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Science AMA Series: Hi Reddit, I'm Wilson Smith, an Associate Professor of Chemical Engineering at TU Delft in the Netherlands. My group studies the conversion of sunlight, water, and CO2 into chemicals and fuels, AMA!

Dr$_Wilson_Smith^1 and r/ScienceAMAs^1$

[1]Affiliation not available

April 17, 2023

Abstract

Hi reddit! I'm Wilson Smith, an Associate Professor in the Department of Chemical Engineering at Delft University of Technology in the Netherlands, studying solar energy. My team researches various ways to convert solar energy into electricity and chemical fuels using only water and CO2 as the raw materials. These processes try to replicate what nature has done for over a billion years in photosynthesis, and thus this process is sometimes called 'artificial photosynthesis'. However, plants have generally very low efficiencies (˜1%), so we try to find ways to beat nature using only cheap and abundant materials. Recently, we were able to achieve an efficiency of 12.7%, but still have our work cut out for us. Our ultimate goal is to design systems and devices that can help contribute to the global transition to a renewable energy society that is sustainable and clean. You can catch up with our work on our group website (www.smithsolarlab.com), or follow our updates on twitter (@smithsolarlab). Outside of r/Science, I've been known to lurk in r/Phish and r/ASOIAF, and went to high school with Jean-Ralphio from Parks and Rec. I'll be here as long as it takes to answer your questions about solar fuels, sustainable energy technologies, and what its like to set up a research lab (and life) in Europe as an American. Lets get this going reddit, ask me anything! I'll be back at 1 pm EST (10 am PST, 6 pm UTC) to answer your questions, ask me anything!

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REDDIT

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DR_WILSON_SMITH R/SCIENCE

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How much money do you have to invest to get 1 kWh of energy? And what is the reason plants aren't this efficient, yet your team is?

Just_Dont_Reply

Hi, thanks for the great question! This is a bit complicated for a few reasons, but I'll try my best. First, you want to know cost per kWh of energy. This depends on lots of factors, especially with the term 'energy', which we should be careful to separate from 'electricity'. Putting a solar panel on your roof will deliver electricity, but when you pump your car full of gas, thats energy (very over-simplified comparison). The point being a gallon of gasoline if very cheap, and for the artificial photosynthesis technology, the overall price is very closely tied to the cost of electricity. So if you get very cheap electricity (for example by a photovoltaic in a very sunny part of the world, around noon, with subsidies), then your 'fuel' from these systems could become cost competitive. However, if you aren't in the ideal place (or time), then the cost is lower for conventional fossil fuels. As the field gets better at this scientifically (improving efficiencies, lowering cost, improving lifetimes), this balance will shift. Regarding nature's efficiency, its a matter of perspective. I like to think of it in terms of the daily life of a plant. Plants don't need to move around, pick up heavy things, etc., and so they actually don't need much energy to survive. If you look at a big old Oak tree, they get to be so big, but it takes 100 years to get that size. Plants are not in any rush, and don't require a lot of energy to survive. That is perhaps

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why plants only absorb a small portion of the solar spectrum, because its all they need to absorb to be able to maintain cellular structure and store sugars during the night. We (as humans) aren't as patient as plants, and like to use lots of energy to enjoy life. Therefore, only converting 1% of sunlight to usable energy isn't enough to take care of the enormous scale of energy covering the whole planet.

What were the biggest factors in your decision to pursue an academic career in Europe? What aspects of the academic culture there (advising, teaching, grants, etc) are most different/surprising?

