Changing the role of climate change at our school

As the Earth's temperatures increases, students and schools must take action.

■ **Story** by Jeffrey Chen and Rishi Mohan ■ **Graphic** by Jeffrey Chen
■ **Photos** courtesy of National Park Service

Climate change is a major crisis that endangers how society can function. According to NASA, each year the Earth's surface temperature rises 1.62 degrees Fahrenheit. As a result of climate change, rising sea levels threaten coastal cities, natural disasters become more frequent and extreme, and shrinking ice caps endanger wildlife native to glacial areas. What can our school do to combat this?

The best source of climate change information on the planet is the United Nations' Intergovernmental Panel on Climate Change (IPCC). Compiling credible research that is widely-agreed upon by 97-98% of all climate researchers, the IPCC declared that human influence on the climate system is clear.

For shifts in temperature to count as climate change, the IPCC agreed that studies of weather trends must take place over long periods of time. In their 2014 Synthesis Report:

> *Each of the last three decades has been successively warmer at the Earth's surface than any preceding decade since 1850. The period from 1983 to 2012 was likely the warmest 30-year period of the last 1400 years in the Northern Hemisphere, where such assessment is possible. The globally averaged combined land and ocean surface temperature data as calculated by a linear trend show a warming of 0.85°C over the period 1880 to 2012, when multiple independently produced datasets exist.*

While the IPCC has confirmed that temperatures are increasing, global warming results in gradual changes over time. Because this change is so slow, people often do not notice the weather being a bit warmer each year, Dan Northcut, Director of Environmental Studies, notes.

"Climate change happens slowly enough that people don't notice much, so they're not motivated," Northcut said. "Humans are much more motivated by sudden catastrophic things, not by, you know, a degree or two difference in temperature over a few years of time. Humans just don't notice those kinds of differences."

While extreme events have been observed since about 1950, their causation by climate change is still in a probable state. The IPCC affirmed that it was only very likely that human influence has contributed to higher occurrences of heat waves, heavy precipitation events, and heat-related human mortality in various locations.

"We've definitely had climate change events easily a dozen times, at least, during our history," Northcut said. "The biggest difference, though, and what we're seeing now is that there is a likely correlation between human activities and more and more extreme weather."

Many organisms, mainly plants and animals, are unable to handle the rapid shifts in weather. Ecosystems deteriorate under quick change because organisms must move or adapt or they die, and evolution is a slow process of adaptation that cannot accommodate the speed of global warming.

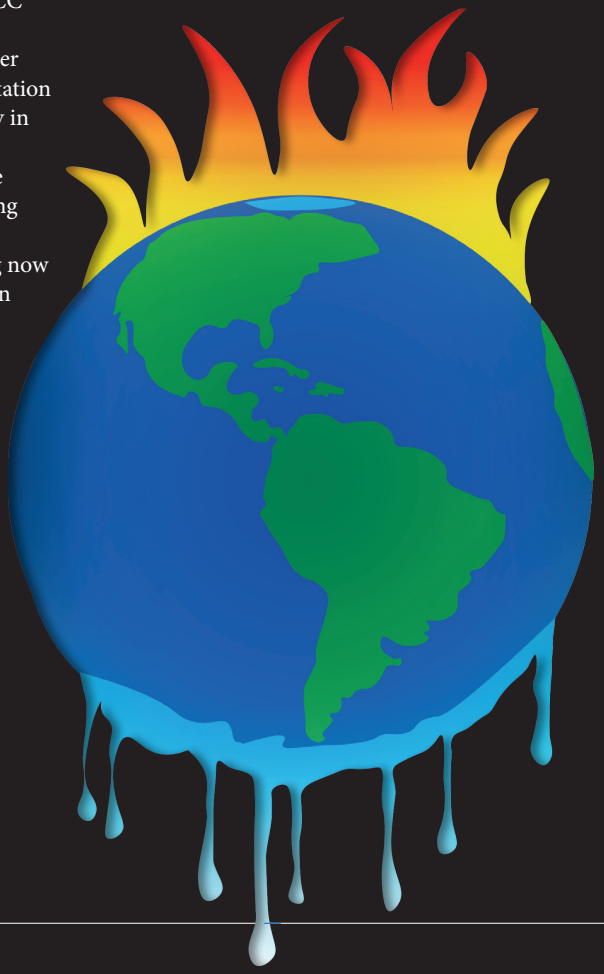
"Organisms can't deal with rapid global warming very well," Northcut said. "If you're a plant, you can't move, so you just die out. Most people don't realize that we've had climate change before, for sure, but the rate that we're doing it now is unprecedented. And that's the most dangerous: just how fast it's happening."

As a private school, our institution has dedicated a large portion of funds in the past few years to increase sustainability in buildings and practices. In 2010, a statement of environmental policy was laid out. The statement reads:

> *Respecting the needs of future generations, St. Mark's School of Texas will provide leadership in environmental sustainability and responsibility. The School assigns significant priority to integrating environmental awareness, understanding, and stewardship into its academic mission, campus improvements, and operations.*

In accordance to this declaration, 10600 Preston Rd. has a few buildings that have been certified in Leadership in Energy and Environmental Design (LEED) requirements by the United States Green Building Council (USGBC), including Centennial Hall, Hoffman Center, the Winn Science Center and the renovated McDermott-Green Science Building.

The LEED system rewards points on a 100 point scale for buildings that achieve excellency in five distinct categories for eco-friendly and energy-saving design: water efficiency, energy and atmosphere, materials



^ Top- The ice levels on Lyell Galcier in Yosemite National Park have significantly decreased from 1883 to 2013.

< Left- If we do nothing, our planet will be burning on one side and melting on the other.

and resources, indoor environmental quality and sustainability. To obtain the silver level, a building must have at least 50 points on the scale.

In addition to fulfilling energy concerns through architecture, our school has also switched to recycled copy paper, installed electric vehicle charging stations, held two e-waste recycling drives in the past two years and installed filtered water fountains in the Winn Science Center.

While these ambitions have certainly reduced the carbon footprint of our school, is there more we can do to help combat global warming?

? DEFINE ME

While these two terms are used interchangeably throughout the climate change articles, their definitions are slightly different.

Global warming: the long-term heating of Earth's climate system observed since the pre-industrial period (between 1850 and 1900) due to human activities (NASA)

Climate change: long-term change in the average weather patterns that have come to define Earth's local, regional and global climates (NASA)

As the need for climate change education becomes more dire, St. Mark's must integrate effective and unobtrusive climate change units into science classes, particularly Earth Science.

