Creating a Climate of Change

A history of climate science, how we've got to where we are, and how we are going to get to where we need to go.

A BRIEF HISTORY OF CLIMATE SCIENCE

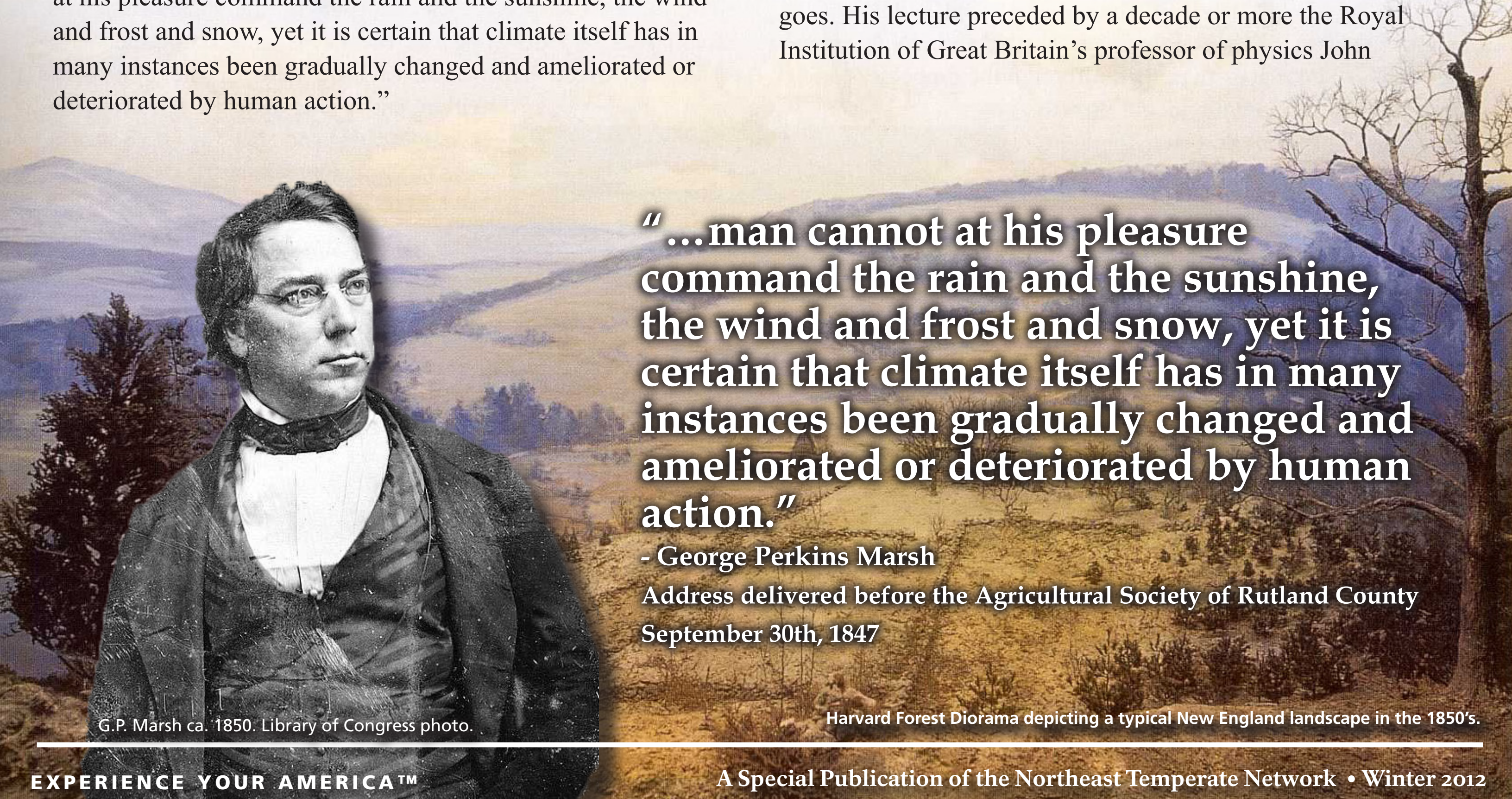
In a 2010 interview, Jon Jarvis, the eighteenth director of the National Park Service, stated that climate change is "the greatest threat to the integrity of the National Park System that we've ever faced". Long before that interview, in the fall of 1847 and a full generation before even the *first* director of the park service (Stephen Mather) was born, a man who would later become one of the namesakes of Marsh-Billings-Rockefeller National Historical Park was already speaking of people's ability to permanently alter Earth's natural systems and climate.

Born and raised in Woodstock, Vermont, George Perkins Marsh (1801-1882) witnessed first-hand the destruction of the state's (and much of the region's) forests, where by the mid-1800's 70 to 90 percent of the virgin trees had been cut.

On September 30th, 1847, when serving as a Congressman for Vermont, Marsh gave a lecture to the state's Agricultural Society of Rutland County where he would become one of the first to directly correlate human behavior to changes in Earth's climate. In that speech he declared: "…man cannot at his pleasure command the rain and the sunshine, the wind and frost and snow, yet it is certain that climate itself has in many instances been gradually changed and ameliorated or deteriorated by human action."

Marsh was not referring to humanity's use of fossil fuels in this speech as the industrial revolution was barely in its nascency (the first oil well was yet to be drilled in 1859 in Pennsylvania and Thomas Edison opened the first coal-fired electricity plant in New York City in 1881). Rather, he was referring to the massive deforestation wrought by New Englanders. Sheep farms, hillside farms, wood exportation, the need for fuel wood, and other land-use decisions all took a heavy toll on Vermont's forests, wildlife, lakes and rivers, climate, and landscape. Marsh observed that the draining of swamps and the clearing of forests was having a noticeable effect on evaporation from the earth, as well as the average quantity of moisture in the air (a large tree can transpire several hundred gallons of water through its leaves on a hot day). In his speech he noted that deforestation modified "the electrical condition of the atmosphere and the power of the surface to reflect, absorb and radiate the rays of the sun, and consequently influence the distribution of light and heat, and the force and direction of the winds." In other words, deforestation was altering the climate of Vermont and the Northeast.

Marsh was truly ahead of his time as climate science goes. His lecture preceded by a decade or more the Royal Institution of Great Britain's professor of physics John



G.P. Marsh ca. 1850. Library of Congress photo.

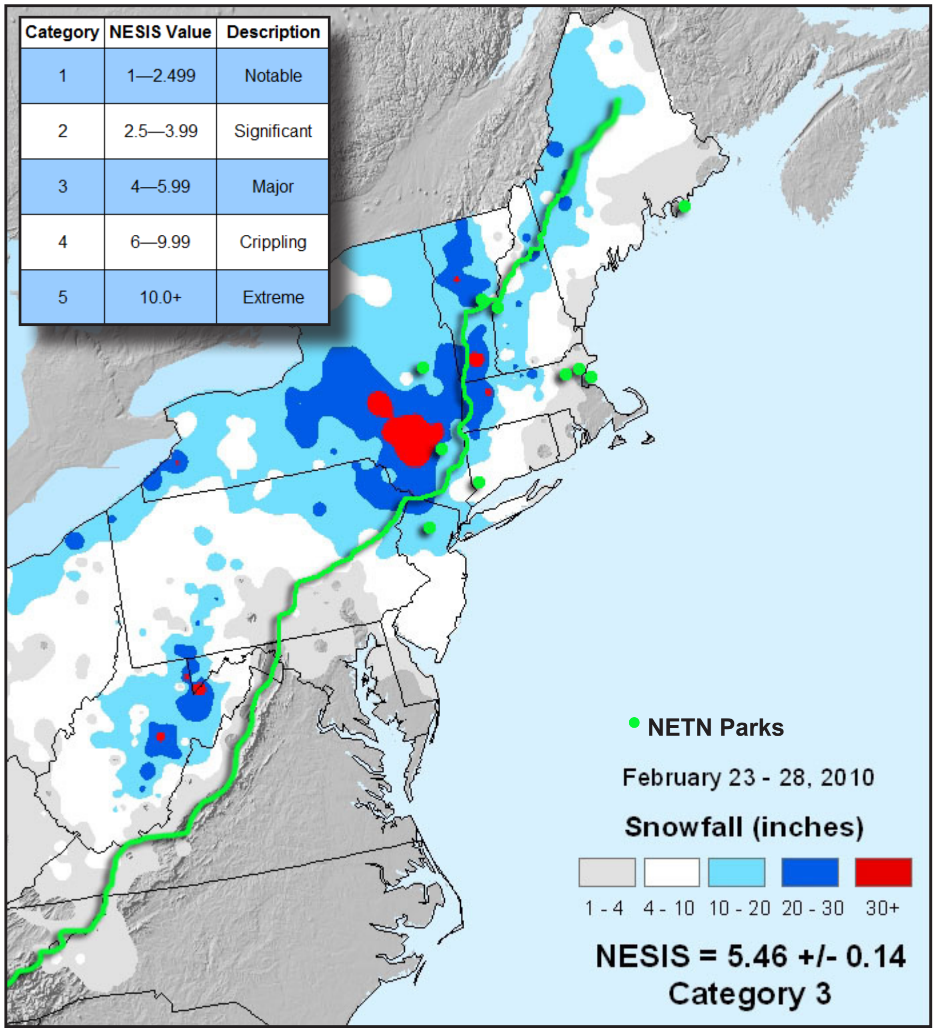
"…man cannot at his pleasure command the rain and the sunshine, the wind and frost and snow, yet it is certain that climate itself has in many instances been gradually changed and ameliorated or deteriorated by human action."

- George Perkins Marsh

Address delivered before the Agricultural Society of Rutland County September 30th, 1847

Harvard Forest Diorama depicting a typical New England landscape in the 1850's.

