David Archer’s 11 year old Oddish (Peer Assessments)

The aim is to answer his questions (ignoring the word limits, if necessary) such that the Oddish can understand them. Note that all the questions are here; I missed the Verified Certificate by 1% last time.

~ ธนยุจัตน์ งกัป่วันฉัก้อจังใ ปังเส็ง

David Archer's Explain It question from Coursera: What is heat? And, how can you warm something up in space?

Heat, also known as thermal or internal energy, is defined as the sum of kinetic and potential energy of the particles in a substance. The potential energy comes from the energy between the bonds of each molecule (intramolecular forces) and van der Waals/metallic/ionic/hydrogen bonding/dipole moment bonding between the different molecules. The kinetic energy is from the translational, vibrational and rotational motion of the molecules. Temperature is a measure of the amount of heat in the given object or system. The first law of thermodynamics state that a change in internal energy of the system is equal to the heat input into the system minus the work done by the system.

When there are multiple objects with different temperatures in the same system, it means that there are molecules in the system which possess more potential and kinetic energy than others. The molecules will come into contact with each other and the one with higher amount of energy will pass it on to the less energetic ones. The result is that heat flows from a hotter object to a colder one as the system strives to achieve thermal equilibrium; only when it successfully achieves thermal equilibrium does the net transfer of heat energy stop.

There are three different means of transmitting heat: conduction, convection and radiation. Conduction means that the heat energy flows from one body to another within the system through solids; in other words, the objects would need to be in contact with one another. Convection is used to describe the flow of heat in a fluid (that is, a liquid or a gas) because the molecules here are not bound as tightly through intermolecular forces. When a fluid has a higher temperature, it is typically less dense and will float towards the top of the system; when it is cooler and denser, it will sink towards the bottom. If there is heat input into such a system, it is normally done at the bottom so that through the process of convection, the entire system gets heated.

In space, however, there is a lack of any matter (solid, liquid, gas). This would prohibit conduction and convection methods of heating. This is where all heating would have to be done solely by radiation. Heating stuff in this manner involves the transmission of electromagnetic waves (infrared, microwaves etc.) where the energy within the waves stimulate the more intense vibration of the molecules, thereby increasing its thermal energy. Radiation does not need any intermediate material and is as such the primary way of heating something in space.

Therefore, in space, you should have a way using radiation to heat your food. Perhaps the use of a microwave (assuming you worked around the lack of gravity)? Or you could somehow expose the stuff to the Sun’s radiation such that it can become heated.

David Archer's Explain It question from Coursera: Why is CO_2 a greenhouse gas, and O_2 not?

Each gas has one or more natural frequencies, which means that any radiation incident to it would result in the maximum energy transfer from radiation of that frequency to the molecule and it then gets reradiated. In the context of greenhouse gases, this means that at least one of its natural frequencies lies in the infrared region and hence would allow maximum energy transfer to the molecule. As the direction of reradiation is random, it would mean that some of this energy can be reradiated to Earth, hence increasing the total amount of infrared energy in the Earth's atmosphere. The temperature of the Earth is dependent on the amount of heat (infrared) energy that it has.

Some properties of molecules will help to determine whether their natural frequencies lie within the infrared zone. Molecules are able to undergo three types of vibration in the infrared region: Symmetric stretching, asymmetric stretching and bending. In the case of oxygen, it can only undergo the former two, neither of which are infrared active. It cannot undergo bending since that process requires two atoms bonded directly to the central atom to change their relative orientation. It is impossible to change the dipole moment of the oxygen molecule, hence making it infrared inactive.

To be "active" means that absorption of a photon to excite the vibration is allowed by the rules of quantum mechanics
However, carbon dioxide is able to do so. The asymmetric stretch and bending (relative to the carbon atom) for carbon dioxide is infrared active because there is a change in the molecular dipole moment during this vibration. This allows the trapping of heat to take place and as such makes it a greenhouse gas unlike oxygen.

David Archer's Explain It question from Coursera: What are positive and negative feedbacks?