A study done at Montview High School in Denver, Colorado, showed that a student-driven climate change unit not only educated students about climate change, but also motivated them to care about fighting it.

"My students understood the science behind climate, the evidence of why it's changing ('humans'), and reached consensus that something needs to be done" science teacher Lara Thomas said. "But this is where their learning stopped—in their eyes, climate change was systemic, inconvenient, someone else's problem."

Thomas implemented the Climate and Resiliency professional development project in her classroom. ►

"I was very impressed with the level of audience engagement," Thomas said. "Feedback from classmates reinforces the fact that the student teams need to ground their ideas in scientific reasoning backed up with evidence."

With her strategy, Thomas' students developed communication and research skills while learning that sustainability could reflect in reducing costs for the school as well.

"I learned that changing even small things makes a big impact," a student said, "Change takes time and energy, and it's important to be realistic."

Our school already has stellar teachers and excellent curriculums that make it stand out among private and public institutions alike. While climate change is a signficant element of the Earth Science classes, which all students must take, it may become necessary to include active participation in the fight against the disaster, as other schools have done.

What else can we, as students, teachers, and staff members of a high school, do?

One way people can help is by reducing their carbon footprint. A product's carbon footprint is the amount of carbon dioxide produced to make it, usually produced by factory fuel costs.

"The best thing consumers can do is to watch how much they buy and what they buy," Northcut said. "If shoppers watch what they buy then they can decide to buy products with a lower carbon footprint."

Another way people can also reduce emissions is by eating more vegetables instead of meat. Raising livestock takes more resources to grow than plants.

"Anything that is meat-oriented has a bigger carbon footprint," Northcut said. "Environmentally, meat takes a lot more energy and resources to grow."

Livestock consume lots of food, land, and other resources as they grow and mature. About one third of agricultural land in the US is used to grow crops for cattle and other farmed animals according to a study by the United States Department of Agriculture (USDA).

"Instead of growing all those crops to feed the cattle, we could save a lot of resources by using that land to grow crops for humans to eat," Northcut said. "That would be more sustainable in the long run."

Bottled water also leaves a big carbon footprint. Drinking tap water is much more environmentally friendly.

"You can use a water filter, instead of buying bottled water that is from places far away," Northcut said. "Bottled water leaves a huge carbon footprint, you know, for some thing you can get out of the tap."

Instead of thinking that, as an individual, we are too small to help, everyone should work together as a team to combat global warming.

"A lot of people throw up their hands and say I'm too small to change this, and that's true for any single person by themselves," Northcut said. "But if we all work at it together, then it can be done. We've faced major problems before as a country and as the world."

Northcut believes that it is humanity's responsibility to slow down climate change because we caused it. We have to create a healthy environment for the next generation of people to live in.

"We gotta keep trying," Northcut said. "I mean, a lot of times it's easy to get bogged down and feel helpless. But we all want to have a decent world for our offspring. We owe it to all the other life on earth to keep trying, because we made this happen. And it's our responsibility to stop it." ■

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Below- Our school has an electric vehicle charging station, which increases accessibility for students driving electric cars.

Right- The glaciers of Kenai Fjords National Park in South Alaska are in jeopardy as temperatures rise about 1.62 degrees Farenheit each year.

> "If we all work at it together, then it can be done. We've faced major problems before as a country and as the world."
>
> Director of Environmental Studies Dan Northcut

Electric vehicles: combatting global warming with tech

As the electric car industry expands, models predict emissions to drop significantly. Is there hope in the future?

Story by Jeffrey Chen

Graph data courtesy of Carbon Brief and the Electric Power Research Institute

Electric vehicles (EVs) are the future of transportation. More and more car manufacturers are investing into the new technology. They can run on renewable energy, which is better for the environment and reduces air pollution.

EVs do not produce harmful carbon emissions. In addition, electricity is cheaper compared to gasoline.

"Electricity right now is relatively inexpensive," said Stephen Balog, Cecil H. and Ida Green Master Teaching Chair.

The battery packs in electric cars are very similar to the batteries in other electronic devices.

"It's basically that lithium-style battery like in phones and iPods," said Balog. "However, it's much larger. It has to be larger because it must generate a lot more power. This is also why it takes a while for them to recharge. These newer batteries are like the new batteries we have in our phones, they can take lots and lots of recharges before you have any issue with what's known as degradation."

However, EVs have some drawbacks when compared to standard gas powered cars.

"From what I've been reading about them is that electric cars don't have the same acceleration compared to a standard car," Balog said. "So when a light turns green a gas car will take off faster than an electric car.

Another drawback is that electric cars have limited range and take longer to recharge.

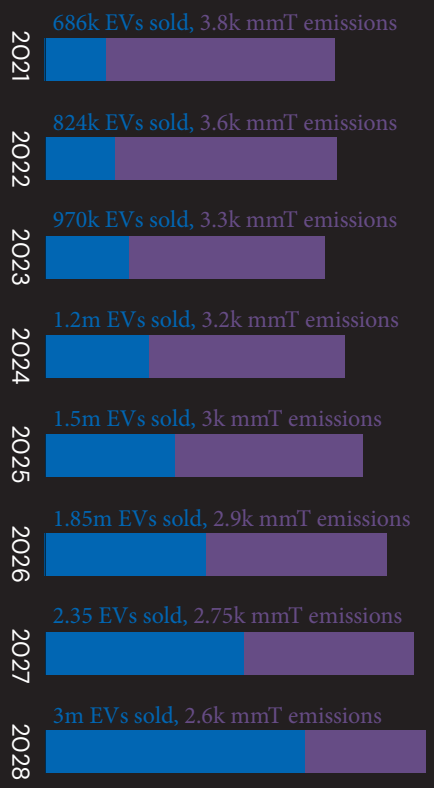
"Typically a car or truck or anything will go about 300 to 400 miles on a tank of gas," Balog said. "To recharge your gas car you just stop for ten to fifteen more minutes to put more gas in the car and then you're ready to go. In an electric car you may only go two or three hundred miles and then you have to stop for hours to recharge the batteries before you can go again.

On the St. Mark's campus there are two electric charging stations by Hicks Gym that students and faculty can use to replenish the batteries of their electric vehicles.

"Mrs. Barta, who used to be the department chair here, had an electric car for several years," said Balog. "In fact, that's why we have a charging station out there by Hicks, it was because she got it put in for her car."