boonamobile

Hi and thanks for the question that is totally different from the others! Its a long and complicated story that I'll try to shorten here. Basically I graduated with my PhD and got married within the same month in May of 2010. My (amazing) wife and I traveled a bit to relax after a long few years of my PhD, and an opportunity came up for a postdoc in Paris. We both love Paris, and the position was at a really good school on a topic that was very close to my previous work, so it seemed like a natural fit. We moved there and after about 1.5 years, this new opportunity came up for a tenure-track position in the Chemical Engineering department at TU Delft, so I threw my hat in the ring and the rest is history! The academic culture is very different over here in every aspect. The students in Europe are a bit more laid back and (typically) work more of a 9-5 in the lab, though theres always variations of that. My experience in the States was more of the 80 hour week in the lab, so this has been a constant struggle for me to still adapt to here. Teaching is the same for me, big class of students, and fortunately the laws of thermodynamics are the same everywhere in the world (and Universe as far as I know....), so that aspect transfers well. For funding, I think I benefit a lot from my current position. I hear a lot from my American colleagues about how hard it is to get funding, and in a country of over 300 million, with a plethora of incredible researchers, theres simply a surplus of talented people and a finite amount of money that drives intense competition. Where I am now, I have access to funding opportunities both within Europe (EU commission) and within the Netherlands (from various national science foundations). So I have access to more funding calls than some in the US have, but theres still a rigorous process of writing proposals, defending them, and hoping that a review panel of internal reviewers like my ideas! One other thing that I find unique (and really great) here in Holland is the strong ties that academia have with industry. I do a lot of research with Shell, and many of my colleagues have strong industrial partnerships, which helps drive scientific and technological advances from a practical motivation that (in my opinion), helps progress research. For me, this is unique and was unexpected, but I certainly benefit from it.

What are your thoughts on the recent news that CO2 emissions have reached an all time high and are believed to never go back down to below 400 PPM within our lifetime? Also do you agree with the statement a scientist said (I forget his name) that said up to one-fourth of all species on earth could potentially be extinct by 2050? The same study also said that by the year 2100, there is a very large possibility that any culture or life near the coast line (within 20-30 miles I do believe) will be required to relocate due to the increase of melted ice causing the water levels to rise to new heights, effectively nearly eliminating the current coast lines.

Edit: a word.

Edit #2: adding on slightly

rainbowsieger

Thanks for the great question! We are at a peak of CO2 emissions, since we've never before had as many cars, houses, factories, and most importantly people ever before on Earth. We've passed the 400 ppm threshold, and certainly this will not come down in our lifetimes. This actually won't go below

400 ppm for several centuries (or even longer), unless we start taking it out of the atmosphere. To address this we need two key things to happen: (1) we need to remove CO2 from the atmosphere, and (2) we need to keep it out of the atmosphere! Even if we make carbon-neutral technologies, this will not be enough to address this problem, so we really need to get the CO2 out, and keep it out. Regarding species going extinct, that may or may not be true, but this also depends on how you count species. I'm sure theres millions of species of insects (see the other AMA going on in parallel right now), so discussing total number of species may not be the best comparison. Certainly a lot of animals are having a hard time adapting to the changing climate, but we should also put this in a long term perspective on a time-scale that is more relevant which is on the orders of millions or even billions of years. The Permian mass extinction wiped out 90% of all species on Earth, yet here we are today with an abundance of species in the ocean, on land, and in the air. Generally extinctions take 10's of millions of years to ebb and flow, so discussing mass events happening in the coming decades is not only unprecendented, but also impossible to predict. Coast lines will also definitely move, but I don't know if 20-30 miles is accurate. In any case, a vast majority of people live within a few miles of coastlines for obvious reasons, and when the oceans steadily rise there will be mass migrations away from what is now the coast, to what will be the coast. This won't only be a human migration, but we will also need to move infrastructure on an enormous scale.

Does your team see any potential using CSISPR gene modification techniques to achieve your goals?

adismail

Thanks for the question! We only work on inorganic materials (like semiconductors, metals and metal oxides), so gene modification is not in our wheelhouse. In general, inorganic materials have proven to be a bit more stable than organic counterparts, so our lab only uses inorganic materials (though there are still cool uses for organic materials in energy conversion and storage!)

Hello,

How long do you think it will be before electrolysis derived hydrogen can compete with hydrogen synthesized from fossil fuels? Could an increase in demand for hydrogen energy in the present times actually serve to strengthen fossil fuel companies?

What is it about your membrane that makes electrolysis more efficient?