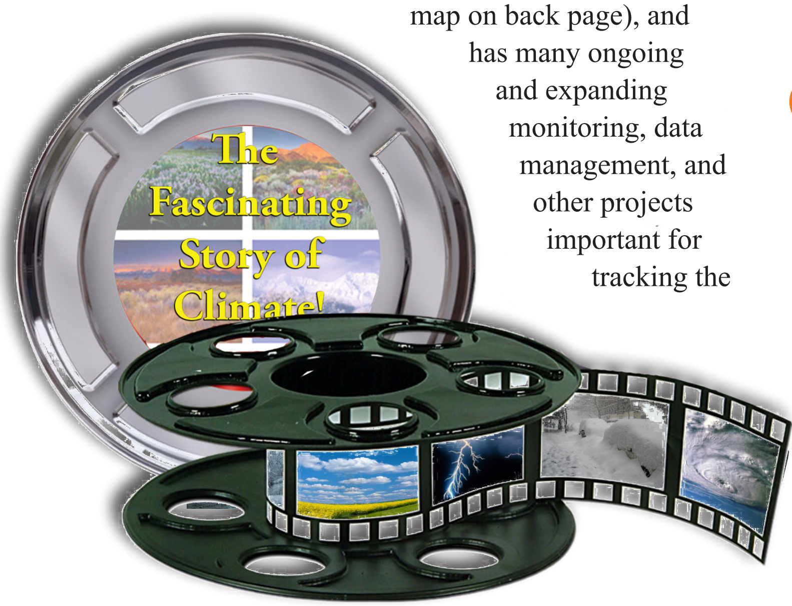
Tyndall's exploration of the thesis that small changes in the atmosphere's composition could cause climatic variations. It would be another 50 years before Swedish physicist and chemist Svante Arrhenius proposed that the carbon dioxide (CO_2) released by the "enormous combustion of coal by our industrial establishments" could warm the planet, though then it was viewed as a beneficial side effect. Marsh actually had quite a lot to say about humanity's ability to alter Earth's natural systems, and more of his remarkable insights are spread throughout this article.



Northeast Snowfall Impact Scale (NESIS) for a February storm in 2010. Overall it was a relatively snowy winter, though it featured above average temperatures for the Northeast.

Today, with the help of satellites from NASA and NOAA, and thousands of scientists conducting natural resource studies, we are more aware than ever of our ability to have dramatic impacts on the Earth's climate and ecology. Though they are protected by borders and laws, National Parks are no exception and cannot escape from climate change. Studies show that 96% of National Park Service (NPS) land and 84% of National Parks have experienced warming since the 20th-century began. In order to continue to fulfill its mission of leaving parks "unimpaired for the enjoyment of future generations" the NPS is looking at new ways of thinking about and planning for the effects of climate change. Monitoring park's natural resources is an important aspect of this planning and helps park managers understand how ecological systems react and respond to a changing climate. With this relevant, long-term information at hand, better informed managers can make better informed decisions about how to direct their natural resource programs.

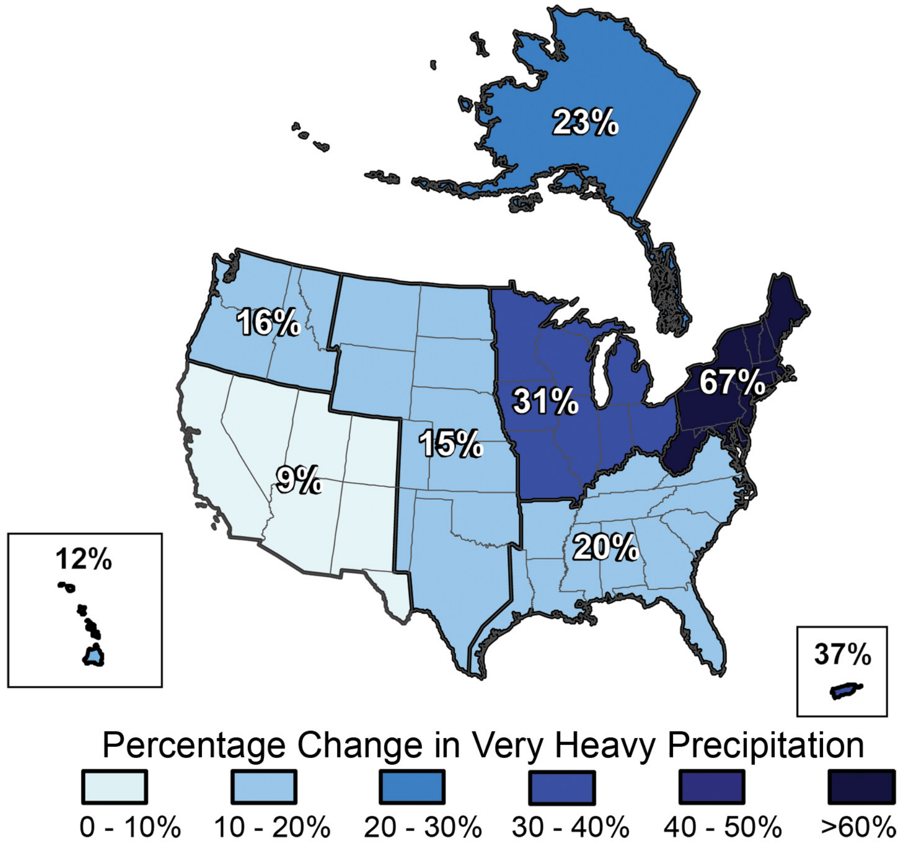
The Northeast Temperate Network (NETN) studies the ecological health of 13 National Parks in the Northeast (see map on back page), and has many ongoing and expanding monitoring, data management, and other projects important for tracking the current and future effects of climate change. The goals of this article are threefold: to look at how people have become the primary driver in changing the Earth's climate, to explore the ways NETN monitoring activities will help the NPS follow and understand how these climatic changes are affecting ecosystems, and to show how we can begin to get out of the situation we have gotten ourselves in.



It takes many thousands of weather photos to tell the long story of climate.

SPEAKING THE LANGUAGE: CLIMATE TERMINOLOGY

Defining a few key terms is critical to laying the groundwork for any discussion about climate. The first and perhaps most important word is **weather**. Weather can be defined as the state of the atmosphere at a given time and place. It is very specific, local, and ephemeral - a snapshot in time, much like a photograph. This is in contrast to **climate**, which is made up of long-term weather patterns with average temperatures and precipitation totals (including the typical occurrences of weather extremes) that are used to characterize a particular region. Think of climate more like a documentary movie. It takes thousands of 'weather photos' put together to see the 'climate movie' and to tell its story (and it is a *long* story, lasting a decade or much longer). Taking any one or two frames out of the movie reel to tell the story of climate would not only be misleading, but useless. Only the aggregation of all the photos tells the whole story. This distinction is very important because it is often misplaced references to *weather* events that are used to either bolster or weaken evidence of climate change. Neither a particularly snowy winter in D.C. nor a powerful summer hurricane necessarily say anything about climate change, they are only evidence that *weather happens*. As climate scientist Dr. Gavin Schmidt of NASA's Goddard Institute for Space Studies puts it: "When I get called by CNN to comment on a big summer storm or a drought or something, I give the same answer I give a guy who asks about a blizzard. 'It's all in the long-term trends. Weather isn't going to go away because of climate change.'"



The map shows the percentage increase in very heavy precipitation (defined as the heaviest 1 percent of all events) from 1958 to 2007 for each region. There are clear trends towards more very heavy precipitation for the nation as a whole, but particularly where Northeast Temperate Network parks are located. The Figure is from *Global Climate Change Impacts in the United States*, Cambridge University Press, 2009.

Climate science is really good at looking at past climate trends, and getting better at predicting future ones, but it is not very useful for looking at a recent specific weather event and saying definitively: "This is a direct result of human-induced climate change!"

What climate scientists do know is that a warming climate increases the odds, or "loads the dice" as some like to say, for the Earth to experience more weather extremes including floods, droughts, hurricanes, and - perhaps a bit unintuitively - record setting snowfall events. "Heavy snowstorms are not inconsistent with a warming planet," according to Dr. Jeff Masters, director of meteorology for the *Weather Underground*. "In fact, as the Earth gets warmer and more moisture gets absorbed into the atmosphere, we are steadily loading the dice in favor of more extreme storms in all seasons, capable of causing greater impacts on society."

Paradoxically, a warmer winter can actually produce more snow than a very cold one. This is because a colder atmosphere can hold less moisture than when warm, limiting the amount of snow that can fall. A recent study shows that a high percentage, as much as 80%, of all snowstorms in the U.S. of more than 6 inches during the 20th century occurred in winters with above average temperatures. In line with this trend, during the past two winters (2010-2011) the Northeast experienced above average winter temperatures and was also buried by three snowstorms that qualified as Category 3 storms or higher on the Northeast Snowfall Impact Scale created by the National Climatic Data Center. That has happened only one other time in the past 50 years (the winter of 1960-1961). Looked at individually these storms don't say much, but when viewed in the context of long-term trends, they are consistent with what scientists expect to see in temperate parts of the country: as the climate warms, more heavy snow events are likely until average winter temperatures become too warm for them occur consistently.

When scientists are talking about climate, whether it be snow, rain, temperature, or drought, they are talking about long-term trends. What do the past 10, 50, or 100 years show in terms of average temperatures and weather events, and what can we expect over the coming decades? One long-term study shows that during the last 50 years or so, the Northeast U.S. has seen a dramatic change in not only the amount of rainfall that hits the earth, but also in the way it is being delivered - namely in the form of very heavy storms. The Northeastern U.S. has experienced a 67% increase in the amount of very heavy precipitation over the span of 1958 to 2007, and that trend is expected to continue as temperatures warm.

In general, water resources in the temperate Northeast are projected to be profoundly influenced by climate change. Freshwater habitats are diverse and productive ecosystems and provide a home for myriads of aquatic plants, amphibians, and insects. Long-term projections indicate a substantial range reduction for some cold-water loving fish species like brook trout due to increasing water temperatures. NETN's ongoing water quality monitoring program will continue to provide valuable data on hydrological changes in network parks. In order to help detect change in the status of physical, chemical, and biological attributes of aquatic ecosystems, monitoring data collected includes water temperature, pH, dissolved oxygen, nutrient enrichment, water quantity, detection of invasive plant species, and more (see NETN's summer newsletter from 2011 for an explanation of many of these measurement parameters).