Feedback is defined as the effect from the input into a given system. Suppose there is a system consisting of input part, feedback part and output part. The feedback part moves from outcome part to the input part. The positive feedback occurs when the outcome increases, the feedback makes the output larger. The negative feedback works conversely. Positive feedback tends to result in a chain reaction if the cause for it to carry on (the catalyst) remains available.

An image of me, because I’m Glam!

David Archer's Explain It question from Coursera: Tell a story of what happened to put an atom of carbon into a fossil fuel, and what will happen to it after it is mined.

The carbon atom in the question once used to belong to a plant or animal that existed a long time ago (at least several millions of years).
When the plant or animal dies, it results in it falling to the ground. The action of microorganisms will result in them being decomposed, and these remains gradually become buried under layers and layers of mud, rock and sand. Gradually, hundreds and sometimes thousands of feet of earth covered them. This creates the high pressure needed to allow further decomposition to take place and produce the fossil fuel. The type of fossil fuel (coal, oil, natural gas) is dependent on the combination of animal and plant debris, how long the material was buried and the exact conditions of temperature and pressure existed during their decomposition. Oil and natural gas were created from organisms that lived in the water and were buried under ocean or river sediments. In most areas, a thick liquid called oil formed first, but in deeper, hot regions underground, the cooking process continued until natural gas was formed. Over time, some of this oil and natural gas began working its way upward through the earth's crust until they ran into non-porous rocks, preventing them from seeping to the surface; oil and natural gas is are found just below the layers of non-porous rocks. Coal is a sedimentary organic rock that contains a lot of carbon and is formed by ancient plants and animals accumulating in moist peat bogs. As plants die off in a wet area, they pile up into peat.

The atom of carbon would remain trapped in the fossil fuel for a long time, until some humans dig through the non-porous rock and mine the fossil fuel. Fossil fuels are mined due to their relatively low (monetary) cost per unit power that can be supplied. As an energy-dependent society, large amounts of fossil fuels are needed in order to sustain our demand for energy. Where the carbon atom in the fossil fuel would end up would depend on who mined the fossil fuel as well as the form.

For most of the fuel, it is transported through pipes and/or vehicles. In the case of coal, its pulverized form is blown into the furnace where it burns while airborne. For oil and natural gas, it is sent to the refineries and undergoes fractional distillation before it is sent to the power plant to be burned. Water flows through tubes that run through the furnace. The water is heated to boiling by the burning fossil fuel while under pressure. This pressurized steam blasts through a turbine, which turns a generator to produce electricity. As the fossil fuel is burned, it converts the carbon into carbon dioxide (carbon monoxide in the case of incomplete combustion) and this is let out into the atmosphere. It then results in it contributing to global warming through its heat-trapping abilities (seen in David's previous question). It may eventually get taken up by plants through photosynthesis (with light and water) so that it gets stored within the plant. This plant may also get eaten by animals. Barring immortality from technological advancements, these plants and animals today will eventually die and fall to the ground, which will behave as the carbon that is to contribute to the formation of future fossil fuels.

David Archer's Explain It question from Coursera: Tell a story of what might happen when an atom of fossil carbon is burned and released to the atmosphere.

The world is highly dependent on energy to facilitate its growth and economic development. Apart from relatively small amounts derived from wind, solar, hydroelectric, nuclear energy and biofuels, the world gets its energy from burning fossil fuels.

To utilize the fossil fuel requires it to undergo combustion, which can be defined as getting energy from heating the fuel (hydrocarbons; molecules with only hydrogen and carbon atoms) in excess oxygen; when combustion goes to completion the fossil carbon atom will have broken bonds with the other atoms in the hydrocarbon, as with the oxygen molecules involved, and new bonds will be formed between the carbon atom and two oxygen atoms. This forms carbon dioxide; water vapour is also formed through combustion. Sometimes, when the combustion fails to go to completion, the carbon atom may get into other molecules (methane, carbon monoxide) or may simply end up as soot. As this is an exothermic (energy-releasing) process, it can allow for the turbine to be driven and allow the generator to use the kinetic energy to produce electricity.