Carbon Impact

Models show that the popularity of EVs may be able to drop metric tons (mmT) of carbon emissions from transportation by 24% by 2030.



TaaS

Transportation as a service

Column by James Shiao

Transportation, or transport, as a service (TaaS) is a term used to describe the combination of electric vehicles and autonomous driving. Tony Seba, an entrepreneurship and clean energy professor in Stanford, believes it will dominate the future of mobility.

"Transport as a service is autonomous electric and on demand transportation owned by fleets, not individuals," Seba said. "The day that it's approved, the cost per mile of TaaS will be ten times cheaper than the cost of owning a car."

Many companies such as Uber, Waymo, and Tesla are already creating technology to faciliate TaaS. Since 2017, Waymo has deployed over 600 vehicles in Pheonix, Arizona, to test the service.

"One year ago, Waymo became the first and only company in the world to launch a public self-driving ride-hailing service," Dan Chu, Chief Product Officer at Waymo, said. "We've accomplished a lot this past year, but we're never finished learning."

Seba predicts that by 2030, 95% of miles traveled will be using TaaS rather than using owned vehicles. According to his models, there will be a 90% decrease in greenhouse gases from transportation in the U.S., and an 80% decrease in energy consumption.

Not only that, but worldwide, more than a million people die in car crashes each year. Because 95% of accidents are caused by humn error, these figures could plummet by at least 80% with TaaS.

"At the end of the day, TaaS might be the biggest medical innovation in decades, even though it has nothing to do with pills or new equipment," financial researcher Whitney Tilsonn said.

Why are entrepreneurs and financial researchers praising TaaS so highly, when it seems unknown to most people in the scientific world?

Despite most knowing about self-driving cars, the impact of combining autonomy and electricity powered vehicles has potential to be society-changing.

The question now isn't if TaaS will be relased, but rather: when it inevitably is released, how will we as a society react, and how will it change our lifestyle?

Forecasting the tornado and extreme climate in Dallas

How does a tornado happen and what techologies are in use to anticipate one's occurence?

Story by Tamal Pilla, Antonio Quiñones **Photos** by Miscellaneous

Debris scattered across the road, houses crumbled into piles of their former glory and cars flipped over with smoke originating from a broken part. A tornado is violent, powerful, and destructive; that much has become evident to the members of the Dallas community.

As part of the colloquial tornado alley, Texan citizens were generally used to tornadoes, but nothing of the magnitude that the October tornado brought. They saw the sheer force of the whirlwind and its ability to level houses and leave nothing but rubble in its wake.

While the effects of a tornado are clear, what causes such a deadly natural phenomenon?

Tornados are elements that can form in ordinary storms, but require certain conditions. According to National Geographic, like a thunderstorm, a tornado forms when warm, humid air collides with cold, dry air.

The hot air rises, and if the third crucial ingredient, wind, is present, the air will begin to spin and form what is called a supercell. The supercell is the name given to the spinning air high above the ground, which causes a tornado down toward the surface. This, however, only causes a tornado 30 percent of the time.

Although some initial conditions are known, the reason that a tornado sometimes forms and other times does not is still a mystery. After a tornado is formed, it usually lasts less than ten minutes, but the reason for it dying is also unknown. Scientists have different hypotheses about a tornado's death, one being that a tornado stops when the air gets too cold, 'choking' the airflow into the storm.

As scientists began to understand more about tornadoes, they needed a system of classification to rate the power of tornadoes. The Fujita scale was an effective solution to this problem, pioneered by severe storm researcher Tetsuya Theodore Fujita. From a paper published by the National Oceanic and Atmospheric Administration:

> *Fujita showed that a damage assessment could be performed in a systematic, analytic manner, with the goal of determining airflow characteristics of tornadoes and their immediate surroundings. The damage scale assigned levels of destruction to "well-built" homes in a range of F0-F5 levels.*

> **"We kind of have to walk a fine line in that we can't go out every time and say that it's going to be wind and hail and tornadoes."**
>
> NBC Meteorologist Rick Mitchell

In other words, the Fujita scale measured how much damage the tornado caused and worked backward to find how fast the winds must have been moving. Because the scale would often underestimate the damage caused to residential houses, people began to doubt its accuracy. According to Roger Edwards, a researcher at the Storm Prediction Center, due to a lack of rural DIs, or damage indicators, the scale could not accurately rate the wind speeds of the tornadoes.

"The process of rating the damage itself is largely a judgment call -- quite inconsistent and arbitrary," Edwards said. "Even meteorologists and engineers highly experienced in damage survey techniques may come up with different F-scale ratings for the same damage."

The scale was eventually replaced in 2013 by the Enhanced Fujita (EF) scale. The EF scale was created to fix some of the flaws that the original scale had.

"A steering committee, composed of meteorologists and engineers, was convened in the early 2000s to discuss these concerns and incorporate an engineering-based understanding on the wind speeds leading to common failure levels of various potential DIs," Roger Edwards, a researcher at the Storm Prediction Center, said.

The transition to the Enhanced Fujita scale meant that more precise damage indicators were spread out in order to ensure more accurate results. This system continues to be used in the United States today. ▶