Thank you for your time sir!

peaceoutwhat

Hi, thanks for the great question! Right now it all comes down to cost. Current methods of hydrogen production center around steam methane reforming (SMR), which is incredibly efficient and incredibly cheap. However, it also produces a lot of CO2 (which is bad). So for 'clean' hydrogen to compete, it needs to be very very very (very very) cheap. A lot of really smart people have worked on technoeconomic analyses of this technology and a few conclusions of interest are: (1) the major effect of price is tied to the cost of electricity, and (2) the balance of systems strongly outwieghs the cost of active materials (i.e. the system itself with pumps, tubes, etc., cost significantly more than the catalysts used to split water). Using these two conclusions, it means we need major engineering solutions to this problem in addition to materials scientists working on finding new catalysts. The hidden variable in these situations is political, and can be changed (almost) with the stroke of a pen. If renewable electricity and electrolysis received substantial subsidies, and methane/fossil fuels received none anymore, then in a very short time clean hydrogen could be more competitive than current production means. The most promising places to watch for this right now are in Germany and Japan. Germany has promised to build a large (~300 unit) infrastructure for hydrogen fueling stations across the country for fuel-cell vehicles, many of which will be produced in Germany. This is interesting because it seems the automotive industry will be the main driver (pun intended) for the emergence of the hydrogen economy. On the other hand, Japan has lead the way in establishing their own hydrogen economy (expedited after the Fukishima disaster), as a way to power their country which does not have many natural energy resources. In fact, if you watch the 2020 Olympics in Tokyo, they plan to unveil a large hydrogen powered infrastructure, including the entire Olympic village! This will be a much more welcome talking point about the location of the Olympics than Zika and clean water!

Our membrane is actually not special (in general terms), but is a case of taking an already established material in one field and applying it to another. The bipolar membrane (BPM) has been used in electrodialysis on an industrial level for a few decades, but until the past 1/2 years, never for electrochemical water splitting (or CO2 conversion). The reason it works so well in these new applications is because it allows the ability to completely separate the anode and cathode materials for an electrochemical reaction. This is important because many anode materials work very well in a base environment, and many cathodes work well in an acidic environment. Until now, one or the other material has had to suffer form being in a non-ideal environment, or a neutral solution has been employed to try and find a middle ground. Now, using the BPM, we can operate an anode in strong base, and the cathode in strong acid, all while not introducing any significant thermodynamic losses, and actually improving the overall cell stability. Finally, by using this membrane (or any membrane for that matter), the hydrogen/oxygen cross-over is significantly reduced, so the products of the reaction are separated by the two compartments, thus giving the overall cell built-in safeguards from mixing the two gases (thus preventing it from going BOOM!).

What would be the (in your opinion) most useful application of CO2?

Huntylicious

Hi, thanks for your question! To me, the most important thing is that we get CO2 out of the atmosphere, and keep it out! We can use CO2 for almost anything that fossil resources are used for today. For example, we don't only use gas/coal/oil for fuels, they also make most of the things we use in our everyday life including our clothes, cars, furniture, polymers, etc. Anything that has carbon in it is therefore able to be made from recycled CO2. So to me, the most important thing is first get it out of the air. Second, keep it out. I wouldn't mind a clothing line made from recycled CO2, but there are probably a lot more useful things we can do with it, as long as we keep it out of the atmosphere.

Hi! I am currently studying chemical engineering in college (freshman). What should I expect job market wise by the time I graduate? Any suggestions while I am so early in my studies? Thanks for your time.

Qtoastntuger

Hi there! This is a great question, and fantastic that you are already thinking about it! The job market in 3/4 years will look similar to what it is today, i.e. no major technological innovations will reshape a trillion dollar industry in such a short time. However, I would think more long term if I were you. In the coming decades, the chemical engineering landscape will look very different than it does today, and thus I think you should try to anticipate what that will look like. To me, there will be a shift to renewable energy conversion and storage, and for a chemical engineer that means a lot of process control issues will be the same, but the chemicals/compounds that are moved and converted will change. Luckily, whether we use fossil fuels or renewable resources, all of these will require chemical engineers to work. So stick with the program you're in, and focus on systems level engineering (product and process control), and you will have a very bright future!

Once you achieve your goal in the lab, how long would it take to scale your solution to mass production? Is it easier because you are using fewer materials or harder because of the processes?