The molecule that the carbon is in may not be released to the atmosphere in large. Depending on the sophistication of the technology used, Carbon storage and catalytic converters may prevent their emission. Carbon storage is when carbon dioxide is stored deep in the Earth and enters tiny holes in the solid rock, similar to the way water is captured in a sponge. Catalytic converters, typically found in cars and factories, aim to remove some of the gases such as carbon monoxide and methane and convert them to carbon dioxide and water, which could in turn be removed with scrubbing towers (for factories). Scrubbing towers are tall buildings with a fan at the bottom that sucks air in and ejects the air out again at the top. In the process, about half the carbon dioxide is removed from the air.

Much of the carbon-based gases, especially in relatively less green countries, would allow these gases into the atmosphere. This can be bad, since the carbon dioxide molecule will then interact with infrared radiation and reflect more of it to the Earth’s surface, thus raising its temperature. If there is a lot of carbon dioxide emitted, it can remain in the air for longer before natural processes such as photosynthesis use it up. Higher temperatures lead to changes in the ecosystem as well as flooding through the melting of the polar ice caps. Mass relocations can take place as the most populated (and arable) land is being inundated by the seas, thus inconveniencing and starving many people as arable land becomes unusable.

Furthermore, the fossil carbon atom could happen to dissolve into the sea, making it form carbonic acid. Carbonic acid is a weak acid, meaning it dissociates only partly in water to form the hydrogen ion. However, this still results in a decrease in the pH of the ocean. The increasing acidity has inhibited shell growth in marine animals may have resulted in reproductive disorders in some fish. It can disrupt the entire marine food chain as well as spoil the beauty of coral reefs.

In conclusion, it might be interesting to observe the one carbon atom undergoing this process, but with its myriads of siblings all doing the same thing, they can harm the Earth in many ways.

In this situation, the synthesis of energy can possibly happen inside the Town Hall in the centre of the base, as it needs to provide for the needs of the base.

However, not producing clean power can result in production of more greenhouse gases. Having more carbon dioxide and other such gases can favour the formation of Boggans, creatures which destroy most types of plants and Aura. This would prove dangerous to the four 11-year olds, since the Archer Towers are not efficacious in defending against the Boggans. Petilil and Grimer in particular would be in greater peril; Petilil is weak against Wood and Wind Boggans while Grimer is incapable of damaging Earth Boggans. This would expose the Town Hall and literally kill many living things. With a greatly reduced number of plants, there would also be less production of oxygen in the vicinity and asphyxia is going to be much more common.

Hence it is important to prevent excessive emissions of your greenhouse gases, for failing to do so can literally result in your demise.

David Archer's Explain It question from Coursera: Is the Earth warming, and if so, is it because of human activity? By what scientific evidence do we know?

The Earth has gone through many phases of warming and cooling in its history. It had moments where there was no ice on it (http://www.dinosaurtheory.com/thick_atmosphere.html) and others where it took on a Snowball Earth appearance (http://www.cosmosmagazine.com/features/ice-world-catalyst-life). All but the latest one have occurred due to natural means alone. These include: atmosphere thickness, brightness of the Sun, number of sunspots, axial tilt, distance from the Sun. For instance, having a higher number of sunspots would affect the trade winds in the Pacific Ocean and hence cause cooler climate as well as a change in precipitation patterns on Earth. A thick atmosphere would prevent heat from being lost into space, which results in higher global temperatures.