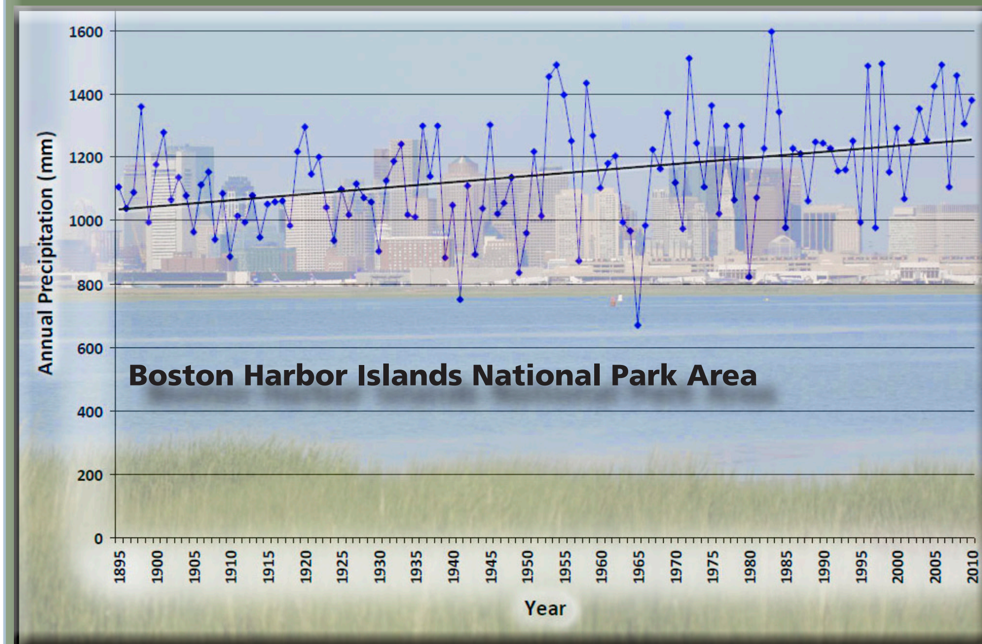
Climate change involves changes in the climate as a whole, not just one single element of the weather (i.e. temperature). This is one reason most scientists prefer that term rather than "global warming", which implies a uniform, linear warming of temperatures across the Earth.

Speaking in geologic time scales, climate change is always happening and always will be as long as there is an Earth for it to happen on. The Earth gets warmer or cooler; deserts, lagoons, and oceans ebb and flow; continents shift, and mountains uplift and erode (where many NETN parks are now, 200 million years ago they would have been sitting in a young mountain chain as high as the Himalayas - with a very different climate!). The coming and going of ice ages and the warming and cooling of the climate are all part of the normal machinations of the planet's complex climate system[1]. The Earth is not static, it is dynamic, and the climate would change with or without the presence of people. So if climate is always changing, why are scientists so concerned about current and future changes? Because changes being experienced today are happening very rapidly, are being driven primarily by human activity, and similar rapid climate changes in Earth's past have never been good news for the majority of species living on the planet at the time.

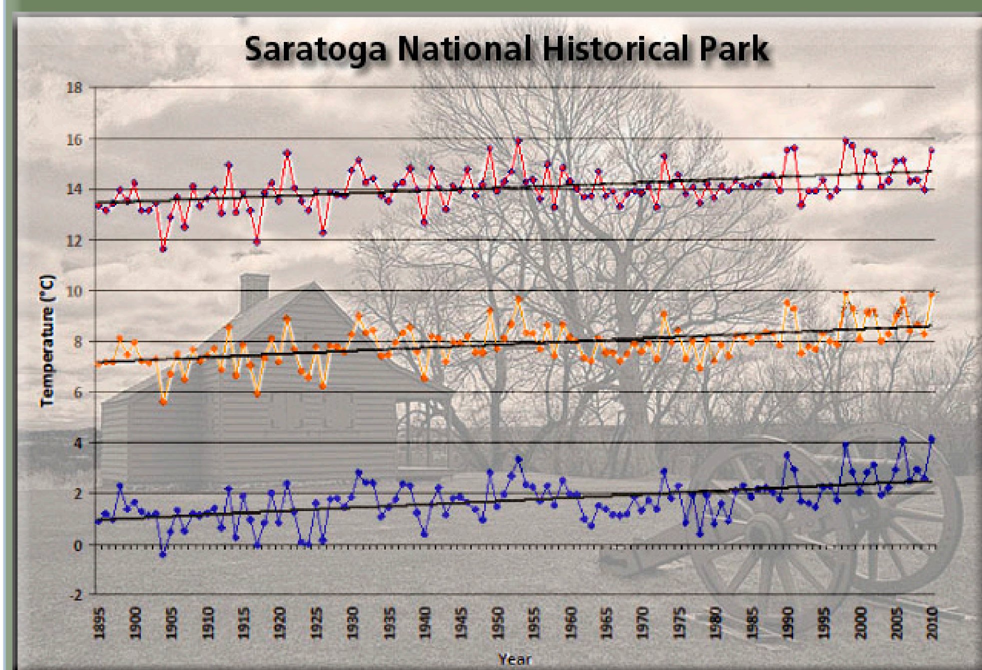
We have all been the benefactors of an unusually stable climate the past 10,000 years, a period that has seen the flourishing of civilizations across the entire globe. In a 2002 issue of *The New Yorker Magazine,* paleoclimatologist J.P. Steffensen described how research into Earth's past climate helps provide a different perspective on the development of civilization. The present

NETN Monitoring Project: Long-term Climate Studies

NETN is currently compiling decades worth of climatic data for network parks. Reports will be published starting in 2012. Long-term trends (1895-2010) for many parks show that not only have their average maximum temperatures been increasing over the past century, but the average low temperatures have been increasing even faster. Data also shows that as temperatures have increased in the Northeast, so has the amount of precipitation. This is not a surprising find as scientists have known for a long time that warm air can hold a lot more water than cold air. Below are sample graphs for two network parks.

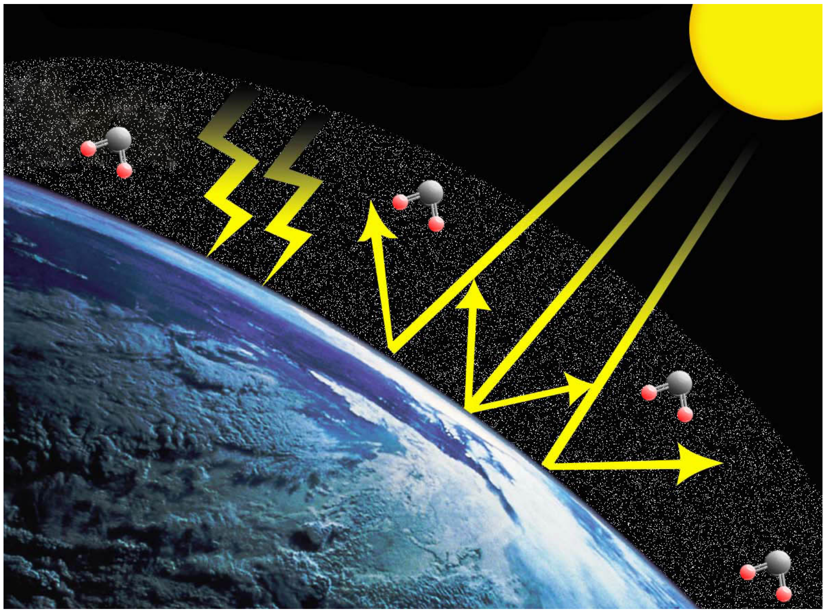


Total amounts of precipitation in the Boston Harbor Islands shows typical inter-annual variability, but the overall long-term trend clearly shows that as temperatures have warmed over the past century, precipitation has steadily increased as well.



Saratoga shares in a common trend throughout the region: average minimum temperatures (blue) are increasing faster than average maximum temperatures (red).

[1] Technically, our long-term climate cycle is now in the midst of an ice age, it is just in a warm interval between numerous periods of large-scale glaciation known as an "interglacial". During the present ice age, glaciers have advanced and retreated over 20 times, often blanketing the Northeast with thousands of feet of ice. The most recent period of glaciation, which many people refer to as "the last Ice Age", was at its height approximately 20,000 years ago.



Visual representation of the greenhouse effect. Note the thickness of the atmosphere is greatly exaggerated.

> The ravages committed by man…destroy[s] the balance which nature had established… and she avenges herself…by letting loose… destructive energies hitherto kept in check…but which he has unwisely dispersed.
>
> George Perkins Marsh
> *Man and Nature*, 1864

interglacial that has provided 10,000 years of very stable climate has offered the perfect conditions for agriculture to thrive and civilizations to flourish. Cultures in Persia, China, and India all made major advances at about the same time 6,000 years ago. They all developed writing, agricultural practices, and built large cities during this period of climatic stability. Even though what are considered to be big-brained, modern humans (i.e. *Homo sapiens sapiens*) have existed for the last 50,000 years, this kind of development would have been difficult to sustain during most of this time - with unstable ice sheets, rising and falling sea-levels, shifting climatic patterns, and other factors interrupting or inundating any cities or civilizations that may have begun to develop (archeological research continues to find evidence of human cultures under 10's to 100' s of feet of ocean water). Ironically, human activities now appear to be pushing the climate back into an era of instability, and some scientists say that human impacts on the natural world have already been so significant that it warrants the delineation of a new period of geologic time in the planet's history. The new proposed epoch, dubbed the *Anthropocene* for its human-dominated influence, is marked by measurable changes in the Earth's climate, geography, and biological composition. Many of these changes can be traced directly to our energy production choices, and how they amplify the greenhouse effect.

At its essence, the **greenhouse effect** is a wonderful thing. Without it the planet would have an average temperature of 0° Fahrenheit (instead of the much more agreeable ~59° F it currently enjoys – though that number is climbing) and little if any life could exist here. The short hand definition of the greenhouse effect is that long wave heat energy passes through our atmosphere in the form of sunlight. This heats the surface of the Earth and changes the heat to short, infrared wavelengths which are radiated back towards the atmosphere. About 90 percent of this heat is then absorbed (or trapped, if you prefer) by the greenhouse gases (water vapor, CO_2, methane, etc.) and then re-radiated back toward the surface. This would all be well and good if human activities were not literally releasing many billions of tons of greenhouse gases into the atmosphere every year, adding to the layer of greenhouse gasses that form a blanket around the Earth, trapping more heat, and steadily changing our climate. In fact some of the CO_2 released by those earliest coal burning power plants in the 1800's is still up there, as CO_2 can last for well over 100 years in the atmosphere.