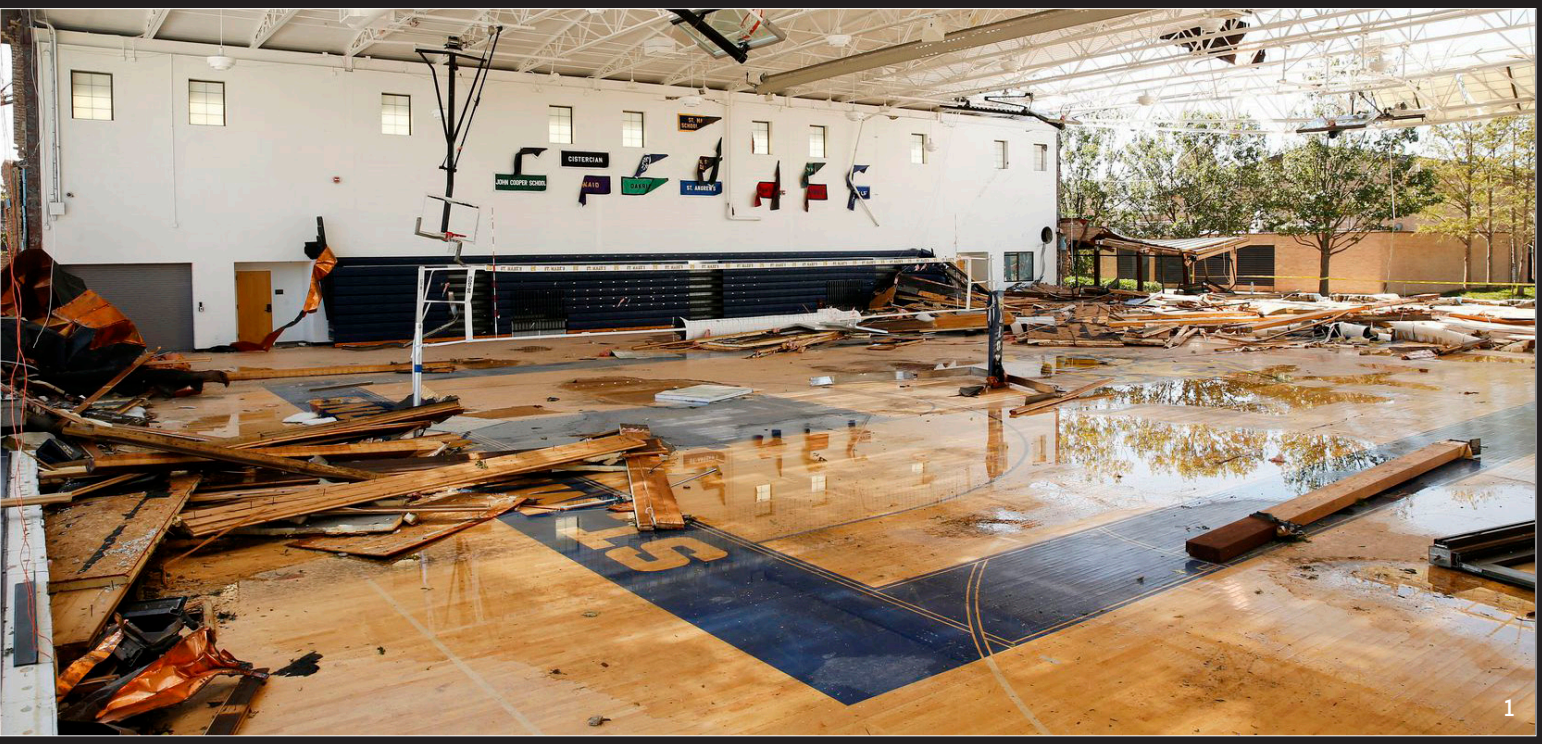
? DEFINE ME

Tornadoes aren't the only type of cyclone that can cause catastrophe. Here are how some other ones are caused:

Hurricane: Winds funnels into a low-pressure disturbance, evaporating warm surface ocean waters and releasing energy as rising air, which condenses into storm clouds. (Sciencing)

Mid-latitude cyclones: The dynamic interaction of warm tropical and cold polar air causes the warm air to be cyclonically lifted vertically into the atmosphere where it combines with colder upper atmosphere air. (U Illonois Atmos.)

Polar lows: Frigid air from the Arctic icecap or cold landmasses flows out over the warmer sea. Drawing heat and moisture from the water, this creates a type of thunderstorm. If the overlying atmosphere is also cold, the result is an extremely unstable air mass. (BarentsWatch)



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^ 1 Hicks gym was severely damaged by the tornado. 2 Rennovations and repairs took upwards of three months to complete 3 The tornado's path cut through some of the busiest parts of the city. 4 Local businesses were devastated, including the Preston Hollow Shopping Center. 5 Imagery from the air shows the path the tornado took through parts of Dallas. 6 Estimates of $2 million of damage was caused in the city of Dallas.

Understanding the scale that rates tornadoes is important to understand the power of the tornadoes that hit Dallas.

"The EF scale is comprised of EF0 through EF5. 0's and 1's are considered to be weak tornadoes," Mitchell said. "That's what you have for most tornadoes in the United States, most of them fit into that category. The 2's and 3's are considered to be strong tornadoes. They don't happen quite as much, but they do happen. Finally, you have the 4's and the 5's, and those are considered to be violent tornadoes…I know the 5's occur less than 2% of the time, but they're responsible for 70% of all fatalities."

Dallas was hit by not one, but three tornadoes that each had varying degrees of severity. According to CBS DFW, an "An EF-3 tornado hit Dallas, an EF-1 tornado hit Rowlett, and an EF-0 tornado struck Wills Point. To grasp what that means, the largest tornado, an EF-3, had estimated winds of up to 165mph and caused severe damage.

School-owned vehicles, including school buses, were blown away and destroyed the night of the disaster.

As important as assessing the damage done by a tornado is, getting accurate prediction results are just as important. After the Dallas tornado, there were many misconceptions about how much the weather experts knew before the event. The words that the weather service use are so important in accurately representing the certainty of the information they collect.

"We kind of have to walk a fine line in that we can't go out every time and say that it's going to be wind and hail and tornadoes," NBC Meteorologist Rick Mitchell says. "We have to try to use that word tornado respectfully… This is what we will say: 'the threat for wind and hail is the highest, we can't rule out a tornado or two.' I don't remember that we downplayed it in October, but we just didn't play it up."

If the weather service issues a tornado warning every time there is severe weather, there will be widespread public fear. But if they say there may be a tornado and there isn't, over time people will start to ignore the warnings.

This leads to a dilemma the weather service has to face every time they detect the possibility of a tornado. In order to determine whether it is worth reporting to the public, meteorologists have to determine how likely a tornado is and whether it is safer to not cause panic in the public by not issuing a tornado warning.

In order to assess the likelihood of a tornado given certain weather events, the meteorologists have a few tools at their disposal. There are two main stages of the process: detection and prediction.

"For detection we are using an S-Band Radar, and it's a wonderful piece of equipment and we have our own radar. A lot of TV stations don't necessarily have their own radar. They are ingesting the radar information from the national weather service which comes in roughly every two to three minutes where ours comes in every thirty seconds and so that is a tool that is tremendous in detection."

Mitchell says prediction, on the other hand, is a bit more abstract in terms of the actual process.