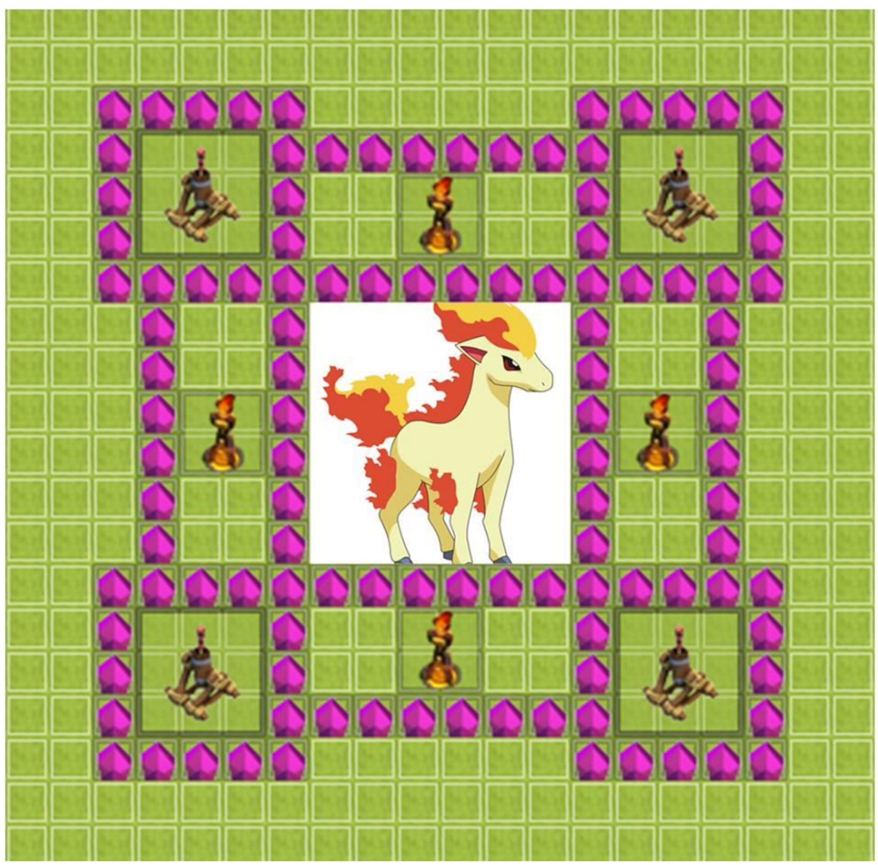
However, with the onset of humans and the rapid growth in energy consumption, the Earth has been warming at an unprecedented rate. The Earth has warmed by 1°C in the past 30 years, which is similar to the amount that it has warmed up by in the millennium before that (during the Little Ice Age) and much less than the predicted warming in the coming century. Over a really short geological time frame, natural causes will be able to account for some but most likely not all of the changes. It is highly probable that human activity has contributed to much of the warming.

Much of this warming would be due to our dependence on fossil fuel for energy. Although we can harness alternative sources of energy to sustain our needs, fossil fuels remain as the dominant source of energy. Burning fossil fuels produce carbon dioxide, methane and water vapour. With the additional greenhouse gases, production of them exceed the natural intake rate. The system will result in the increase in the concentration of said gases. Since they would trap heat in the Earth’s atmosphere, it would only be natural that the equilibrium temperature be higher.

Our use of scientific technology has come a long way. We are able to make use of tree rings, fossil records and ice cores, among other things, to ascertain conditions of the past. An ice core is a long column of ice that is dug up from an ice sheet. For tree rings, wider rings indicate a favourable growing season while narrower and missing rings indicate poor growing conditions such as drought. Each tree ring represents one year that has passed. As for fossil records and ice cores, there are trapped bubbles of air separated from the surroundings; various isotopes can be examined to find out the conditions of the time. Radioactive isotopes can help to determine the age of a sample, since any given isotope will have a fixed half-life, and in one half-life, the remaining amount of the isotope will half (since it cannot be replenished from the surroundings). For instance, carbon-14 is often used in the form of carbon dating, while beryllium-10 can measure solar intensity in the past. It has been found that the carbon dioxide concentration and the temperature are closely related to each other (http://upload.wikimedia.org/wikipedia/en/thumb/6/63/Co2-temperature-plot.svg/400px-Co2-temperature-plot.svg.png). We can conclude that we are responsible for the global warming.

Of course the Earth is warming! Especially when you have a base like THIS.
Note that the Ponyta in the middle has the abilities Drought and Flash Fire.