Aterius

Thanks for the question! This is a really complicated and interesting question that doesn't have an easy answer. When you say mass production, I presume you mean on a truly global scale, and producing terawatts (TW) of energy. Even at smaller scales like gigawatt (GW) or megawatt (MW), the complications are enormous. To me, the biggest question in any form of scalability, is how do you do this: do you make one huge plant that centralizes the power conversion and distribution, sort of like what we have today, or do you make lots of really small individual units and let everyone have a solar powered device on their own roof? This is an argument for the economy of scales, and invokes the age old question: would you rather fight 100 duck sized horses, or 1 horse sized duck?
Assuming that we want to make modular units that can de-centralize this process and give power to the individual, the mass-production could happen on the order of decades. This may sound long, but this is the normal pathway for any new technology. A lot of infrastructure, testing, safety, etc. needs to be ironed out before a high efficiency in the lab can be turned into a powerful unit on your roof. Right now the field is working both on lab-scale efficiencies, but also on technological scaling up of this process so that we don't have to wait for a magic efficiency number to come up to then start to think about what to do. Even working in parallel, it will take many years. The last caveat to bring in is the only thing that matters in all of these systems: cost. As soon as this technology can be built and deliver kWh that are reliable and cheaper than what you pay now, it will be on your roof tomorrow! Unfortunately, that will still be some years/decades away. But this is the slow and steady march of science that is incredibly exciting to be a part of, because once this change happens (and it will!), it should be sustainable for centuries and millenia (and beyond)

How sensitive is your process? Would it work under real life conditions or does it require lab quality CO2 and water? Do you see scalability issues inherent in the technology that would prevent larger installations in the short term?

Walrave

Hi, thanks for the question! Right now, we do all testing at the 'lab-scale', meaning the active areas of the materials are on the order of 1 to 2 cm2, and in very controlled environments. It's interesting to think about 'real-life' conditions, because the science we work on has not yet been developed into a technology. So once we get a great efficiency and a low cost, there is no industrial system that can just plug our materials into. In fact, we have to work on developing the technology in parallel with the science, so the 'real-life' conditions are still not known yet! One of the things my group does to help this is to work on different scales all under one roof. We make 'lab-scale' materials to test, but also make several demonstration level devices that are an order of magnitude bigger to see what happens to the overall efficiency as we get bigger. This allows us to find new ways to understand our system, and find an effective and quick feedback loop that can help us to establish design rules for our 'lab-scale' materials to be improved and ready for the next scale operation.

It's been said that using solar energy to synthesize chemical compounds wastes a lot more energy than just charging a battery so why would we do this?

lance_vance_

Hi and thanks for the question! In general, any energy conversion loses some energy, since there we have yet to find any process that converts energy with 100% efficiency. So the question then comes down to the value of a chemical fuel versus a battery. The long story short comes down to energy density. Theres a reason we use fossil fuels now, they pack so much energy in such a small volume and small weight, that we don't know anything else that can beat that. Batteries (like Li-ion) are fantastic for small scale things like personal electronics, but we'll never fly a 747 on Li-ions for various reasons. The other important aspect for this is practical use for long term storage. Batteries are great for short term energy storage; just think about how you plug your phone and computer in every day (hopefully), and then use it, then rinse and repeat. However, you don't refill your car every day (I hope you don't drive that much). A good example is to think about seasonal storage. If we create a lot of renewable electricity in the summer when the days are long and the sun is shining, we want to store the excess energy that we don't use right away. We need to store the energy for use overnight (batteries can be used for this), but we also need to store the energy for the winter, when the days are not as long and the sun doesn't shine as much. To store 'summer energy' for use in the winter, a stable material is needed, and for this chemical fuels can sit in a tanker for months and be fine. However, I don't think if you charge your laptop in June, then open it in December that you will be at 100% charge. So batteries are great, and will still be needed in the future, but will be limited to relatively small scales (time and space). However, to have large scale energy storage in terms of volume/weight and time, we need chemical fuels for their stability and energy density.

I would like to see carbon fuels as almost like a highly energy dense battery in the future, but my biggest concern is the very low energy effeciency of combustion engines, do you think it is possible to create a new fuel that can be used with comparable efficiency to electric cars?

Johnboyofsj

Hi and thanks for the question! The way you are looking at carbon fuels is exactly correct, and so are your concerns. A possible 'new fuel' that is 'combusted' more efficiently than carbon fuels is hydrogen, which can be made from (solar-driven) water splitting. When hydrogen is 'combusted' with oxygen it produces electricity with an efficiency around 60%, and the only by-product is ultra-pure water (i.e. no CO2)! Therefore, I think the hydrogen economy can (in part) satisfy these conditions, and is a large part of the artificial photosynthesis community!

algae produced biofuel has always sounded like an interesting concept to me but it seems likely lately i've been hearing less about it.