WHAT'S OLD IS NEW: FOSSIL FUELS & MODERN CLIMATE

So what activities are causing all this CO_2 and warming? Most of it comes from actions we take in our everyday lives. The vast majority of CO_2 is created through the burning of fossil

Earth has a surprisingly thin atmosphere. If the planet were the size of a beach ball, the atmosphere would equate to the thickness of a paper towel laid on top of it. NASA photo.

Ancient Carboniferous swamps from hundreds of millions of years ago are the source for most of the fossil fuels we burn today.

fuels to run cars and trucks, light, heat and cool homes and businesses, and to power factories. And while from ground level our atmosphere looks limitless as we gaze up into the sky, the thin layer of atmosphere and soil that supports life (known as the biosphere) is only a scant 10 miles deep, less distance even than the average person's one-way, daily 16-mile commute to work, yet every day we pump, dump, exhaust, spill, leak, and inject millions of tons of chemicals, gasses, and pollutants into it.

A quick inventory of the items around your home or office and a glance out your window might give a good summary of why we create so much CO_2 in our lives today, much more than just a generation ago. Using coal as an example, the numbers show that in 1980 America used 569 million tons of coal a year to generate electricity. By 2006, coal use grew to 1.1 billion tons a year[2]. Of course part of that growth was due to a gain in population, but a large part was also due to all the new gadgets like smartphones, 70-inch plasma screen TV's, ubiquitous home computers, and a whole host of other power hungry devices that did not exist in 1980. Though we have a lot of new technology in our homes and offices, we are still getting energy to power these hi-tech devices the same way our great grandparents powered their Edison-invented light bulbs over one-hundred years ago. In most places in America, when you plug that smartphone charger into the wall you can walk outside and follow the electric cable from where it attaches to your house on to its end point: a coal fired power plant. There are not too many other century-plus old technologies we rely upon as heavily as we do coal. The coal power plant is a simple concept whose basic formula hasn't changed much since the earliest plants: light coal on fire to boil water and make steam, which turns a turbine to create electricity.

As most of us were taught in science class, our fossil fuels come primarily from ancient forms of life. It took hundreds of millions of years for plants and animals to live, die, and be buried and compressed to form the deposits of oil, natural gas, and coal that are now concentrated in certain areas across the globe. In little more than 250 years, however, we have burned through a large amount of this storehouse of carbon and as a result thrown the carbon cycle out of balance. As NASA scientist Peter Griffith likes to explain, carbon can be thought of as coming in two forms: "old and slow" and "young and fast". The former can be likened to a hunk of coal and the latter to a banana. Two very seemingly different things on the surface, but both derive from plants, are made of carbon, and provide us with energy. Coal (and all other fossil fuels for that matter) stores carbon that plants took out of the atmosphere hundreds of millions of years ago, carbon that has not seen the light of day since long before even the dinosaurs roamed the Earth. A banana, on the other hand, stores carbon that was in the atmosphere just a few short weeks or months prior. When you eat a banana, your body converts it to energy and you then breathe the *young carbon* (short-term carbon cycle) it contained back into the atmosphere. Similarly, when we burn coal it also helps create energy, and its *old carbon* (long-term carbon cycle) is released back into the atmosphere, which accumulates far

Mmm... Young carbon...

Old and slow.

[2] The numbers million and billion are in statistics we hear all the time, but few of us grasp the huge differences between them. To illustrate: when a baby is born, it will celebrate its first one-million seconds after 11 days have passed. That same baby will have to wait until it is 31 years and 8 months old however, to mark its one-billionth second on Earth. If you're keeping score at home, a person would need to reach the crotchety old age of 30,000 in order to notch their one-trillionth second of existence.

1816 - THE YEAR WITHOUT A SUMMER

Climate has been markedly impacted by volcanic activity in the past and will no doubt be impacted again in the future. Though they do emit CO_2, large volcanic events often serve to cool global climate in the short term. The cooling effect is due to the sulpahtes that they eject into the atmosphere during an eruption. Sulphates are not only a leading cause of acid rain, but also reflect heat back out into space and can measurably cool the Earth. Though volcanoes may contribute to long-term warming as well, when the combined CO_2 output of eruptions is compared to human emission levels, it shows that volcanoes only marginally impact long-term climate change. One of the more famous relatively recent volcanic events with global-weather consequences was the massive April,1815 eruption of Mt. Tambora in Bali, Indonesia. The eruption was the most powerful explosion of the past 10,000 years and was heard 1,000 miles away. The eruption ejected 400 million tons and 400 cubic miles of sulfurous gases and ash into the upper atmosphere. It's cooling effects were felt around the world and even though Bali is more than 10,000 miles away from the Northeast, average temperatures in New England fell 2° to 4.5°F below normal for the region, and 1816 became known as "the year without a summer". On June 6th, 1816 , 9"-12" of snow fell over the region from New York to Maine, and severe frosts spread as far south as Trenton, New Jersey the next day.

A diary kept by an unknown person near Fryeburg, Maine provides a fascinating description of the weather of 1816. Below are a few snippets:

"April came in warm, but as the days grew longer the air became colder and by the first of May there was a temperature like that of winter, with plenty of snow and ice. In May the young buds were frozen dead, ice formed half an inch thick on ponds and rivers. By the last of May in this climate the trees are usually in leaf and birds and flowers are plentiful. When the last of May arrived in 1816, everything had been killed by the cold.

"Frost and ice were common [in June] and every green thing was killed. All fruit was destroyed."

Weather records show that throughout New England it snowed during five separate days in June.

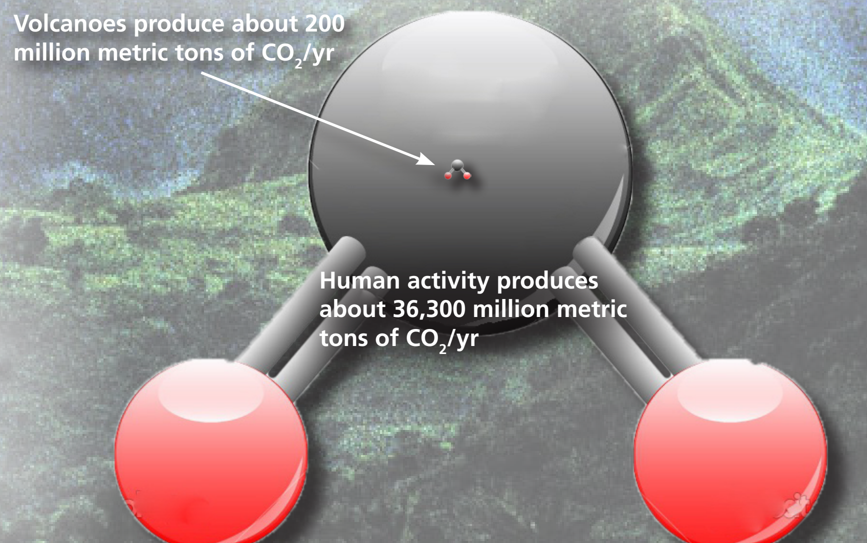
"July came in with ice and snow. On the 4th of July, ice as thick as window glass, formed throughout New England, New York, and some parts of Pennsylvania.

"August proved to be the worst month of all. There was great privation and thousands of persons in this country would have perished but for the abundance of fish and wild game."

Months that should be summer's prime
Sleet and snow and frost and rime
Air so cold you see your breath
Eighteen hundred and froze to death.

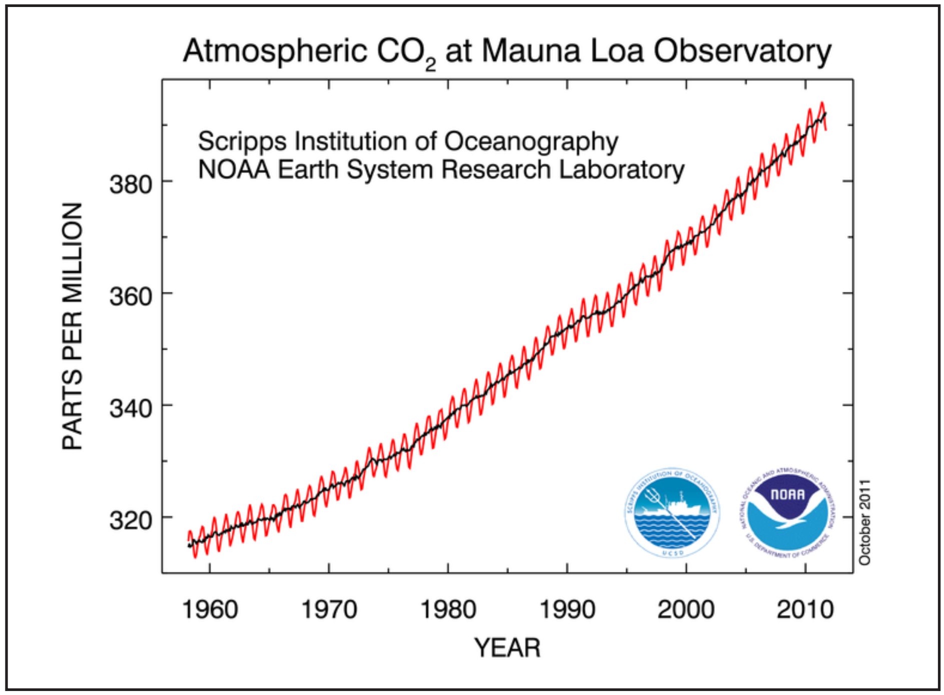
- author unknown

The Year without a Summer is just the kind of climate story that shows how a seemingly short-lived and distant event, can have planet-wide ramifications. Though people do not cause exploding volcanoes, we do make hundreds of millions of much smaller explosions everyday when we drive our gasoline powered cars, and thousands of coal power plants across the world spit out vast amounts more CO_2 than all volcanoes in the world combined each year.