As such, it absorbs the Inferno Tower rays if there are no other targets within the range. This would make the Ponyta emit lots of heat and hence cause the Earth to warm. The Air Defenses, apart from repelling flying targets, also help focus the Inferno Tower rays to the Ponyta, making a curmudgeon-like effect.



David Archer's Explain It question from Coursera: What do they mean by "Global Weirding"? Be as specific as you can in your explanation.

A rather interesting question; this is easily explained by Thomas Friedman.

It is a well-known fact that the presence of human activity has led to the increase in concentration in greenhouse gases such as carbon dioxide and hence leads to global warming. The term 'global warming' on the surface level implies that the world's temperature is going up; something that is uniform, gradual and likely benign. While the world's temperature has indeed increased, the actual effect is quite uneven geographically. Additionally, this change is rapid and affects many other climatic phenomena too: precipitation, humidity, soil moisture, atmospheric circulation patterns, storms, ice cover, ocean covers. All of these are interdependent on each other and hence are influenced due to the enhanced greenhouse effect. The weather becomes weird as compared to the past, hence the name 'global weirding'

Do you know about some of the recent extreme weather around the world? The extreme cold and ice storms just three months ago in eastern USA which, in the case of Atlanta, resulted in overnight gridlock from the icy roads and some motorists simply abandoning their vehicles on the highways at one point? Or how the drought is worsening in California and other regions which has crippled their crops and fueled wildfires with the intense heat, affecting all the residents there? Or perhaps the devastation in England when floods from a record wet winter inundated their homes? These are all effects of our actions which have placed more greenhouse gas into the atmosphere–global weirding. It is a bit like your body being unable to function properly just because your body temperature is slightly higher than usual: you head hurts, your limbs ache, and it feels like much more than a couple of degrees of extra warmth. In that regard, it is silly for the American politics to believe that climate change is a hoax due to their particularly snowy winter.

You may think that the raise in temperature should implicate more heat waves. Yes, that is true as a direct consequence of global warming. However, it does not stop there. The extreme weather conditions/natural disasters around the world (besides heat waves) are also instigated by the warmer atmosphere. Temperature gradients create winds; the effect of warming the Earth results in changes in the wind patterns and hence the distribution of precipitation.

The hydrological cycle is the process which describes the movement of water in the Earth's atmosphere. It starts with water evaporating from bodies of water such as lakes and seas. The water vapour will then rise until it reaches a cooler region of the atmosphere, where it will condense into clouds. These clouds gather more mass from water vapour before it is let out in the form of precipitation (snow/rain). Evaporation is defined as the transformation of water from liquid to gaseous state, while condensation is defined as the transformation of water from gaseous to liquid state. This precipitation will then fall onto the Earth, where it may get taken in by plants, absorbed into the ground, form part of glaciers or runoff into the bodies of water on the surface. The cycle repeats itself.

The effect of temperature has two profound effects in relation to the water cycle. The first thing is that the atmosphere is able to hold a greater amount of water vapour when warm, which means that there would overall be more precipitation. The other is that evaporation will be more rapid as its rate is proportional to that of the surrounding temperatures. These, together with the changes in wind patterns, mean that the result is a change in the distribution of precipitation. This can make some regions receive far more rain than usual, while others may simply get hotter and longer droughts. Even places which may get the same amount of precipitation are more likely to get them at irregular intervals. Likewise, temperature extremes will also diverge. While there may be the El Nino and La Nina effects, the changes in the wind have resulted in the amplification in the strength of the resulting storms bringing them to record levels.

Whatever the effects, global weirding has influences on our daily lives, since more intense weather (droughts and floods) will affect our infrastructure in the long-term. With more intense weather, the area of the arable land will decrease, and with a booming population, this can make even sustainable feeding a challenge. Floods can wreck entire regions through the sheer force of the water itself. What’s left of the affected region can be vulnerable to water-borne diseases such as cholera and malaria as any drinking sources would most likely be contaminated and mosquitoes are able to breed in the stagnant water. Extensive droughts can make places similarly uninhabitable since a city will have to rely more on groundwater, which is most likely not being topped up with the lack of precipitation. As daily living requires a certain amount of fresh water, having none of it would force emigrations and relocations.

