How can a knowledge of science help us tackle climate change?

Our Plight

Climate change: It is one of the most cataclysmic and pressing matters our modern society faces. Scientists predict we have only around 9 years to prevent irreplaceable damage from climate change and yet, most countries are not hitting their climate goals.

Most of us know what causes climate change. Increasing amounts of greenhouse gases in the atmosphere leads to an increase in the greenhouse effect, causing global warming, however, there are other significant things to consider. I was especially interested in how quantum mechanics, which shows much promise for real-world applications, can affect how we approach climate change.

Climate Change from a quantum level

To understand how quantum mechanics can explain climate change, let us consider the photoelectric effect. It was first described by Albert Einstein in 1905, for which he won a Nobel. The fundamental idea behind it is that when electromagnetic radiation, such as light hits a material such a semiconductor, electrons are emitted. The photons that collide with the metal use some of their energy to dislodge the electron.

What was also discovered by Philipp Lenard, was that increasing the light intensity did not dislodge the electrons with any more energy, though it did increase the number of dislodged electrons. This was a contradiction of the predictions, which would expect the electrons to move more violently since, at the time, light was thought to be strictly a wave (rather than the notion we now have of its dual wave-particle nature). The key to understanding why is to think of energy received by electrons as several packets of energy, which we now call photons. Therefore, if only the photons have enough energy, can they dislodge the electrons. It was therefore credited that electrons don’t absorb electromagnetic radiation of certain frequencies and energies.

This idea that we now know of quantized energy can be applied in other phenomena. For instance, gas molecules can only absorb and emit electromagnetic waves of certain energies and frequencies, which means only certain colors of light can be absorbed and emitted. Therefore, as light travels through the atmosphere, visible light is not absorbed, so it passes right through. This is since gases in the atmosphere such as carbon dioxide and nitrogen cannot absorb light of that wavelength. However, when light is emitted back from the earth, in infrared form, carbon dioxide can absorb it. Therefore, temperatures have a correlating effect with the amount of carbon dioxide in the atmosphere.

How quantum mechanics can help us tackle climate change

Quantum dots

Quantum mechanics, although seemingly alienated from practical use at first, shows promise for prodigious future technologies. In fact, the photoelectric effect has already had direct applications in the use of solar cells.

Solar energy is regarded as the energy source of the future. Solar energy is renewable, can save money, and requires low maintenance. It can help us reduce carbon emissions. However, its initial cost is fairly high and it takes up a lot of space. Furthermore, there are also some hazardous materials used during the manufacturing process of solar cells, which can harm the environment. It is these reasons that restrict their widespread use. However, solar systems can be improved to better meet higher energy requirements for the future. Through our detailed scientific understanding of the photoelectric effect, we now have the tools to implement that knowledge into developing future technologies, such as advanced solar cells, which will be much superior to current ones.

How a normal solar system works is when the sun’s rays move the electrons on the surface of a semiconductor, such as silicon, and since it’s connected to a circuit, the electron can escape from the plate to the circuit and complete it. This generates electricity. The new generation of solar cells, however, will make use of quantum dots. From the photoelectric effect, we know that atoms in nature have specific energies and can only absorb and emit light on some wavelengths. We can now use this knowledge to build atoms with structures that can absorb and emit certain wavelengths of light. These artificial atoms are known as quantum dots. They were first constructed by Louis E. Brus in 1980 and are the principal basis for the development of the new generation of solar cells. From our understanding of climate change from a quantum mechanics point of view, we can build the quantum dots so they can be more efficient in absorbing the wavelengths we receive from the Sun.

I was able to get in touch with Paul Mulvaney of the University of Melbourne, who has done substantial amount of research on quantum dots, and ask him about his thoughts on solar systems using quantum dots. He quoted, “When a semiconductor crystal is extremely small, its absorption spectrum shifts. This is useful because different sized crystals can be used to tune the absorption of sunlight more efficiently. However, the main advantage of QDs is considered to be the fact that they can form an ink which allows the solar absorbing layer to be printed. This should be much cheaper than the energy intensive process used to make ultra-pure silicon. A solar cell is only useful if it produces more energy than is used to make it. People often forget that. The energy needed to make solar cells is a little controversial, since we cannot see what actually goes on.“

So we know that with the new generation of solar cells, we can eliminate many of the disadvantages that current solar cells have. For current solar cells, the conversion efficiency is about 20%, however, with the new generation of solar cells using quantum dots, the conversion efficiency will increase. They can also be miniaturized so they can take up less space than regular solar cells. They are more versatile and can be used from windows, not just rooftops. They could also be attached to battery stores for use in hours of darkness. Quantum dots would replace other bulky materials such as silicon and copper in solar cells, therefore changing the manufacturing process completely.