The 1991 Mt. Pinatubo eruption (pictured) was many times smaller than the Tambora eruption, but it still discharged nearly 20 million tons of sulphur dioxide into the stratosphere and caused global temperatures to drop by over 1°F from 1991 to December 1992.

240 barrels-o'-oil. Don't blink! Up in smoke about every second or so.



Carbon dioxide data collected on Mauna Loa, Hawaii constitutes the longest record of direct measurements of CO_2 in the atmosphere. The black line represents seasonally corrected data. NOAA graph.

faster than things like bananas can store it. This is carbon that would have stayed locked up in the ground if people had not dug it up and burned the coal that contained it. As a result, carbon gases build up in the atmosphere and warm the Earth more than would happen naturally.

Another major fossil fuel we heavily rely upon that is also derived mostly from ancient plants is oil. Virtually all the energy consumed in the transportation sector in the U.S. comes from petroleum based products. An ecologist at the University of Utah conducted a study to calculate just how much ancient plant material it took to create one gallon of gasoline. The answer is that an incredible 98 tons of prehistoric, buried plant material (that's 196,000 pounds) was required to produce every gallon of gas (~6 pounds) we burn in our Prius's and Pilots according to the study published in the journal *Climatic Change*. For the average American car, that is the equivalent of loading 40 acres worth of wheat – stalks, roots and all – into the fuel tank about every 20 miles. Then consider that burning that one gallon of gasoline creates about 20 lbs of CO_2, and that we consume an average of 380 million gallons of gas every day in America alone. For the year 2009 that totaled 1,542 million tons of CO_2 released just through the burning of gasoline.

> "We are never justified in assuming a force to be insignificant because its measure is unknown, or even because no physical effect can now be traced to it as its origin"
>
> George Perkins Marsh
> *Man and Nature*, 1864

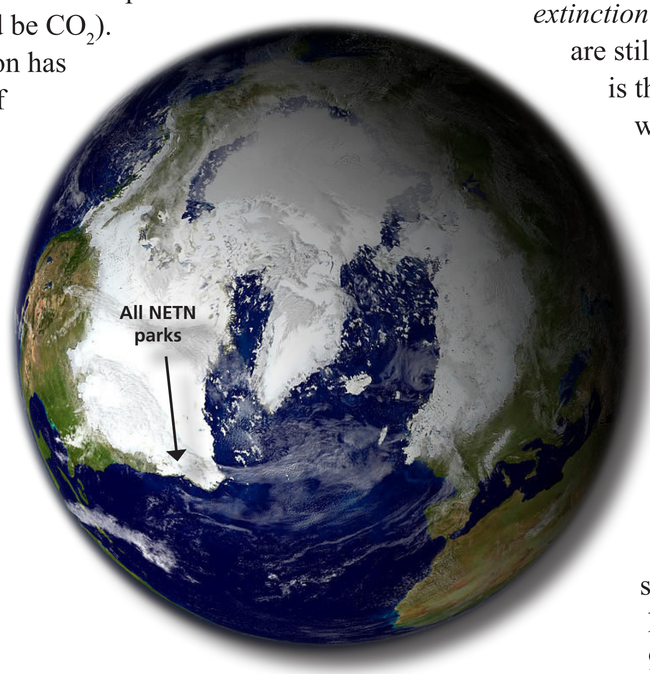
Is your head spinning yet? No wonder if it is - the numbers surrounding our consumption of fossil fuels are truly dizzying. In the U.S. we consume 6,140,000,000 lbs. (billion) of coal every day (National Mining Assoc., 2008 statistics). Oil is equally as impressive – more than 20 million barrels of oil (EPA, 2007 statistics) are burned every day in the USA. That's 239, 42-gallon barrels of oil every second. In the time it took you to read that last sentence about 1,000 barrels were burned. Over a typical year this equates to more than 7 billion barrels[3].

[3] For comparisons sake, the oil industry estimates that the Arctic National Wildlife Refuge in Alaska contains somewhere between 5 (95% probability) and 16 (5% probability) billion barrels of oil. Put another way, what numerically amounts to somewhere between 8 months to about 2 years worth of oil at our average consumption rate.

Ice sheets contain a record of hundreds of thousands of years of past climate from air bubbles trapped in the ancient snow. Scientists recover this climate history by drilling cores in the ice, some of them over 11,000 feet deep. In this photo a researcher works with an ice core drill during the 2003 Antarctic Megadunes expedition.
Photo: Ted Scambos & Rob Bauer, National Snow & Ice Data Center.

It is these kinds of studies and stories that help to illustrate the reasons so much CO_2 has been released in our atmosphere in recent times, and why Earth's carbon cycle can't keep up. Just how much CO_2 is up there right now? Recent studies show that concentrations of CO_2 are up 39 percent since the start of the industrial era in the 1750's, and now stand at 389 parts per million (ppm: if a million molecules in the atmosphere were randomly sampled, 389 of them would be CO_2). The World Meteorological Organization has soberly pointed out that the increase of 2.3 ppm in CO_2 between 2009 and 2010 shows a marked acceleration from the average 1.5 ppm increase during the decade of the 1990's. Perhaps 389 out of one million does not sound very impressive, but a little CO_2 can go a long way. If our atmosphere were composed of just 1% CO_2, it would bring the surface temperature of the Earth to the boiling point (currently CO_2 concentrations are about 0.0387% making its relative power to influence climate impressive).

Ancient ice-core measurements show that CO_2 concentrations are higher now than at any other time in the last 850,000 years. Levels of methane, an even more potent greenhouse gas, have more than doubled over the last 100 years alone. Those same ice cores show that over that 850,000 year span, it took an average of 1,000 years for CO_2 to increase 30 ppm. It has risen by more than that since 1995. This is not to say CO_2 and global temperatures have not been much higher than today in Earth's ancient past. In fact paleoclimatic research (which involves gathering data from ice cores, corals, tree rings and lake/sea floor sediments) shows that throughout much of Earth's 4.5 billion year existence CO_2 levels have been significantly higher than today's levels. While this is a scientific fact, it is also true that people are quite fond of this current iteration of Planet Earth, and many of these "past Earths" would have been hostile towards our current way of life and the resources we are dependent upon. Just 34 million years ago a "greenhouse world" existed in which global average temperatures were a whopping 14 to 27º F warmer than today, and with CO_2 levels between 600 and 2,000 ppm. This was a world no human eyes ever saw and it would appear quite alien to us today, with no ice at the poles and crocodiles swimming within the Arctic Circle![4] The point is that the Earth has survived quite well these earlier periods of dramatic climate change thank-you-very-much, and as long as there is an Earth it will survive any future ones as well. It is the species living here during these unstable times that do not fare quite as well. For example, 250 million years ago an estimated 70 percent of all land plants and animals went extinct, along with 84 percent of ocean organisms—an event known as the *end Permian extinction*. The exact (likely multiple) causes are still being debated, but what is known is that this period experienced rapid warming. A recent analysis of the temperature and fossil records over the past 540 million years reveals that the end of the Permian is not alone in this distinction: climate change is consistently associated with planet-wide extinction events.



Earth: 20,000 years younger and 5 to 10 degrees cooler.

So far, human activities have helped to warm the Earth by about 1.5°F since 1900, with more than half of that increase occurring since the late 1970's. Analyses of human and natural factors attribute 93% of this detected warming to human emissions of greenhouse gases. This may not seem like a whole lot of warming for an entire century, or by any measure for that matter. The temperature of the room you are in has likely changed by at least that much since you've been there and it's probably a safe bet that you've been able to stave off panicking about it. But to put this temperature change into perspective, consider that 20,000 years ago during the peak

[4] Significantly, for modern climatologists trying to understand our current and future climate, this warmer world also included hyperthermals – abrupt global temperature spikes of 3.5 - 9°F from which ecological recovery took tens to hundreds of thousands of years, possibly the result of massive methane discharges. The largest and best known, around 56 million years ago, may be a useful comparison for the future as research continues into climate change causes and consequences.

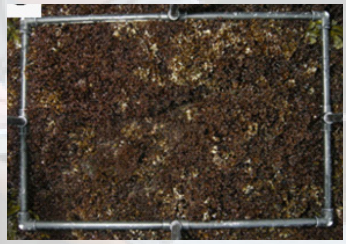
NETN Project: Coastal Resource Monitoring

At the intersection of terrestrial, freshwater, and marine systems – intertidal zones, estuaries, and salt marshes serve a number of important ecologic and economic roles. Salt marshes are some of the most productive ecosystems in the world and provide nursery habitat for a variety of important fisheries. Coastal zones also serve as a resource for migrating birds and act as natural buffers between land and water. Rocky intertidal communities are dominated by invertebrate species and seaweeds that provide habitat and food for a diversity of other animals such as snails, birds, and crabs. With respect to climate change, all of these communities are ideal for long-term monitoring because two factors that are predicted to change over the next few decades - sea level and temperature - are both critical to determining the range and quality of habitat for many species. Sea level rise creates the potential for the submergence of salt marshes and the loss of coastal habitat in NETN's coastal parks that include Acadia National Park, Boston Harbor Islands, and Saugus Iron Works NHS. NETN currently has several coastal monitoring programs being implemented and developed that will help to track how these areas are being impacted by climate change.

A SET is used to measure the surface elevation of a marsh. NPS photo.

SET Monitoring: Salt marsh systems are highly susceptible to a variety of human caused impacts, and in the U.S. it has been estimated that more than 50% of tidal salt marsh habitat has been lost since European colonization. There is increasing evidence in the Northeast that some marshes are facing a new challenge in the form of wetland submergence. NETN, in collaboration with USGS, NOAA, the Northeast Coastal and Barrier I&M Network (NCBN), and the Southeast Coast I&M Network, implemented the Surface Elevation Table (SET) and Marker Horizon Method monitoring programs at Boston Harbor Islands and Acadia National Park in 2009 and 2010. For marshes to survive sea level rise, their surface elevations must keep pace. The elevation of a salt marsh is controlled by sediment and subsurface organic matter build-up, which increases elevation, while below-the-surface sediment compaction, organic matter decomposition, and erosion of surface sediments can result in elevation loss. This monitoring method measures accretion and erosion of marshes by repeated sampling of the height of the marsh relative to a fixed point and depth to artificial marker horizon plots.