In conclusion, global weirding is significant and will be mostly detrimental to our lives especially in the coming years.

Some resources that can explain global weirding:

Hot, Flat and Crowded by Thomas Friedman (the section around ‘Daffodils in January’)

Last chapter of Blackout by Richard Heinberg

http://thinkprogress.org/climate/2010/02/17/205518/global-weirding-global-warming-climate-change-tom-friedman/

http://thinkprogress.org/romm/2009/01/26/203610/noaa-climate-change-irreversible-1000-years-drought-dust-bowls

http://thinkprogress.org/romm/2009/03/28/203878/an-introduction-to-climate-progress/

http://mashable.com/2014/05/14/california-wildfires-santa-ana-winds

David Archer's Explain It question from Coursera: The 11-year-old wants to know how hard you think it would be for humanity to decarbonize our energy system in time to prevent climate from changing too much. This is a subjective question, but use specifics in support of your position.

We are currently living in an era where we are prospering. In doing so, we have managed to become more reliant (at least in developed countries and regions) on luxuries that did not exist in the past such as the air-con, heater, car, computers and the like. Many of them require an energy source in order to become operational. As these goods are becoming cheaper and more widely available around the world, it means that it becomes affordable to the middle class and hence more of them will be used.

There are several ways to get the energy needed on a large scale: solar energy, hydroelectric, nuclear, wind, biofuels and, of course, fossil fuels. Many of our companies are profit-driven meaning that they would naturally choose the cheapest source of energy so as to reduce their operating costs and hence make more profit given a fixed amount of revenue from the sale/use of their products. The problem with all the clean and/or renewable sources of energy is that the cost to extract the same amount of energy from those sources is much higher and funding research to make them more efficient is also quite expensive. As such, even when there are measures like carbon taxation to attempt to cut down on the carbon emissions, companies would rather pay this tax as it is relatively cheaper even into the long-term, resulting in higher overall profits for them. Furthermore, there are reliability issues. For instance, a nuclear power meltdown will force such a power plant to close down and would be hazardous for any nearby areas for significant periods of time. Wind and solar energy would depend heavily on the weather conditions, which may mean that little energy is generated if such conditions are not favourable. Hence, fossil fuels remain our primary source of energy, due to their dirt cheap cost and high reliability.

