bulk heterojunction solar cells, and hybrid bulk heterojunctions solar cells, artificial photosynthesis, water oxidation, carbon dioxide reduction, metal organic frameworks, and chemistry. I would welcome discuss around the economic outlook for solar energy. Additionally, I would be happy to answer steps we all can take to reduce our carbon footprint and the role solar energy can play in our own households. Lastly, I am open to discussions around academic career paths and diversity in science.

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Can you explain how artificial photosynthesis works as opposed to traditional solar technology?

[ProfThadBach](#)

Traditional solar technologies, as many of us view them, are solar-to-electricity generators. For example, in a silicon solar cell, light is absorbed by the silicon to create an electron/hole pair. This electron/hole pair is separated and the electrons enter the external circuit (wire) producing electricity and ultimately powering electronics. Alternatively, artificial photosynthesis harvests solar energy for the purpose of storing the energy in chemical bonds. That is, the electrons and holes created by light absorption are used to drive chemical reactions - more specifically, the oxidation of water and reduction of carbon dioxide or protons. The end products are oxygen and fuels like hydrogen or methane. These fuels can be used in a traditional sense to power our cars and homes, but the process would be overall carbon neutral. - Prof. Amanda Morris

Do any of our current solar panels "earn" off the emissions produced by manufacturing? What about tracking panels?

[bounding_star](#)

Life-cycle assessment (LCA), as a tool, has been developed to evaluate environmental impacts of products and power-generating technologies. According to the National Renewable Energy Lab (NREL), 60%-70% of emissions from solar panels come from processes including raw materials extraction, manufacturing, and installing the solar panels. Also according to NREL, the time required to "pay back" the emissions is estimated at 3-4 years for common solar panels. The warranty length of these solar panels is typically 25 years, much greater than the time required to "earn off the emissions produced".

Ph.D. candidate in Prof. Amanda Morris' lab

<http://www.nrel.gov/docs/fy13osti/56487.pdf> <http://www.nrel.gov/docs/fy04osti/35489.pdf>

How important do you see complete grid independence as a factor in the widespread adoption of solar power ?

[Bokbreath](#)

Total grid independence would require the homeowner to 1. produce enough electricity to offset total electricity usage and 2. store that energy for dispersion when the sun is down. The technology required to support the energy storage component currently lags behind solar cell technology. The efforts of Tesla (<http://www.teslamotors.com/powerwall>) in the area of home battery technology is pivotal in accomplishing this goal. However, currently cost is prohibitive in both size of solar installation (harvesting enough energy to offset all usage) and battery storage.

Nationally, we have already seen an increase in residential and commercial applications. So, from that standpoint, I do not think one requires the other. In fact, commercial applications that rely on the grid have the potential to make substantial contributions to the energy market in the near future.

-Prof. Amanda Morris

Welcome Professor Morris,

Could you give a laymen's overview of how solar cells operate and how we currently store

energy in case readers aren't familiar with the science/technology?

Thank you,

[adenovato](#)

Absolutely! However, I also point readers to the following article by Scientific American that does a very good job explain how solar cells work (<http://www.scientificamerican.com/article/how-does-solar-power-work/>).

The most common solar cells that are currently on the market are silicon solar cells. Silicon is formed completely of silicon atoms bonded to each other by sharing electrons. Upon light absorption an electron in one of those bonds is excited - promoted to a higher energy state equivalent to the energy given to them by the light. This electron can move more freely through the silicon material and produce a current. However, for solar cells, we need these electrons to enter a wire that would run to the device we would like to power. And, in natural silicon there is no driving force - motivation - for electrons to do so. Therefore, silicon solar cells are made of two types of silicon sandwiched together. Scientifically, they are called p-doped and n-doped silicon. In layman's terms, we have put other atoms into the silicon structure. In n-doped materials, these atoms have more electrons than silicon and in p-doped materials, we add atoms with less electrons. By putting these two materials in contact, we essentially make a slide for the electrons to flow down. Thus, we chemically gave them the motivation to move. The electron will then flow through the wire and return to the solar cell with less energy (the energy used to power your electronic device) and then the whole process starts all over again.

Currently, the most common form of energy storage is in batteries. Batteries convert chemical energy into electricity. Batteries are comprised of three major components an anode, a cathode, and the electrolyte. A chemical at the anode gives an electron to the external circuit and releases an ion into the electrolyte. This electron then returns to the cathode after powering your device. Disposable batteries do this until the reactants are "used up". More specifically, until the chemical potential at the anode and cathode are the same. Some batteries, can be recharged and this is the process we are interested in to store energy. We can force the electrons to move in the opposite direction (from cathode to anode) with extra energy (say from a solar cell) and regenerated the chemicals needed to run a battery in the traditional sense.