"With prediction, you're relying on your knowledge, your experience, and your computer models to help you to get an idea. When you model the atmosphere, you're basically saying 'ok, I want to know what's gonna happen not now, but six hours from now'... [the computer models] are going to be very high resolution. In theory, you're going to be able to see thunderstorms that could produce tornadoes, but you don't know when they're going to be accurate, because at times, they are going to be inaccurate. So you're left to wonder 'this model is showing this. Do I believe it? Or is it going to lead me astray?' And that's where being a meteorologist is critical." ■

Sources used: Edwards, R. (2010). The enhanced fujita scale: Past, present and future.

Above- Despite the awesome wind speeds and surrounding devastation, the Path To Manhood statue remained unscathed.

Is climate change correlated to tornadoes?

What evidence is there to show that climate change is contributing to the rise in tornado occurences?

Story by Tamal Pilla, Antonio Quiñones

As so many families attempt to rebuild and move past the devastation caused by the tornado, people look to the future and wonder if another similar event is likely. Researchers around the world are trying to communicate the dangers and problems caused by global warming. The news seems to say that as the world gets hotter, severe weather events will become more common. It certainly seems that way with so many hurricanes and tornadoes in the news, but is there really a connection?

The first step in understanding

whether climate change could increase the likelihood of a tornado would be to understand what causes a tornado.

As previously mentioned, however, this is a very difficult concept to fully understand, and scientists do not fully comprehend why a tornado was created in conditions that in other times a tornado was not created. This lack of understanding of the severe weather event impedes scientists' ability to find a link between climate change and tornado frequency.

Lack of data is a problem throughout more than just the creation of tornadoes, however.

According to the Center for Climate and Energy Solutions (CCES), "Measuring the presence of tornadoes relies on eyewitness accounts and aftermath damage assessments rather than quantifiable data."

Researchers find it difficult to analyze long-term data when that data is potentially unreliable. The problem goes even deeper, since it is difficult to identify long-term trends in tornado records, which only date back to the 1950s in the U.S.

Fortunately, the population in many areas affected by tornadoes has grown, contributing to increased eyewitness reports and greater property in harm's way (CCES), so the number of reported tornadoes has increased as Americans moved into areas that are likely to be hit by tornadoes. Before, when tornadoes strike in empty fields or scarcely populated areas, little to no people would report them. This may change with time.

Even though the basic effects

of climate change are fairly well known, the repercussions they would have on the frequency of tornadoes are still difficult to understand.

A warmer world would have two outcomes that have potentially opposite effects. On one hand the climate will likely be unpredictable, experiencing wild shifts more often than before. On the other hand, the warmer weather may lessen chances for wind shear, or sudden shifts in wind current (CCES). It is unclear which factor may outweigh the other, and it is still possible there are other effects that have yet to be considered.

Atmospheric carbon levels can be mapped back thousands of years, but the tornado data only goes back around seventy years. By the time the data for tornadoes spans enough time to properly analyze, the effects may already be clearly visible.

The answer, however, is not a resounding "we do not know."

According to the fourth climate science special report from CCES, "Tornado activity in the United States has become more variable, particularly over the 2000s, with a decrease in the number of days per year with tornadoes and an increase in the number of tornadoes on these days."

In other words, there may be fewer days with reported tornadoes per year, but on days that have tornadoes there are more tornadoes per day.

Although these results again seem to point in two different directions, it does follow what the news often say about climate change: global warming makes the weather more unpredictable.

Severe weather, when it occurs, is more devastating since there are on average more incidents in a given outbreak.

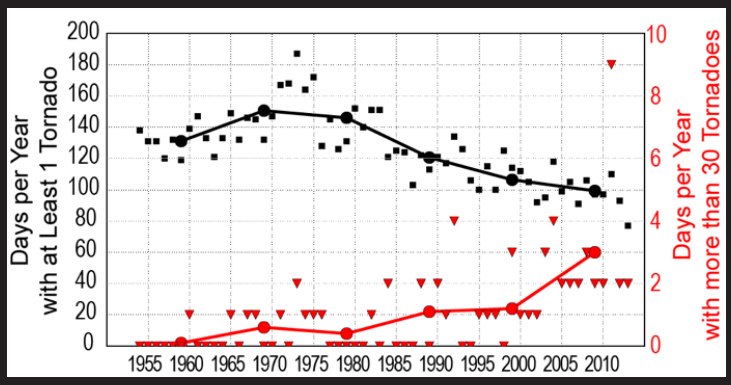
"The extent of the season over which such tornado activity occurs is increasing as well: although tornadoes in the United States are observed in all months of the year, an earlier calendar-day start to the season of high activity is emerging," a team of climate change scientists led by D. J. Wuebbles said.

None of the data suggest that the world will be inundated with more tornadoes, but there are consequences of global warming on these severe weather events.

For our community, this issue is even more important since Texas has the largest average number of tornadoes in the United States per year at 140.

As new methods for analyzing tornadoes and their effects emerge, the correlation will be better understood. Regardless of the effect global warming has on the frequency of tornadoes, it is clear that a changing climate affects severe weather events in some way, but how exactly is still yet to be understood.

Sources used: Fourth National Climate Assessment (NCA4), Volume I; Center for Climate and Energy Solutions: Tornadoes and Climate Change



< Meteorologists are finding that the number of single tornado incidents has been decreasing since the 1980s, but the number of collections of more than 30 tornados in a day has been steadily increasing since 1955.