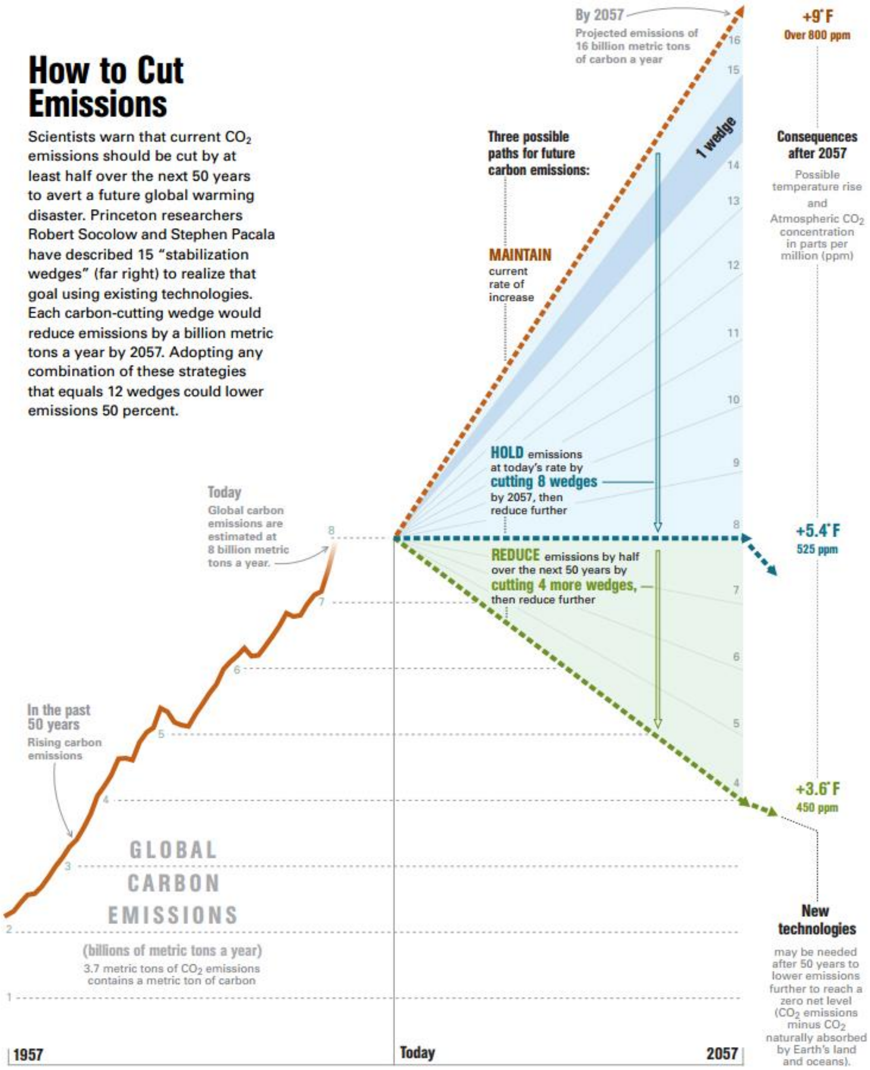
However, what the profit-driven companies forget to consider are their negative externalities (the costs borne by third parties not directly involved in the consumption or production of the goods, for which there is no compensation) from using the fossil fuels. This includes the carbon emissions, which can cause respiratory problems, global warming/weirding, rising sea level (resulting in damage to low-lying areas), loss of species and many more deleterious effects.

Indeed, there is a tipping point that we are fast approaching (about 2 degrees Celsius of further warming from today), beyond which no further human intervention is needed for the effects to continue to propagate; for instance, melting enough of the glaciers to cause the rest to absorb more energy from lower albedo or simply slide into the oceans. There is some dispute about precisely what carbon dioxide concentration is needed for this to happen, but many scientists believe that it is at 450 parts per million (ppm), less than 50 ppm above the current carbon dioxide concentrations. We are currently adding about 2 ppm into the atmosphere every year; this would bring us above the tipping point in a matter of about two swift decades. This is made harder by the fact that carbon dioxide will remain in the atmosphere for a long time; even if no further emissions were made, the temperature can still rise by over a half degree Celsius.

There may have been agreements like the Kyoto Protocol but these have been largely unsuccessful. This is because we know approximately how much we have to cut down on carbon emissions collectively as a world. However, the problem lies between the different countries since none of them really want to use a larger proportion of their GDP to invest in green technology due to the opportunity cost involved. If we stopped burning fossil fuels, it would affect the stock exchanges around the world; the amount wasted in the form of reserves that cannot be burned would reach $6.74 trillion.

How to Cut Emissions

Scientists warn that current CO_2 emissions should be cut by at least half over the next 50 years to avert a future global warming disaster. Princeton researchers Robert Socolow and Stephen Pacala have described 15 "stabilization wedges" (far right) to realize that goal using existing technologies. Each carbon-cutting wedge would reduce emissions by a billion metric tons a year by 2057. Adopting any combination of these strategies that equals 12 wedges could lower emissions 50 percent.



SOURCES: ROBERT H. SOCOLOW AND STEPHEN W. PACALA, PRINCETON UNIVERSITY (UPDATED REPORT); OAK RIDGE NATIONAL LABORATORY (GLOBAL CARBON EMISSIONS DATA); ICONS BY JONATHAN AVERY; GRAPHIC BY JUAN VELASC

ONE WEDGE AT A TIME

Each strategy listed below would, by 2057, reduce annual carbon emissions by a billion metric tons.