- Prof. Amanda Morris

With electric cars and solar power starting to come into mass consumer usage. Do you think it is fair for the government to invent new taxes to make up for lost tax revenue from more traditional forms of energy like gas and coal.

[damitdeadagain](#)

Given a large portion of the taxes incurred by the government are meant to be used towards maintaining infrastructure, we think it only makes sense that the revenue lost from taxation of gas and coal should be recuperated from sales and usage of electrical and solar power. These taxes may be circumvented if using independent power storage units (e.g. for solar harvesting systems); however, this technology is still being developed and has not fully matured.

- postdoctoral research assoc in Prof. Amanda Morris' lab

Can you go a bit more in depth about your "photosynthesis" storage system? Would it store solar energy for future reuse or would it store electricity from any source?

Also, even if I suppose it's too early in your research, can you give a ballpark figure of what kind of performances you expect (storage efficiency, energy stored per kg, maximum power achievable per "unit" (volume? mass?))

Thanks!

[lucaxx85](#)

In my research, we are actually open to both options. If you check out my website (www.ajmorrisgroup.chem.vt.edu), on the research tab I have a schematic of an artificial photosynthetic array. This architecture directly harnesses solar energy and stores that energy in chemical bonds namely methane. However, you don't have to use the materials in that configuration. If you took the components on the ends (they are the catalysts responsible for driving the chemistry) and instead placed these in an electrochemical cell, we could use any energy source to drive the reactivity and get the same end result - energy stored in the bonds of methane. So, both options are possible and ultimately cost and efficiency will drive the end-product design.

The questions you ask regarding efficiency come down to what bonds we store the energy in. If we chose butanol, we get ~39 MJ/kg and ~30 MJ/L. If we choose methane, we get ~52 MJ/kg but very small volumetric energy density.

-Prof. Amanda Morris

I actually worked in a lab in undergraduate (UMD Class of 2010, Chemical Engineering) creating potentially photo active copper oxide films using chemical vapor deposition for water electrolysis ([link to my professor's site and our paper](#))

I now work at the USPTO examining patent applications for thin film deposition, particularly sputtering and PVD. So my question: are there any particularly interesting techniques used in the creation of the next generation of solar cells?

You guys are awesome. I love research, particularly in this area, and I'm sad I'm not still doing it.

[twyphoon](#)

Interesting that you ask! Currently, the most exciting solar cell materials being explored are perovskites. In just 3 years of research, these cells have already reached a maximum efficiency of 20.1%! This material could be the key to cost competitive solar technology (if some other kinks - like stability - are worked out). Now this relates to your questions because it has been demonstrated in the literature that the film preparation method has a large effect of the performance of the cell (J. Phys. Chem. Lett. 2013, 4, 3623–3630). This somewhat makes sense. We know to make a good silicon solar device we need a "clean room" free from contamination. However, with perovskites it seems they are tolerant to a larger degree of defects. These materials can be deposited in a variety of solution and vapor-assisted techniques that may be of interest to you.

Thank you for staying interested and educated in the field beyond undergraduate! We certainly need patent examiners to move the field ahead!

-Prof. Amanda Morris

So one of the things often cited in why solar energy has limited potential is due to the limiting ability to capture the sun's energy. Your approach of imitating photosynthesis on an organic metallo framework is interesting, but I'm curious because natural photosynthesis converts ~3-7% of the solar energy into chemical bonds. Do you hope to surpass this number? And if so, how?

Also on a side note - how easy is it for you to choose what chemical bonds the energy is stored in? If you could produce a lot of methane from it, it would lead to a lot of new opportunities in hydrogen fuel cells as well.