Salt Marsh Vegetation Monitoring: The long-term monitoring of salt marsh vegetation is under development for NETN's three coastal parks and will provide data to assess long-term trends in salt and tidal marsh wetlands. It is being adapted from the NCBN and Cape Cod National Seashore protocols. Although direct salt marsh habitat loss has declined significantly over the last several decades, these systems are still threatened by numerous other human impacts that may result in further habitat loss or degradation. Other threats include altered hydrology and sediment supply, tidal restriction, watershed development, invasive species, and climate change-related alterations such as sea-level rise, increased temperatures, changes in evaporation-precipitation balance, and increasing atmospheric CO_2.



A red alage photoplot. NPS photo.

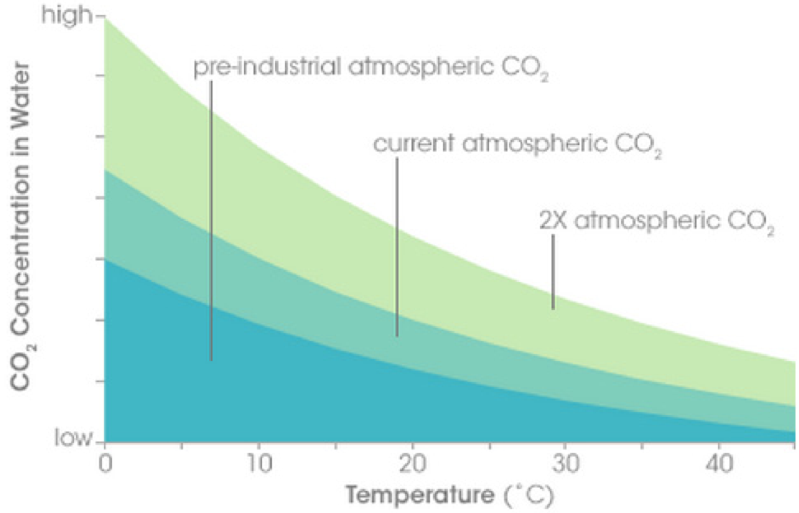
Rocky Intertidal Monitoring: The rocky intertidal monitoring program continues to progress at Boston Harbor Islands and Acadia with sea-temperature loggers and additional permanent bolts placed along surveyed vertical transects in 2010 to document sea-level rise with more detail. Other monitoring goals of the program that should help track the effects of climate change are to measure long-term changes in populations of target species such as barnacles, seaweeds, snails, and mussels; and to correlate long-term changes in intertidal populations with long-term changes in disturbance factors including changes in water temperature, wave height, sea level, and seabirds.

Volunteers help count birds in the Boston Harbor Islands. NPS photo.

Coastal Bird Monitoring: Birds are an important component of park ecosystems and are sensitive to changes within them. They operate close to the limit of their ecological tolerance, and their high body temperature, rapid metabolism, and high ecological position in most food webs makes birds are an important indicator of ecosystem change at the local and regional scale. With the help of a dedicated citizen science volunteer base, NETN has been monitoring coastal birds at Boston Harbor Islands National Park Area since 2007. Some of the stated goals of the coastal bird monitoring program that could be impacted by climate change are to determine annual changes and long-term trends in abundance of high priority coastal breeding bird species and to conduct annual surveillance within the park to identify future use by threatened or endangered species. Waterbird monitoring data can also be correlated with data on park management actions, rocky intertidal communities, water quality, climate, and other data to assist park managers in their efforts to protect and, in some cases, encourage the recovery of coastal breeding birds in the park.

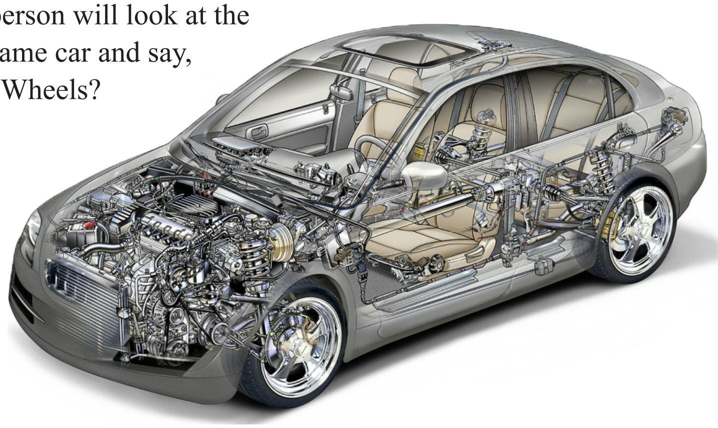
For more details on all of these programs, see NETN's Education and Outreach and Vital Signs webpages for resource briefs, protocols, and other publications.

of the most recent advance of ice sheets, global average temperatures were only between 5 and 10 degrees colder than our current climate. If you are reading this in the Northeast, that's the only difference between today's weather and an ice sheet more than 5,000 feet thick in places sitting on top of you right now. As best as can be determined, the world is already warmer than it has been at any point in the last two millennia and if current trends continue, by the end of the century it will likely be hotter than at any point in the last 2 million years (as noted earlier, no humans would have been around the last time it was that warm). And the impacts associated with this deceptively small change of 1.5°F are evident across the globe. Long-term trends show that there is heavier rainfall in some areas, and more frequent droughts in others. Glaciers are melting in most areas that contain them, spring is arriving earlier, and oceans are warming and rising.



The concentration of CO_2 in ocean water depends on the amount of CO_2 in the atmosphere (shaded curves) and the temperature of the water. As atmospheric CO_2 begins to increase from pre-industrial levels (blue) to double (2X) the pre-industrial amounts (light green), the ocean CO_2 concentration at first increases as well. However, as water temperatures continue to increase, its ability to dissolve CO_2 decreases. Climate change is expected to reduce the ocean's ability to absorb CO_2, leaving more in the atmosphere, which will lead to even higher temperatures, and so on. NASA graph by Robert Simmon.

An important and sometimes frustrating concept to keep in mind when thinking about climate is to remember that it is a sensitive and complex system. Climate is not controlled by a single one-to-one relationship (e.g. more CO_2 = higher temperatures) but by a whole host of inputs and outputs that influence and react to each other. As such, we cannot say that climate is influenced solely by the sun, or by the oceans, or aerosols, or land use, Earth's orbit, volcanoes, people's use of fossil fuels, the albedo effect, or by some other single cause and effect. When climate scientists speak about human-induced climate change they are not saying that climate isn't also being simultaneously influenced by the oceans or the sun, what they are saying is that actions by people have become the *primary* driver of climate change and are the root cause of most of the recent changes we've seen. One analogy is to look at the modern automobile. Some people may look at a car and say: "It's the wheels that make a car go." Another person will look at the same car and say, "Wheels? You're not getting anywhere without an engine!" Yet a third person can look at the car and say "Wheels and an engine are good, but what really makes a car go is gasoline." - and so on and so on. The point is that of course a car needs all those things to make it work. But like climate today, what most influences where a car goes is the person driving it. People are the *primary* drivers of cars, and of the current climate change we are seeing by injecting greenhouse gases to the tune of about 197 billion pounds of CO_2 into the atmosphere *every day* of the year (2010 stats).

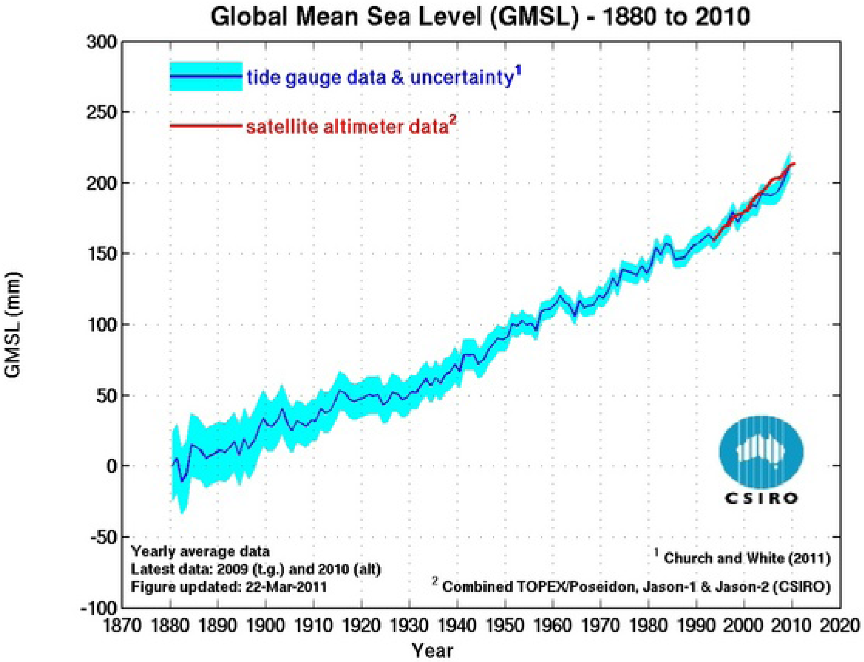


Just like the modern gas combustion automobile, the climate system is very complex with a lot of moving parts. Similar to climate as well, humans are the primary driver in making it go!

A SEA OF CHANGE: CLIMATE AND THE OCEANS

One of the effects of this mostly human-dominated climate change is the acidification, warming, and rising of Earth's oceans. This is problematic on several fronts because of the properties of ocean water. At the risk of stating the obvious, the oceans are big - really big. The oceans of the Earth comprise 71% of its surface, which is why author Arthur C. Clarke once quipped: "How inappropriate to call this planet *Earth* when it is quite clearly *Ocean*." When that 343 billion *billion* gallons of water begins to heat up, things start happening. One effect is that as sea water warms, it also expands, contributing to the overall effects of sea level rise from melting land-based ice. Oceans are also the Earth's largest storehouse of carbon, and another property of water regulates just how much CO_2 it can hold. As water warms, it can hold significantly less CO_2 than when it is cold[5].