"Quantum dots have a host of unusual properties compared to bulk semiconductors", said Arthur Nozik of the National Renewable Energy Laboratory, part of the U.S. Department of Energy. He and his team are researching about how in a quantum dot, a single photon can be used to enter the quantum dot and excite several electrons, rather than just one. This is the main reason solar cells using quantum dots are more efficient than regular solar cells, where a single proton can excite just one electron.

Paul Mulvaney also mentioned, “The main problem with QDs is they are not photo-stable. Over time, the sunlight causes them to degrade. If this problem can be solved I think they might end up going into solar cells.” Stability seems to be the main issue with perovskite cells. Hopefully, this issue can be overcome in the future, and many research groups are invested in finding a solution to it.

Achieving that could finally mean that solar cells can be made accessible to more people and larger production of them could lead to further reduction in prices, arising from economies of scale. This groundbreaking technology could change how we use energy in the future. With this advanced solar technology, we could not only reduce our carbon emissions, but over time, this could lead to a decrease in current pollution levels.

Quantum Computing

Computing has progressed exponentially since the last 5 decades. In fact, Moore’s law observes that the number of transistors on microchips doubles approximately every two years. As computational developments continue, a new generation of computers, called quantum computers have been introduced. As Richard Feynman puts it, “Nature isn’t classical, dammit, and if you want to make a simulation of nature, you’d better make it quantum mechanical.” In truth, a knowledge of quantum mechanics can help us get a more accurate view of the universe.

Quantum computers have harnessed several quantum properties to perform computational tasks. Instead of the conventional binary bits classical computers use, quantum computers use a quantum bit and qubit as their basic memory units. It makes use of quantum superposition, which enables different configurations of qubits to be represented simultaneously and quantum entanglement, which causes different qubits to be linked together. What these phenomenon mean in detail is beyond the scope of this essay, but let’s try to understand it using an example. Using 8 bits, a classical computer can represent any number between 0 and 255, but 8 qubits is enough for a computer to represent every number between 0 and 255 at the same time. So quantum computers can outperform classical ones, especially when it comes to large numbers and their modeling capabilities can be useful in several fields.

Catalysts needed for fertilizer production use a lot of energy and some estimate that they contribute to around 2% of all carbon emissions in a year. From quantum computing, molecules that replace chemical catalysts needed for fertilizer production can be developed and in the future, chemicals that lead to energy efficient fertilizers can be made. BASF and HQS Quantum Simulations have algorithms for replacing Haber-Bosch, a process used in the production of ammonia, although it still needs work. Using quantum computers, they could also develop catalysts in the production of hydrogen to replace expensive platinum catalysts that are currently used. This could lead to the manufacture of green hydrogen becoming more economical. Consequently, more cars with hydrogen as a fuel can be used. This will positively impact the environment since hydrogen is an emission-free and sustainable form of fuel.

Another way we can reduce carbon emissions is through carbon capture. This process involves capturing carbon from where to was produced and transporting it, often underground, so it doesn't go back in the atmosphere. However, this process requires a lot of energy. Fortunately, this is yet another process where the application of quantum computing can be beneficial. They can make better catalysts that can improve efficiency and reduce costs, making the process more feasible and sustainable.

Quantum computing can also help us develop new materials, which are stronger, lighter and have smaller carbon footprints. The expanded simulation capabilities of quantum computers could devise a formula which could make several production processes more economical, therefore reducing carbon emissions.

Moreover, the use of quantum computers can be used to change the design of aircrafts to reduce the effect of drag during flights, therefore reducing emissions. Today, classical computers cannot effectively model fluids on large surfaces, so physical prototypes, which are expensive, have to be produced. However, engineers can use quantum computers to do such advanced modeling. This might significantly reduce carbon emissions since it is estimated that globally 2.5% of all carbon emissions in the world comes from aviation.

Some people estimate that this quantum revolution is a mere 5 years away. But, the main problem seems to be that qubits are highly sensitive to heat, electromagnetic fields and collision with air particles, which causes them to loose their properties. So, quantum computers still have to go through a lots of developments, but it a promising field nevertheless.

Conclusion

In truth, the solution to climate change will not be a simple one and will likely involve us pursuing a list of goals. This might include replacing high carbon footprint materials with more sustainable ones, inventing technologies to reduce carbon emissions or building more sustainable infrastructures. But overall, a knowledge of science gives us the tools to reach those goals and helps us get a more complete picture of the solution.

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