[gojqvu](#)

Excellent points! You are spot on that natural photosynthesis is only 3-7% efficient and actually the catalytic centers in plants fall apart once every 30 minutes! So, our goal is to do just what you mention - increase the efficiency and the stability. There are many strategies that researchers take to address these areas. For example, plants are green, so by simply making a black artificial photosynthetic system we can harvest more of the solar photons. This would lead to higher efficiency. Another example, to address the stability concerns many are investigating metal oxide catalysts. These materials are incredibly stable to a variety of conditions. I personally, hope to provide a rigid, stable framework comprised of individually optimized structures. Tuning light absorption and catalytic rates through synthetic manipulation. I personally feel metal organic frameworks have some advantages in this area:

- They can be prepared through layer-by-layer deposition enabling seamless integration of light harvesting, charge separation, and catalysis in one array
- They exhibit aqueous stability over a wide range of pHs (pH 2-11)
- They are the highest surface area material known. We can exploit this surface area to have a greater degree of catalytic centers per geometric area. Thus, producing more catalytic products as compared to traditional approaches.
- The molecular nature and crystallographic orientation afford synthetic diversity and structural rigidity for systematic studies and control over reaction mechanisms.

Now for your second question, what chemical bond do we want to store the energy in? Well, that very much depends on the application. For stationary applications hydrogen can work beautifully. It is extremely high in energy density (120-144 MJ/kg). However, for mobile applications, storage remains a slight technological roadblock. For these applications, a liquid fuel and higher volumetric energy density is favored. For example, butanol (29 MJ/L) would be ideal. However, as chemists, we are still searching for a method to make butanol directly from carbon dioxide selectively (no side products) without needing intense temperatures or pressures.

-Prof. Amanda Morris

Hey Prof. Morris! Long time no see!

Why the focus on bhj/dsscs? It's already a crowded field, and has been that way for almost a decade. What do you hope to do that is new in that area?

[itsajug](#)

It is certainly true that dye sensitized solar cells and bulk heterojunction solar cells are active and crowded areas of research. However, we work on slightly different architectures.

1. We work on quantum dot sensitized solar cells. To understand the reasoning behind our research in this area, I must introduce the concept of maximum theoretical efficiency with regards to a traditional single junction solar cell - 32%. QDSSCs could break this barrier - with a maximum efficiency of ~40%. However, more research is needed to learn how to actually harness this excess theoretical energy through component design and optimization. WE would on the optimization of the redox electrolyte - responsible to completing the circuit within the solar cell device.
2. We work on hybrid bulk heterojunction solar cells. These devices replace the fullerene acceptors in BHJs with titanium dioxide. In traditional BHJs, there is the possibility to get electronically isolated fullerene domains that do not result in photocurrent. From the standpoint of solar cell design, it may be advantageous to provide an acceptor electrode with continuous contact to the external circuit. This role could be filled with titanium dioxide. However, historically these devices have performed poorly. We are trying to understand the fundamental reasons why this is and see if we can achieve hybrid BHJs with efficiency better than traditional BHJs. Indeed, we feel that we may have uncovered the fundamental reason these devices have performed poorly (<http://pubs.acs.org/doi/abs/10.1021/am500101u>) and are now working on tuning devices to

achieve record efficiency.

I hope that through our fundamental studies we uncover scientific principles that can be applied across multiple solar cell architectures and facilitate the development of competitive solar technology.

- Prof. Amanda Morris

Hi thanks for doing this! One of the main problems with solar is obviously the off time when the sun is covered and at night. What are some exciting solutions to this problem in terms of energy storage? Are there any feasible solutions that are close to commercial availability?

[nerd_terd](#)

There are few commercially available systems for energy storage. The most common method is to use a whole house battery. I already had referenced Tesla's PowerWall, but there are other companies in this market as well including Samsung and SolarCity. Some residential costumers also have installed electrolyzer systems. These devices take the excess electricity generated by solar panels during the day to produce hydrogen from water (water splitting - or sometimes called a version of artificial photosynthesis). The hydrogen can then be used in a fuel cell to produce electricity overnight. These electrolyzers are currently pretty simple, comprised of stainless steel electrodes immersed in basic water.

In terms of exciting new discoveries, these are mainly coming in the area of carbon dioxide reduction to form carbon-based fuels. That could then be used in combustion to produce energy when needed. The key to making this competitive is selectivity. When one goes to reduce carbon dioxide, a mixture of products can be obtained carbon monoxide, methane, methanol, formic acid. Researchers are manipulating catalysts to produce a single stream of value-added product. I would keep my eye on this field in the near future.

-Prof. Amanda Morris

Sorry for the maybe silly question, I haven't studied semiconductors in the last 4 years and maybe I'm not up to date.