[5] The oceans contain about 50 times more CO_2 than the atmosphere and 19 times more than the land biosphere. The oceans mix much more slowly than the atmosphere, which results in large horizontal and vertical changes in CO_2 concentration. In general, warm tropical waters release CO_2 to the atmosphere, and high-latitude, cold ocean waters take it up. More than twice as much CO_2 can dissolve into cold polar waters than in the warm equatorial waters. Major ocean currents like the Gulf Stream move water from the tropics to the poles where it is cooled and takes up more CO_2 from the atmosphere. As it cools, ocean water also becomes denser and sinks to the bottom taking some of the CO_2 accumulated at the surface with it. CO_2 concentrations are about 10 percent higher in the cold deep ocean than at the surface.



Sea-level rise is caused by both melting land-based ice and the expansion of warming water. This graph is composite image composed from several papers from the Australian CSIRO (Commonwealth Scientific and Industrial Research Organisation) Marine and Atmospheric Research group.

Anyone who has ever opened a warm can of soda has experienced this phenomenon, as it is more likely to foam over or go flat quicker than a cold can because the CO_2 in it separates from the liquid much easier. Extrapolating these properties to ocean water, you may begin to see a major problem: as human activity warms the atmosphere by releasing CO_2, the oceans warm, releasing more of their CO_2 which in turn warms the atmosphere even more, which causes the oceans to warm more releasing more CO_2, and on, and on. This is an example of what scientists call a "positive feedback loop", where the effects of climate change start feeding into the causes of climate change.

Luckily for us, over the past 250 years the oceans have incredibly been able to absorb almost half of the about *one-trillion* tons of CO_2 humanity has liberated back into the atmosphere. This has resulted in not only atmospheric CO_2 concentrations being much lower than they otherwise would be, but also planetary temperatures. This free service the oceans have provided for us has not come without a cost to their health however, and the increase in the amount of CO_2 dissolved in them has concurrently increased their acidity levels. Ocean acidification affects calcium carbonate saturation in ocean waters, making this building block of shells and skeletons for marine organisms like crabs, lobsters, snails, corals, clams, and some microorganisms less available. As acidification intensifies, it is expected to have increasingly detrimental impacts on these marine species and could cause giant disruptions in the food chain.

As temperatures warm and more land-based ice melts, the melt-water adds to sea-level rise. Currently, observed sea level rise is tracking at the upper range of the Intergovernmental Panel on Climate Change's (IPCC) projections. A tide gauge at San Francisco's Golden Gate National Recreation Area has a record of 155 years of sea level monitoring and provides the longest sea-level time series in the Western Hemisphere. The gauge has detected a sea level rise of 14 cm (5½ in) per century attributable to climate change.

Further north, the Greenland ice sheet is already shedding enough ice every day to supply New York City's water demands 30 times over, according to scientists measuring the glacier's melting rates. When the accelerating ice loss from Greenland and Antarctica are factored into sea level projections, the estimated sea level rise by 2100 is expected to be somewhere between 2.5 and 6.5 feet. This sea level rise will create problems for island and coastal communities and ecosystems around the world.

PHENOMENAL PHENOLOGY: "SEEING" CLIMATE

Melting ice is not the only indication that things are heating up, phenological cycles around the Earth are also shifting because of climate change. The study of the timing of natural events, phenology is a key indicator of the pace of climate change and is critical to both people and the functioning of ecosystems. Phenological events mark the changing of seasons: the emergence of the first leaves and butterflies, the sounds and activities of birds and frogs, and the flowing of maple sap all herald in the arrival of spring; while fall foliage, bird migration, and crop harvest mark the onset of autumn and winter. Because phenology is coupled inseparably with climate, it also provides a way that people can actually "see" climate change and its impacts wherever they are. Studying phenology provides information for National Park managers and local

The phenological event of fall foliage is a very popular time of year for many NETN parks. This view is from Marsh-Billings-Rockefeller NHP in Woodstock, VT. Ed Sharron photo.

NETN Project: Phenology Monitoring with Citizen Scientists

In a period of rapid climate change, understanding the ways phenological events are changing along with climate is very important. Almost every ecological relationship and process—including predator-prey and plant-pollinator interactions, the spread of disease, pest outbreaks, and water and carbon cycling—depends on the timing of phenological events. Scientists are finding that many of these ecological relationships and processes are shifting because of climate change. In addition to its role in ecosystem functions, phenology provides one of the most fundamental ways people relate to nature. Timing of festivals tied to phenological events, such as flower displays or migrations, is also changing because of both climate change and urbanization. In Boston, for example, the annual lilac festival at the Arnold Arboretum now occurs 3 weeks earlier than it did 90 years ago.

Climate-driven changes in phenology are highly consequential to National Parks because they are linked to important processes such as outbreaks of forest pests and increases in fire severity in the West, declines in and disappearance of wildflower populations in the Northeast, and the spread of invasive species throughout the country. Visitor seasons will likely shift as well as the timing of the growing season changes, lengthening in some areas and shortening in others. Parks can play a key role in understanding the causes and consequences of these changes.

NETN and the NPS as a whole are taking a leadership role in the effort to monitor phenology and improve our understanding of the effects changes will have on plants, animals, and people. Most current NPS phenology monitoring efforts rely on volunteers to make field observations. This citizen science approach works well because most people already observe phenology every day—they just do not write down their observations. To help organize the project, NETN is working with the USA National Phenology Network (USA-NPN) and other NPS units, organizations, agencies, educational institutions, and individuals to develop monitoring standards and online tools for training, data submission, reporting, mapping, and graphing. NETN monitoring projects focus on science and education, and address questions such as how phenology is related to invasive species, water dynamics, and other natural resource issues.

Scientists from NETN and the University of Vermont set up an automated listening device near a wetland in Marsh-Billings-Rockefeller NHP. The microphones capture the first spring calls of amphibians, insects, and birds. Ed Sharron photo.

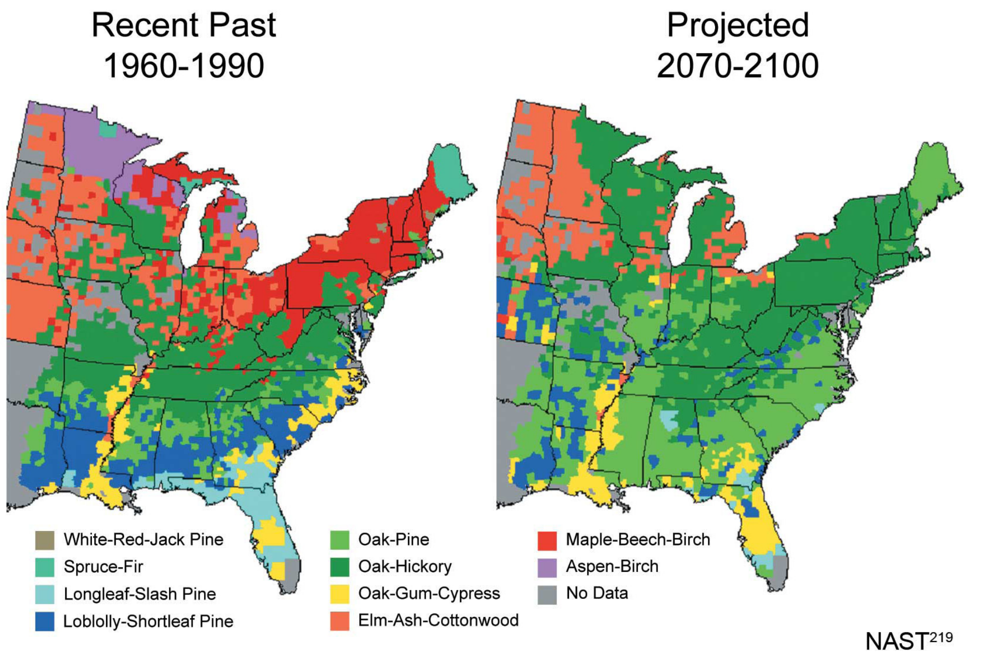
Several NETN parks are testing and implementing different styles and approaches for monitoring, and the Network and partners continue to be on target to complete a multi-method phenology monitoring protocol by the end of 2012 that could be suitable for use by organizations nation-wide. Pilot phenology monitoring began in 2009 and continues in Acadia, along the Appalachian National Scenic Trail, Boston Harbor Islands national park area, Saugus Iron Works NHS, and Marsh-Billings-Rockefeller NHP. Depending on the monitoring goals and capacity of their volunteer community and park staff, parks rely on combinations of trained volunteers, staff, and automated cameras and audio recorders to make field observations. Phenology monitoring projects under way in the National Park Service are actively testing these and other approaches to find which ones best achieve their science and education goals.

Trained citizen-scientists have been collecting phenological data at Boston Harbor Islands national park area since 2009. NPS photo.

Phenology monitoring is a great fit for a citizen science program. Observing phenology and actively participating in a national-scale climate change research project gives participants a firsthand look at how scientific research is conducted and why climate science matters at the local level. It is hoped that this experience translates into participants' understanding of the scientific process, and encourages them to take action to promote climate change mitigation and adaptation in their own lives.

Monitoring phenology in parks has the potential to advance many science, education, and even health goals of the NPS and the country more broadly. Phenological monitoring can contribute to priorities like getting youth outside, engaging local communities, building scientific literacy, preserving America's great outdoors, and advancing climate change science.

This article was adapted from the article "Parks use phenology to improve management and communicate climate change" by Abraham Miller-Rushing, et al. that appeared in the Vol 28. Number 2, Summer 2011 edition of Park Science.



These maps show current and projected forest types. Major changes are projected for the Northeast where, under a mid-range warming scenario, the current maple-beech-birch forests will be replaced by oak-hickory forests. Graphic from *Global Climate Change Impacts in the United States*, Cambridge University Press, 2009.

examples of the effects of climate change that are relevant to visitors and the communities surrounding parks. NETN is one of several National Park programs and partners that are utilizing techniques such as citizen science data collection and remote sensing for monitoring phenology, and then using the results to inform science, management, and education. These activities will make significant contributions to the NPS's understanding of the effects of climate change and how best to communicate climate change science to the public.