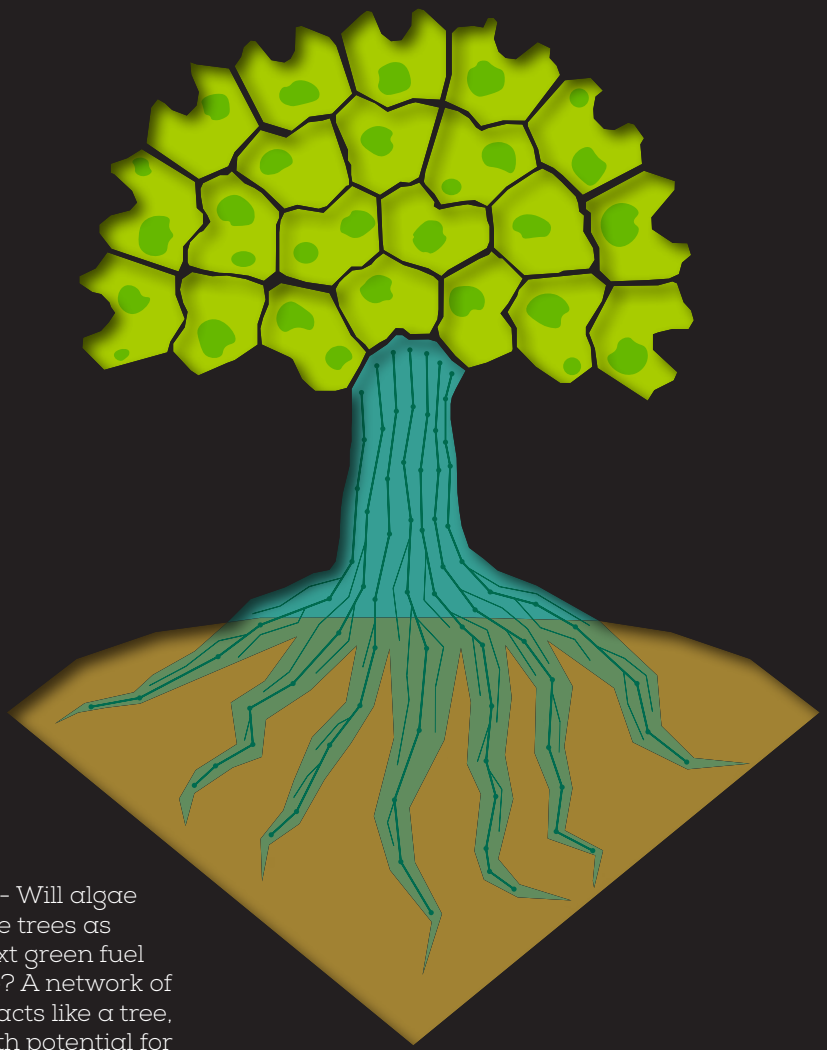
Algae: A new secret weapon to combating climate change?

As awareness of the protection of trees increases, a new method of producing fresh air is on the rise.

Story by Alex Geng and Varun Trivedi Graphic by Varun Trivedi

Trees are becoming less and less sustainable as time passes. With the constant problem of deforestation, ecosystems, mostly in cities, have already adapted to the lack of trees, so planting trees as quickly as possible would not be a viable option. While foresting areas could potentially increase the air quality and serve as a solution to climate change, there are problems. A World Research Paper brings up the fact that planting trees could displace land that would be used for agricultural means, which could drive food prices up. They predicted that up to nine gigatons of carbon a year could be removed, but food prices would in turn be raised 80% by 2050. Even with current technology, it is hard to monitor and control the growth of so many trees at once, and funding is also an issue.

Algae has the potential to fight climate change because a variety of uses, while being very easy and sustainable to grow and harvest. Algae can be grown in bioreactors, which are cultivation vessels that enable chemical reactions within the algae. With an AI-powered bioreactor, algae can be 400 times more efficient than trees at removing carbon from the air. Using algae is also much easier to control because of its relative size, and it grows at a much faster rate than trees do.



> Above- Will algae replace trees as the next green fuel source? A network of algae acts like a tree, but with potential for a stronger impact than planting trees.

Algae does not only serve as a carbon sequestrator, however. Algae can also serve as a very rich source of food as algae oil, which can be turned into supplements. It is less water and land intensive than other similar foods, and could be a viable food staple in the coming years. Algae can also be made into a 3D printer polymer, substituted for the typical plastic filaments. Using the algae as raw material dramatically cuts down the amount of pollution and emissions that would be produced if made with plastic. Major companies like Merrill, Adidas, and H&M have already used algae foam for shoes. Another viable commercial use of algae is biofuel. Using algae is much more sustainable than using other carbon-based fuels like petroleum. However, the process is still very early in the works and requires a lot of effort and cost to be able to produce today.

One company which already started research and development of harnessing algae to convert carbon dioxide into oxygen sustainably as well as provide fuel for daily use is Hypergiant. Their EOS bioreactor is focused around obtaining the biomass from algae to create fuels, food sources, oils, and more. The harvesting system is completely AI based to ensure that the optimal amount of algae is used to convert carbon dioxide into oxygen, and Hypergiant claims the reactor can take in 60-90 percent of CO2 to convert into oxygen.

Obviously, fully switching to algae will be a long, slow process with many challenges. Making big changes will no doubt be very difficult, as consumers and companies alike will need incentive to switch. However, with the growing climate change crisis, it may be necessary in the future to switch from the idea of planting more trees to harvesting more algae and utilizing the world's oceans and lakes. ■

The future of climate change: an economic analysis

Climate change has the potential to impact multiple facets of the economy.

■ **Story** by Alex Geng and Varun Trivedi
■ **Photos** by James Shiao

Even as of the 21st century, climate change has already impacted our economy in major ways. The media attention on the climate increases day by day, and new programs are developed to help manage climate change. Faculty member David Fisher says climate change will inevitably have an effect on the economy.

"Over the course of time, is there going to be an economic effect that results from climate change? Yes."

What this effect may look like for the posterity of America, nobody knows with certainty. However, Fisher believes that the results will be noticeable in our daily lives.

"In everybody's lifetime, we're going to experience more days in which the temperature will go over 120 degrees, more days in which we're hit by tornadoes, because of the climate. The weather is that much more unstable."

Fisher goes on to cite examples of conspicuous results of climate change: "Food prices are likely to go up. People's travels are likely to be hampered by the fact that you're going to be taking into account the uncertainty of weather patterns, and so forth."

As of now, if left unattended and unchecked, Fisher believes climate change will have a big toll on our economy in the future.

"If we do nothing, if there really is no adaptation, will climate change result in negative effects for the economy? The answer is yes. If we just take agriculture, for instance, there is likely to be a net loss of production as a result of climate change. Yes, certain parts of the world might be able to produce more, but there will be significantly more parts of the world that produce less as a result of desertification and increased crop diseases."

However, Fisher believes we can mitigate and eventually prevent some of the effects of climate change. He suggests an interesting idea: a carbon tax.

"A place to start is where most economists want to go, which is with a tax on carbon. It is the most efficient way of dealing with what we know to be the negative effects of carbon. The reason economists prefer it is you are essentially putting a price on carbon. You are letting people know that when we do things like drive a car, we are not only getting a benefit out of driving a car but also creating a negative, pollution". This global warming will lead to harmful effects for the planet.

This method of taxing carbon generates awareness for the public and gives people a decision to make––whether or not to trade time and energy for the cost of using carbon-related items. Of course, many different propositions as to how to implement these regulations for the public to cut down on emissions to better save the climate exist. One thing remains constant: we have to take it slow.