I was under the impression that quantum dots titanium oxide cells had a too large gap. What's the current status of this technology? Which efficiency can you get (both in lab and final setting)

[lucaxx85](#)

You are on the right track. Titanium dioxide has a very large band gap (3.2 eV), which imparts its white color. This means it absorbs no light in the visible region of the solar spectrum - where the majority of sunlight is! So, we cannot simply make a solar cell out of titanium dioxide. You are also correct that some quantum dots have band gaps that are not ideal for solar harvesting. For example, cadmium selenide is yellow to our eyes, which means it absorbs a small fraction of visible light. However, other quantum dot materials, namely lead selenide and sulfide, are black (like silicon, small band gap) and, therefore, can effectively harvest the sun's energy.

-Prof. Amanda Morris

Hi Prof. Morris,

I'm currently a PhD student in an organic photovoltaic research group. It seems to me that it will be extremely difficult for alternative solar technologies to break into the market and compete with existing silicon and CdTe solar tech for large scale power generation. However, I think that smaller niche markets may be more easily accessible to silicon-alternative solar (perovskites,

organics, QD's, DSSC's) in the near-term, and may be used to establish a fabrication infrastructure. When projecting the future of these technologies, what are some of the possible "gateway" applications you see, and how high might the ceiling be for a non-silicon solar technology?

Quoonit

Excellent question and spot on! The manufacturing advantage the silicon has will make it very difficult for new technologies to break into solar applications. I, personally, have my fingers crossed for perovskites though.

In terms of niche applications, solar backpacks, stained glass solar windows, solar powered lamps are all technologies where the solar cell types you mentioned can be and have been applied. My personal favorite are Sony's proto-type Hana Akira lamps. Unfortunately, I do not believe they were ever sold on the market. Michael Gratzel (the inventor of the modern DSSC) had a company produce a solar backpack under his name (found here - <http://gcell.com/product/graetzel-solar-backpack>). They are currently in stock! You can also google stained glass solar windows and see that some buildings are incorporating this technology.

-Prof. Amanda Morris

My daughter is in her 3rd year for B.S. in Chemistry. She wants to focus on renewable energy. What direction should she take when obtaining her Master's? Any school suggestions?

BakoMan

My personal opinion is that she should skip the Master's and go for a PhD. Most nationally renowned chemistry departments only accept students into the PhD program and the Master's program secondary. There are many great schools for renewable energy research. My personal favorite is, of course, Virginia Tech. However, to provide some options - Northwestern University, University of North Carolina Chapel Hill, and CalTech/UC Berkeley/Stanford all have major funding in the form of "renewable energy centers" and, therefore, attract top talent.

The best way to find direction at the undergraduate level is to get involved with undergraduate research either at your daughter's home institutions or through Research Experiences for Undergraduate programs funded by the National Science Foundation. Have your daughter look into these. When she gets her feet wet, she will find her passion and discover the leaders in the area.

-Prof. Amanda Morris

Hi, I am currently a student studying Chemical Physics and am very interested in researching Solar Cells in the future. However I feel like there is this impossible barrier to get over between people who understand Solar Cells and people who don't. I have read through around 20 different peer reviewed articles on Solar Cells, trying to get a better understanding of what kind of research is being done today. But I struggled trying to understand several of the articles, it sometimes felt like I was reading a completely different language. That's why I am wondering if there is a class or something that can help aspiring researchers understand the jargon and methodology used in current solar cell research today? Thank you for taking your time answer all the questions asked today!

samerty7

Hello and thank you for your question! I agree that learning the ins and outs of renewable energy can be challenging. At the undergraduate level, most learn the basics and aren't shown how these concepts translate to complex systems or future technologies. There are many online courses available in solar energy basics (for example, www.solarenergy.org offers RE100). However, having never taken these courses I cannot be sure of their content.

I am very glad that you brought this idea to the forefront. I have a course proposal into the National Science Foundation, where I will design a course to do just what you wish - teach at the introductory level renewable energy to students from different backgrounds - economics, math, environmental science, etc. I do plan to offer the course online. So, hopefully I can provide a resource for you in the near future! Stay tuned!

-Prof. Amanda Morris

Why is it that I must send the energy collected by the solar panels on my house to the power company, as opposed to having the energy be used directly by the house?

[benignbenignandahalf](#)

The energy that you generate from solar cells on your roof is consumed by your house commensurate with the energy you are consuming at the time. If you happen to not be consuming much electricity at the moment, then the excess energy is then sent back to the electricity company.

-Prof. Amanda Morris

How long until I can buy watts which use this technology at my hardware store?