Is it still considered to be a viable method in your field?

And what is the current estimate of what it would cost to produce a gallon of fuel at scale?

Doomhammer458

Hi! Biofuels are really cool and interesting, but in my opinion, not promising for addressing large scale energy problems. Thats because algae has a very low conversion efficiency of light, water and/or CO2, and thus requires enormous amounts of land to get a sufficient amount of energy. To me, the scale required is much too big to be able to implement, so although its really interesting, it seems like the efficiencies are way too low (at the moment, though this is also being researched by others in the field). Right now, making hydrogen with electrolysis is relatively cheap if we use steam methane reforming (SMR). However this also produces CO2 which is not good. Making hydrogen from renewable electrolysis is still possible, but much more expensive. Right now (off the top of my head), using SMR we can get hydrogen around 3$ per gallon, and using renewable electrolysis 8~10$ per gallon at best. So theres a ways to go, but its not totally out of reach.

As a PhD student working in a similar field (but for homogeneous catalysts), I'd like to thank you for taking the time for making this AMA... Perhaps one day, my research will no longer be a taboo topic for casual conversation (just kidding, of course!)

Can you elaborate on what you mean by efficiency? If you are referring to the turnovers of the catalyst, what do you think might be causes of catalyst deactivation? I am totally unfamiliar with heterogeneous water oxidation devices so I apologize in advance if I'm off-track here.

I'm also curious about the context by which to interpret the 1% efficiency figure given for natural photosynthesis - in homogeneous water oxidation catalysis, people usually talk about falling short of beating the turnover number or turnover frequency of the Oxygen Evolving Center in plants. Is there a reason why this doesn't seem to be the case for examples involving heterogeneous water oxidation catalysts?

Could you share your thoughts about collaboration in the field of water oxidation? Do your grad students do all the synthesis, electrochem, and spectroscopy by themselves, or is some of the analytical work offloaded to other PIs' labs?

In the case of the former, are those grad students supported full-time by a research grant (versus having to teach part-time)? Do you think it's needed, given the nature of the work? I'm aware that the grad school in the Netherlands might be a little different than the United States - how would you compare the two?

Finally, do you have any advice or lessons about finding collaborators and coauthors?

Thanks again!

BEARCRAFT

Hi BEARCRAFT, and thank you for taking to time to ask so many great questions here!
So when I say 12.7% efficiency, I am talking about solar to hydrogen (STH) conversion efficiency). Simply put, that is the percentage of sunlight that hits my materials that then is able to turn water into hydrogen (and oxygen), and all without any extra applied voltages (i.e. bias-free). In heterogeneous catalysis and electrocatalysis, I don't really use turnovers for a few reasons. Generally, using inorganic materials for heterogeneous catalysis we aim for turnover numbers of infinity (i.e. we try to work with things that are stable for hundreds of hours). Many electrocatalysts are, but not many photocatalysts, but thats a whole AMA digression for another day!
The 1% efficiency of nature is complicated and not straight forward. Plants are interesting in that they do a chemical turnover, and constantly die and are reborn (basic cellular biology), so turnovers are fast but finite, and the system rebuilds itself fast enough to keep the process going indefinitely.
Heterogeneous catalysts (made from inorganic materials) should not degrade, and thus should in principle be able to turnover a reaction infinitely, and speed (i.e. kinetics) should be the limiting factor.
Collaborations are always fun, always welcome, and always different! My team is quite diverse, and I collaborate with a lot of people inside and outside of Holland. For example, the paper we have reaching 12.7% was done in collaboration with the group of Micahel Graztel at EPFL in Switzerland. Every collaboration is different, and depends on two things: (1) what can you do, and (2) what do you need? My lab specializes in materials syntehsis and characterization, and electrochemistry. However, for example, we don't currently specialize in theory. So I try to find people in the field who are theoreticians that specialize in understanding the reactions we carry out in our labs, and together, we should gain further insights into the fundamental processes involved in water oxidation (for example).
In Europe (at least in Holland), my students are supported solely by my research grants, though to be a PhD student you have to teach ~10% of the year, so a small lab course once a year. The rest is pure research, which is a pretty sweet deal. Compared to the US you need a TA or RA, and those take a significant amount of time, but can also be rewarding. Advice for finding collaborations: be nice, be

friendly, and don't be afraid to ask lots of questions!