"We have an economy. We have industries. We have lines of work and employment that are all geared to the carbon economy. Shifting away from the carbon economy is not going to happen overnight. Nor would I propose that it does happen overnight because that would be a tremendous blow to our economy."

Today, companies that are switching to alternative energy sources and promoting the transition away from harmful emissions are thriving. One such example of a successful company is Tesla.

Tesla's growth as a company exceeded almost the world's expectations, as it grew so fast in such a short amount of time, all while going against the established norm. Its success in creating electric vehicles is unprecedented in our time.

Of course, alternate energy companies still have room to grow. Even in Texas, alternate energy companies continue to grow and expand.

"In Texas, wind farms are big. Companies are making profits from marketing solar panels. Let's do more of that. But we have to encourage those companies. We have to create an environment in which those sorts of businesses can be profitable. This is where I do see some sort of a role for government."

Today, we hear many advertisements on doing our own part individually to help protect the climate. However, Fisher presents a different viewpoint.

^ Above- A solar panel cell on average generates alternate energy upwards of 265 kilowatts per hour per square foot.
Left- Wind energy is used in coastal places like Hawaii for sustainability.

"If you choose not to fly on a plane, you're doing your bit for the environment. On one level, on a moral level, on an awareness level, sure that's doing some good, but in the grand scheme of things, that's doing very little. If we really care about the environment, that has to happen at the level of government".

Fisher believes government intervention is absolutely necessary for regulating climate change and keeping our economy on track.

"The government always intervenes in the market. We usually want the government to intervene if there's such a thing as market failure. The very existence of pollution is evidence of market failure. It means that nobody really knows the price of that pollution".

To resolve these issues, one way Fisher proposes awareness for climate change for everyone is location-based taxing.

"You can have different tax rates depending on where you live, you can have a tax on miles that you cover as opposed to the fuel itself, right, which would be a different way of looking at it. You can have differential taxes depending on the type of vehicle that you have." ■

Utilizing electrocatalytic CO_2 reduction to produce clean fuel

The increasing ability to transform a pollutant into an energy source can change how we use electricity.

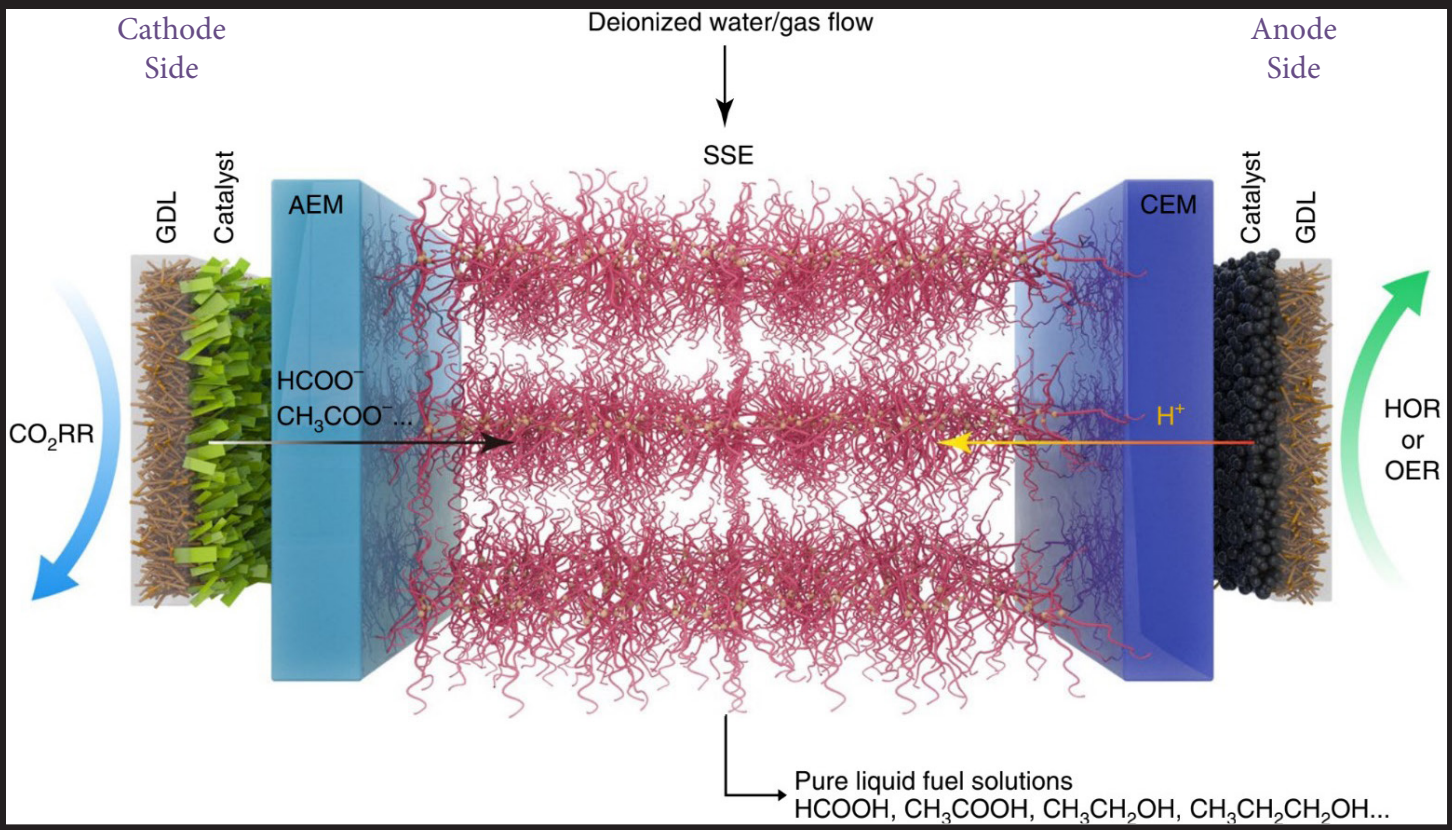
■ **Interview** by Varun Trivedi and Alex Geng
■ **Chart** by Jeremy Yu ■ **Graphic** courtesy of Dr. Chuan Xia

One of the most frequently talked-about topics regarding climate change pertains to carbon emissions and the effects of carbon dioxide released into the environment. Research shows that CO_2 trapped in the atmosphere has led to increased global warming, differences in climate patterns, rising sea levels, and more. Lately, scientists have been attempting to capture the CO_2 and convert it into some sort of fuel source. Until recently, no ways of capturing and reusing carbon dioxide to reduce the impact of carbon emissions on the climate were sustainable commercially.