[zyzzogeton](#)

In terms of solar energy technology, there are low power applications that are available at the hardware store (think about the solar path lights). Also, small systems to power an RV for example can actually be purchased in the form of a solar kit from places like Home Depot and Lowe's (<http://www.homedepot.com/b/Electrical-Alternative-Energy-Solutions-Solar-Power-Solar-Panels/N-5yc1vZbm31>).

However, for large solar panels the installation of these requires a lot of training in electrical installations. Solar panels produce DC current and so large power inverters are needed to tie the solar panels into your home electricity. If you are electrically inclined, you can buy all of the components online through suppliers.

-Prof. Amanda Morris

Prof. Morris: Can you explain challenges facing artificial photosynthesis in space?

[pepperpeterson](#)

This is not something that I have particularly thought about before. So, thank you for getting my mind going.

So, what challenges would we face if this was something we wanted to achieve. Well, first there is the solar output. Our atmosphere does a very good job of filtering out harmful UV rays from the earth surface. Many of the materials currently used for artificial photosynthesis are not stable to the harsher conditions in space. That said, titanium dioxide is very stable and would actually perform better with a larger amount of UV photons. The big question would come down to is it worth it. We would have to send up pressurized electrolyzers with liquid water (and carbon dioxide) to create a fuel that to be used would have to transported back down to the earth's surface. Space travel is expensive, so I would say right now that is the sticking point. Would it every be a cost viable approach? I am just not sure.

-Prof. Amanda Morris

What wavelengths are you trying to emit from the quantum dots in the QD sensitized solar panels?

[StarkTheWolf](#)

We actually don't want to emit any light. To make a QDSSC work, we want the dot to absorb light and then have that excited state be quenched by injection of the electron into the electrical conduit, TiO₂. So, for solar cell applications in contrast with display and sensor technology, we are interested in the absorptive properties as opposed to emissive properties. Thank you for the question!

-Prof. Amanda Morris

what challenges are currently being faced in artificially recreating the photosynthetic process?

[chewychipsahoy](#)

Nature evolved over millions of years to create an perfectly imperfect photosynthetic centers. These elegant proteins are complex assemblies of light harvesting arrays, electron transfer relays, proton transport relays, and catalytic centers. They are matched to keep up with the photon flux. And even with all that engineering, they still are only 3-7% efficient and not very stable.

As chemists, the biggest challenge we face is the integration of all the components. We have many examples of excellent catalysts. We can harvest light effectively. Proton transport membranes? Yup, we have Nafion. But, how to combine these into one device that isn't limited by the efficiency of one component is a difficult task. This is definitely an area of current research, but it's also important that we realize we can always improve on all aspects of artificial photosynthetic chemistry. So, even better catalysts, more stable light harvesters, and more options for proton transport should also continue to be a major research thrust.

-Prof. Amanda Morris

Hi Prof. Morris. I hope you are having a good day. How do you think the next generation of solar cells may impact environmental stewardship, alongside the advances in home battery systems & storage? Thank you!

[mlok](#)

Impacting a persons opinions/habits which include environmental stewardship with a technology is quite hard. Cost is an incredibly important factor in decision making. So, a new technology will not be widely adopted if the cost is prohibitive, regardless of most people's stated priorities. I think in the end if we can provide a cost competitive option to current fossil fuel technology, more people will buy solar installations. Is this truly impacting their opinions of environmental stewardship? I think that will be hard to measure. They may have always wanted to protect the environment but not had the means. So, I think next generation solar cells will enable those environmentally conscious to finally make the impact they have wanted.

-Prof. Amanda Morris

The Large Hadron Collider has made enormous strides since re-opening. Will any of the experiments there contribute to sustainable energy?

[PM me if you dare](#)

The Large Hadron Collider (LHC) at CERN has provided insights into the components of matter and how we understand the physical universe. The LHC is 17 miles long and allows particles to be collided at 13 teraelectronvolts (TeV). Annually, CERN requires 1.3 terawatts of electricity to operate, which is enough to power 300,000 homes a year in the UK. The amount of energy the LHC requires to get particle speeds to nearly the speed of light is incredibly high, making a reasonable energy output from the instrument difficult. In the near future, the researchers at CERN seem focused on colliding particles at previously unattained energies in order to study new particles. Currently, the energy required to

make these particles is greater than the energy output. In theory, chemical bonds are a good way to store energy, but for these particular particles, this is not feasible given the tremendous energy required for their generation. -Ph.D. Candidate, A. Morris's lab