There was a fatality last night in Terneuzen at a Dow Chemical plant.

Nothing to ask, just letting fellow Dutchmen know that a lot of us Stateside folks are sending good vibes in your direction.

Also, stay safe out there, fellow ChemEs.

seredin

Hi, thanks for the comment and concern regarding the Terneuzen plant. Lots of TU Delft people go to work there, so it does hit close to home.
Thanks for the good vibes, and I'll be sure to re-emphasize lab safety in the coming weeks.

Hi, Wilson! What is your view on performing PEC over PV's and coupling it with dark catalysis for electrolyzers? I see that you're focusing on both but I wanted to hear your viewpoint as to why push towards PEC?

fonzynator

Hi fonzynator! What a great question at the end of my AMA using lingo that I am so familiar with! So this is the age old question: is it better to separate light absorption from catalysis (PV + electrolysis), or to integrate the functionalities in one material (photoelectrochemistry, i.e. PEC)? If its efficiency you are interested in, it is well proven that PV+electrolysis is the way to go. It is simply more efficient to have one material harvest sunlight, and using a wire, connect this PV to an electrolyzer with dedicated electrocatalysts whose job is only to split water. The potential advantage of PEC comes in cost, where potentially PEC could save on balance of systems. Integrating functionalities into one device means less materials, less maintenance, but also (in general), less efficiency. Especially when you consider particle based PEC options that can be very very cheap, require no maintenance, and thus need to achieve even lower STH to be economically viable.
Why do I study both? Well, I think PEC is really cool and super interesting. Combining light, electricity, and chemistry at one interface is just too interesting to me. Since the efficiencies of PEC materials is lower than the other approach, it means we need to understand better about the bottlenecks that limit these materials, and thus there is still rich science to be done. I also look at the other approach to focus on PV materials (perovskites for now, Si previously), and electrocatalysis (water splitting and CO2 reduction), because I think they are more industrially relevant, or at least at a more technologically developed level, but still require basic science to improve their performance. So many cool things to study, and so little time (and PhD students!). Thanks for the great question, let me know if you need any more clarification.

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Cool, thanks!

SpaceX is planning to harvest CO_2 and H_2O from Mars to make CH_4 and O_2 and use them as propellant. What are your thoughts on this process? Do you think there is a better alternative?

Cheers.

Orgrimm2ms

Thanks for the question! I think this process is absolutely fantastic, and for Mars, ultimately necessary! Just like here on Earth, you have to use what you have, and Mars has an atmosphere made almost entirely of CO_2, so it makes sense to convert CO_2 to a fuel directly on Mars. As far as I know, based on the huge amount of CO_2 on Mars, this is the best way to form propellants (and other stuff) on Mars.

Do you see this as something we can implement (size/complexity of plants) on Mars as a source of fuel production?

Viktor_Cat_U

Hi and thanks for (another) Mars question! Since the Martian atmosphere is mostly CO_2, finding ways to convert CO_2 to fuels (with sunlight) seems like an obvious choice for fuel and materials synthesis. As the CEO of SolarCity/Tesla/Space-X mentioned two days ago, this is the way to go (it helps to run three companies that can each help make this a reality!)

Hasn't the maximum energy efficiency with the conversion process been at a very slow increase? What are the biggest challenges that prevent a steady increase in efficiency?

moonsfang16

Hi and thanks for the question! The efficiency has been increasing steadily over time like many technologies, and our 12.7% is not even the highest (but is the highest using only Earth-abundant materials). The major obstacles in terms of efficiency are: (1) what materials do we use to absorb light and/or split water, and (2) what does the system/device look like that does all this? For the first part, integrating functionalities has certain advantages, but for efficiency, you need to decouple light absorption and catalysis. For the second part, this is much more unclear. Almost every research group has their own electrochemical cell, potentiostat, GC, wiring, etc., so comparing on a system level is not easy. At the same time, we are all working on a science that does not yet have an industrially mature technology that we can all plug it into. For an example, for photovoltaics (PVs), the National Renewable Energy Lab (NREL) in the US is the place to test for standardization. For water splitting, no such 'neutral' place exists to have standards checked, and so each lab reports their own efficiencies (while adhering to practical standarization with respect to light intensity, current density, etc.). So in summary, to improve efficiency gains we need (a) better materials, and (b) better systems to test.