Just last year, a technological breakthrough made by professor Haotian Wang, Postdoctoral Fellow Chuan Xia, and their team from Rice University changed all that. Wang's research at Rice deals with how to recycle greenhouse gases into usable substances. The original idea: change unusable carbon dioxide released into our atmosphere into a storable and usable form, formic acid. The innovation: construct a new bismuth catalyst as well as a new electrolyte which increases the efficiency of the reaction, enough to be able to be commercially used.

We spoke with Xia and his team to see the ideas and processes behind his findings. Their work has the potential to impact carbon dioxide emissions in the future.

A Schematic Overview of the Cell and Process



Note: Catalyst-coated gas diffusion layer (GDL) electrodes acted as the cathode and anode of the cell, separated by anion and cation exchange membranes (AEM and CEM). The solid-state electrolyte (SSE) is either an anion or a cation conductor, made up of ion-conducting polymers with different functional groups.

The GDL and HCOOH-selective catalyst reduce the CO_2 at the cathode side, generating $HCOO^-$. This negatively charged molecule is pushed by the electrical field through the AEM and towards the middle SSE channel. On the anode side, protons generated by water oxidation move across the CEM to compensate for the negative charge. The HCOOH (formic acid) product is formed via ionic recombination between the middle channel and one of the two membranes (depending on the SSE).

Varun Trivedi: Can you give a brief overview of the process? How is it different from other electrosynthesis processes?

Chuan Xia: We used the porous solid electrolyte (instead of a conventional aqueous electrolyte like 1M KOH) to separate the cathode and anode of the reactor. The humidified CO_2 was fed to the cathode and reduced into $HCOO^-$ anions. Meanwhile, the H_2O was oxided into O_2 and protons at the anode. Then, the $HCOO^-$ anions and protons moved into the solid electrolyte layer driven by the applied electrical field and recombined into HCOOH molecules, which were flushed out by clean water. By tuning the water flow rate, pure HCOOH solution with a different concentration was collected.

The use of a porous solid electrolyte instead of a conventional aqueous electrolyte avoids subsequent separation processes, making our strategy more energy efficient. Additionally, our new Bi-catalyst makes the CO_2-to-HCOOH conversion process more efficient and stable than before.

VT: What are the implications of this process in the larger context of climate change?

CX: Our strategy can help to recycle the emitted CO_2 in the atmosphere, creating a carbon-neutral future. We can collect the CO_2 from the air and convert it into HCOOH fuel. HCOOH fuel is a promising energy carrier that can be used to power cars, industry plants, etc. The generated CO_2 from HCOOH decomposition can be further reduced back to HCOOH using renewable energy.

VT: How does the cost of creating and maintaining these reactors compare with the positive effects generated by them?

CX: The cost for mass HCOOH production using our reactor is far lower than that using current commerical technology (see the techno-economical analysis in our paper),* helping to reduce CO_2 emissions.

VT: How did you come up with ideas for the bismuth catalyst as well as the newly designed catalyst?

CX: Intrinsically, the Bi-catalyst is favorable for CO_2-to-HCOOH conversion. However, its activity is quite low. By nanoengineering, we developed a new process for kilogram synthesis of the Bi nanosheet catalyst.

VT: How does this process compare to simply planting more trees to use up CO_2 and produce oxygen (in the context of climate change)?

CX: This process is much more efficient than simply planting more trees. Using electrochemistry, we can not only reduce the excessive CO_2 in the air but also produce value-added liquid fuels. Then, we can create a carbon-neutral energy cycle, e.g. $CO_2 \rightarrow HCOOH \rightarrow CO_2$.

> **"This process is much more efficient than simply planting more trees."**
>
> Rice University Postdoctoral Fellow Chuan Xia

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The results of Xia and his teams' calculations are as shown in this analysis.

Techno-Economical Analysis

CO_2 reduction to Formic Acid at approximately 200 mA/cm² with HCOOH Faradaic Efficiency of 80%.

Total required current: 6,065,858.4 A

Total electrolyzer area: 3032.9 m²

Power needed: 16.7 MW

Total gas flow: 8589.8 m³/hr

Production costs of central grid CO2 Electrolysis

Ref. electrolyzer cost	$991.7/m²
CO2 electrolyzer cost	$2,789,290
Balance of plant cost	$1,501,926
Distillation cost	$5,963,289
Pressure Swing Adsorption cost	$7,980,731

Total Cost of Production over 3032.9 m² is then $19,217,059

Operation costs of central grid CO2 Electrolysis

Electricity cost	$12010/day
Maintenance cost	$199/day
Distillation operating cost	$13,015/day
PSA operating cost	$1546/day
Water and CO2 cost	$3859/day

Total Operation cost over 1 day: $30,630

Current HCOOH market price: $0.735/kg

Yearly Profit: $15,004,495

Payback time for capital costs = 1.28 years

VT: How is this process improving? What are some components in it that can be improved in the future to increase efficiency?

CX: Improving the CO_2-to-HCOOH selectivity and stability under extremely high production rate (e.g. 1A/cm² current density) can further push forward this technology. Catalyst, solid electrolyte and membrane design can further increase efficiency.

VT: How long did the research portion take? What were some challenges you had to face when designing and carrying out the production of the reactor?

CX: It took us almost one year to finish the research work. The most challenging part of this work was to design the stable and efficient porous solid electrolyte.

VT: Where did the inspiration for this come?

CX: We were inspired by the chemistry of the solid-state battery.

VT: Do you think that this type of process will become commercial? How would it be integrated into the world/society? How long would the process take, and what barriers would prevent it from becoming a mainstream source of energy production?

CX: We believe that this type of process would definitely become commercial owing to its sustainability. The Tesla electric car is a good example. Using renewable energy to replace fossil fuels is the current trend, and we believe that more and more cases like Tesla will emerge within the next ten years.

Looking to the future, science and technology will only get more and more advanced. To truly help preserve and regulate the climate, however, it is imiperative that we use our technology and resources to conquer this challenge. Whether that means an embrace of governmental control, a surge in support for algae and trees, or other innovations like converting carbon dioxide into fuel, the human race must come together to protect this planet we call home. To do so, we must raise awareness, making sure everyone has knowledge of our climate crisis. Only together, with the use of our current and future technology, we can conquer this crisis and make sure the generations to come have a healthy planet to live on. ■