EFFICIENCY AND CONSERVATION

- Improve fuel economy of the two billion cars expected on the road by 2057 to 60 mpg from 30 mpg.
- Reduce miles traveled annually per car from 10,000 to 5,000.
- Increase efficiency in heating, cooling, lighting, and appliances by 25 percent.
- Improve coal-fired power plant efficiency to 60 percent from 40 percent.

CARBON CAPTURE AND STORAGE

- Introduce systems to capture CO_2 and store it underground at 800 large coal-fired plants or 1,600 natural-gas-fired plants.
- Use capture systems at coal-derived hydrogen plants producing fuel for a billion cars.
- Use capture systems in coal-derived synthetic fuel plants producing 30 million barrels a day.

LOW-CARBON FUELS

- Replace 1,400 large coal-fired power plants with natural-gas-fired plants.
- Displace coal by increasing production of nuclear power to three times today's capacity.

RENEWABLES AND BIOSTORAGE

- Increase wind-generated power to 25 times current capacity.
- Increase solar power to 700 times current capacity.
- Increase wind power to 50 times current capacity to make hydrogen for fuel-cell cars.
- Increase ethanol biofuel production to 50 times current capacity. About one-sixth of the world's cropland would be needed.
- Stop all deforestation.
- Expand conservation tillage to all cropland (normal plowing releases carbon by speeding decomposition of organic matter).

Whatever the case is, if we want to have any hope in preventing excessive climate change, we need to cut down on the carbon emissions immediately, at all costs. It may seem like a behemoth (difficult) task, but it can be broken down into relatively easier steps. Steve Pacala and Rob Socolow from Princeton University have published a paper in 2004 on how to achieve this. As they found out, there is no one single, optimal technology that can be deployed to remove ALL of the excess carbon emissions singlehandedly. It comes in the form of 15 wedges, each being able to reduce the carbon emissions by a billion metric tons annually.
The 15 wedges have been listed in the image (National Geographic). Some of the goals may appear easy. For example, we are already phasing out the less efficient incandescent bulbs for more efficient fluorescent bulbs with current technology. However, the majority of the goals can be quite difficult to accomplish. In order to achieve this, there will be the need for extensive cooperation at different levels.

Some of these directly involve sacrificing our own comfort. For example, travelling only half the mileage on cars would reduce the emissions by one wedge. This would imply the use of public transport (buses and trains), which means that travel can be more time consuming in the already fast-paced society.

There are some wedges where the technology to achieve them is available, but only in some developed countries. Bear in mind that with globalization, the world will become more homogeneous and there will be a greater population that will want to reap the benefits of these luxuries more commonly used in the developed world. This is where the developed countries will have to cooperate. They must not only use the green technology for their own industries and residents, but also give subsidies on the availability of such technology to the less developed countries as making them pay the full cost would actually slow down the spread of making a green technology. If the green technology is not passed on to them, they will most likely go through a phase where they would use mass fossil fuels, which would only push us over the threshold of the tipping point even more rapidly. While working on achieving the wedges, we would also need to work on technology to achieve zero net emissions after 2050 or so, since cutting by 12 wedges (as stated in the image above) will merely mitigate passing that tipping point. Zero net emissions would be to have all emitted carbon being able to be absorbed naturally, be it into the ocean or photosynthesis.

In conclusion, there is a lot of work and cooperation that needs to be done in order to save the Earth from the most drastic impacts; indeed, they may already be unavoidable if the real situation is actually worse than the most pessimistic outlook (according to IPCC WGII, one model predicts today's carbon dioxide concentration is already sufficient to cause warming exceeding 2 degrees Celsius). Being unwilling to change from the business-as-usual scenario, however, will wipe out any hope of preventing extreme climate change.

If all else fails in decarbonizing our energy system, there is a way out… but you would really need to believe in Periwinkle, the Winter Fairy. Her wintry magic may be able to save the world by countering all the warming from human activity, but only if believed in sufficiently.