Hello!

I'm a last semester undergrad in molecular biology. Artificial photosynthesis still produces carbon based fuel. As you know releasing this energy means oxidation of these compounds releasing our ever favorite companion CO_2. While the amount produced is certainly less harmful than fossil fuels is it still large enough to be considered a worrisome factor? As our population continues to rapidly expand I would imagine even highly efficient fuel technologies to be challenged from an emissions standpoint. So in summary, even if you achieve efficiency far beyond the initial plan do you think this is a fairly permanent solution?

Blackdawn

Hi! So the main question is: if we make carbon based fuels that we end up burning in the end, aren't we just putting CO2 back in the atmosphere? The answer...... yes! So ideally we want to do two things: (1) simplify, and just do water splitting to make hydrogen and oxygen, which when combusted, make electricity and water (no CO2!), and (2) take the CO2 out of the atmosphere and keep it out! For this, the ideal situation is to convert CO2 to something other than a fuel, or to a fuel that we combust in a way that allows us to directly re-capture it, to make sure it stays out of the atmosphere.
Regardless of what happens, we need to take CO2 out of the atmosphere (keep it out), and find new sources of energy other than fossil fuels. I think artificial photosynthesis can tackle both of these problems.

Is this hoped to be an energy efficient method of scrubbing CO2 from the atmosphere? It seems swings and roundabouts to use all that power just to turn it into combustible fuel again.

xfjqvyks

Hi, thanks for the question! I tried to answer this in another question, but long story short: we need to take CO2 out of the atmosphere and keep it out. So learning about how to convert CO2 to anything can be enormously helpful, especially if we can turn it into something like a polymer or material that stays out of the atmosphere.

Hi!

What kind of Faradaic Efficiencies do you see when converting CO2 to Liquids?
What are the major products?
You mention 12.7% Efficiency, but what the the efficiency if you remove the Solar -> Electricity aspect?
Also, what kind of catalysts do you use?

Thanks!

Dabum17

Hi Dabum, thanks for the question! For converting CO2 to liquids, we have low (but non-0) faradaic efficiencies. However, we focus on making syngas (CO+H2), so we predominantly make gaseous products (and do it quite well!). Some catalysts we use (Cu nanowires) make ethylene, methane and formic acid, but the goal there isn't high yields, but more to understand mechanistic insights to derive meaningful reaction pathways. 12.7% efficiency is 12.7% solar to hydrogen conversion. The solar cells are quite efficiency perovskites with around 18% solar to electricity efficiency (I have to check, maybe higher). Let me know if you need to know anything else!

I graduated in 2015 with my B.S. in chem e. and went straight to industry. Sometimes I wonder what life would be like in academia, and I weigh the pros and cons. As an academic, do you ever wonder about life in industry (or maybe you worked full time before pursuing your PhD)?

kingofthetewks

Hi and thanks for the question! I have spent my whole life in academia (BS into PhD into Postdoc into Professor). I hear mixed things about people who go into and out of industry, but I think its more a personal choice of what you want to do, what company you work for, and what gets you going. I couldn't imagine anything other than the freedom, flexibility and fun of academia, but to each their own!

With the impending water crisis is it a wise idea to convert water to chemical and fuels? Unless of course theres a whole other side of the equation that I've never seen yet.

Also where do you see yourself taking this efforts to? What do you hope to see to be accomplished by you or by the world governments & NGOs from your work?

Thank you for your time sir :)

ixora7

Hi and thanks for the interesting question! Water is a very interesting resource that we should indeed take care of. The water crisis is more about fresh water that is potable, and is in fact a very small portion of the planet's overall water supply. One of the interesting things about using water as a potential source of chemicals and fuels, is that it is also possible to do this with sea-water and water that is not pure and meant for drinking. Of course, if there was also a sustainable, cheap, and scalable way to purify ocean water, then there will certainly be enough of that to go around and address some of the needs of people who need it the most for survival. Right now more effort needs to be done on the basic science of these processes, and basic engineering solutions still need to be addressed. The transition from science to technology is very long, and its really hard to make predictions of when and where this will end up. Suffice to say, the research is incredibly interesting and every day there is a clear motivation to get up and get back to work on these problems!