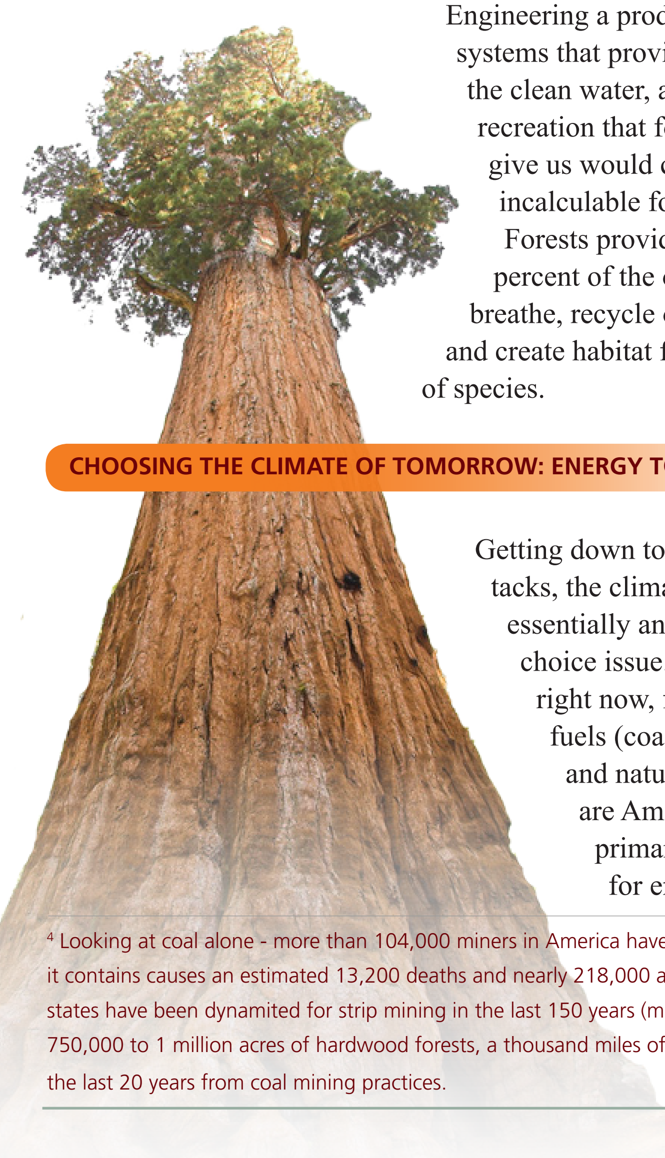
Phenology is changing everywhere climate is, and nowhere is climate changing more rapidly than in the polar and alpine regions of the Earth. Even as recent winters are delivering more snow than the long-term average in many places, (see page 3) they are also becoming shorter - and "spring creep" is causing spring runoff in the mountains of the western U.S. to start an average of 1-3 weeks earlier than 6 decades ago. According to a 2007 report in the scientific journal *Current Biology,* scientists from Denmark's National Environmental Research Institute have found that spring in Greenland now starts much earlier than it did just a decade ago. The team of biologists found, after analyzing the flowering dates of six plant species, emergence times for 12 species of insect, and egg-laying dates for three bird types, that spring in the ecosystem has moved forward by an average of 14.5 days.

Documented phenological changes in the Northeast U.S. thankfully are not quite as dramatic as they have been in the world's polar regions, but things are shifting here as well. Focusing on the fall season, the time of year when the very popular phenological event of the coming of fall foliage takes place, changes are being noticed. Observations at the federal Hubbard Brook Experimental Forest in Woodstock, NH suggest that sugar maples (a primary fall-foliage tree) are going dormant 2-5 days earlier than they were two decades ago, and in Vermont, state foresters studying sugar maples at the Proctor Maple Research Center in Underhill found that the growing season ended later than the statistical average in 7 out of the last 10 years. What all this means for "leaf-peepers" in the short term isn't much. They may have to adjust the timing of their foliage-viewing excursions by a few days. But long-term implications and projections for climate change go beyond impacting people's vacations and take it up a few notches to shifting entire ecosystems. Some climate models show sugar maples high-tailing it out of the Northeast altogether to be supplanted by oak-hickory forests by 2100 if emissions continue to grow.

If more fossil fuels are used to meet our energy needs over the coming decades phenologies across the globe will be irreversibly impacted. At our current pace, projections show that by 2100 the Earth's temperature will increase between another 5° to 10.5°F. Along with these warmer temperatures will come an increase in air pollution with its associated health problems, invasive species, and severe weather events. For NETN parks, these climatic changes will affect the distribution and quality of plant and wildlife habitat in both the interior and coastal regions of the Northeast. Careful and accurate monitoring of key species is crucial to provide vital data on the ways ecosystems are being affected by climate change. Since the late 1990's, the U.S. Forest Service (USFS) Forest Inventory and Analysis program has installed nearly 4,100 sampling plots near NETN's Appalachian Trail. This collection of plots is part of a national network that the USFS uses to report on things such as tree health, growth, and mortality. NETN has developed a process to use these data to characterize the condition of forest resources around the Appalachian Trail, and to establish a meaningful baseline that will help detect and interpret climate-driven change that will affect the region in the future. NETN's primary forest health monitoring program also does this for other network parks and provides data for additional high-priority vital signs including: forest soil condition, white-tailed deer populations, and landscape context. The overall goal of forest monitoring is to assess status and trends in the composition, structure, and function of NETN forested ecosystems. For more on NETN's forest monitoring activities, visit the Network's website to download briefs for each park and annual monitoring summary reports.

The condition of forests in NETN parks are a direct reflection of the climate surrounding them, but as George Perkins Marsh knew, forested ecosystems also directly influence and help regulate climate in several ways. Forests help naturally reduce greenhouse gases by removing CO_2 from the atmosphere and storing it in their biomass - one of the many free services that forested National Parks and other protected areas across the country and around the world provide. The amount of carbon a tree can store depends a lot on the size of the tree and the climate where it is growing. The "average tree", of average age, in an average climate, can sequester about 66 lbs. of CO_2 per year and about 2 tons of carbon during a typical 70 year growth. Studies have shown that coastal redwoods in California, some of which are in Redwood National Park, and Giant Sequoias in Sequoia National Park are the world's top two tree species with the highest carbon densities. It would take about 1,000 average sized trees to absorb the same amount of CO_2 that a single *Sequoiadendron giganteum* absorbs over the course of a year. A single growing giant sequoia can absorb as much as 22 lbs. of CO_2 *per day* (3½ tons a year – about the same amount of CO_2 produced by a 40 mpg car over a typical year).

Besides sequestering carbon created by our fossil fuel habit, healthy forests offer many other free "ecosystem services". Engineering a product or systems that provided the clean water, air, and recreation that forests give us would cost an incalculable fortune. Forests provide 30 percent of the oxygen we breathe, recycle our water, and create habitat for millions of species.



CHOOSING THE CLIMATE OF TOMORROW: ENERGY TODAY

Getting down to brass tacks, the climate issue is essentially an energy-choice issue. And right now, fossil fuels (coal, oil, and natural gas) are America's primary choice for energy, accounting for 85 percent of current fuel use. Climate issues aside, there is little debate that the extraction and usage of these fossil fuels has and continues to adversely affect the world's ecology and human health. From mountain-top removal mining, to oil spills, well leaks, contaminated ground water, acid rain, and air pollution, using fossil fuels has caused great harm to the environment and people[4]. Even with scrubbers on many modern coal smoke stacks that help contain millions of tons of pollutants annually, coal burning power plants still account for more than two-thirds of the sulfur dioxide, 22% of nitrogen oxides, and a third of all mercury emissions in the United States. Every year, the coal that power-plants burn in the U.S. emits 52 tons of mercury, 47 tons of arsenic, 8 tons of beryllium, 3 tons of cadmium, 62 tons of chromium, 52 tons of nickel, and 184 tons of selenium (Citizens Coal Council stats). Many of these elements are toxic to humans and other life-forms in just microgram quantities. Burning that coal also creates some 140 million tons of ash (up from less than 90 million tons in 1990) each year, enough for every American to personally get 900 lbs. of the stuff, and coal ash now constitutes the nation's second largest waste stream after municipal solid waste. In late 2011 the EPA announced new rules that will tighten limits for mercury, arsenic, nickel, selenium and cyanide found in coal-fired power plant emissions. The new rule requires that the vast majority of mercury and other pollutants contained in coal be captured and prevented from releasing into the air, and would require plant operators to shut down or upgrade the least efficient power plants by 2015. Despite federal limits on emissions of mercury from other sources, such as waste incinerators, historically there has not been any limits set for coal power plants, which according to the EPA constitute the single largest source of mercury emissions in the U.S.

More than 900 lbs. of coal ash is produced for every man, woman, and child in America each year.

Over the past few decades, a series of studies have found that the waste emitted by coal plants is even radioactive (according to an article published in *Scientific American*). The reason for this is that coal naturally contains the radioactive elements uranium and thorium, but they occur in such trace amounts in whole coal that they pose little risk. When coal is burned,

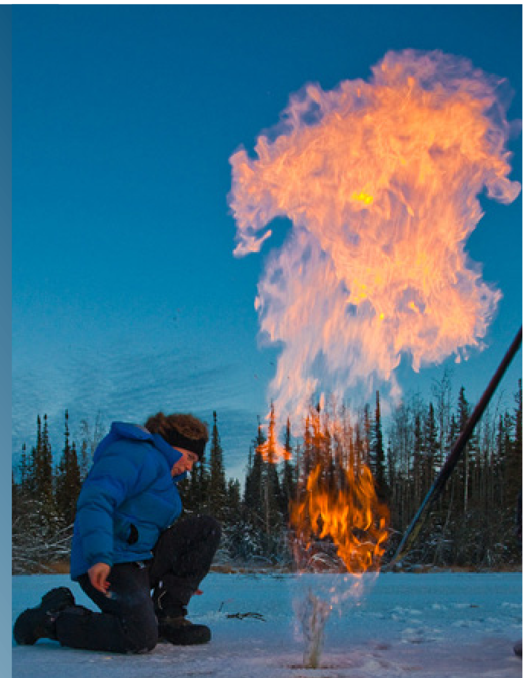
[4] Looking at coal alone - more than 104,000 miners in America have died in coal mines since 1900. Twice as many have died from black lung disease. Smog and the soot it contains causes an estimated 13,200 deaths and nearly 218,000 asthma attacks per year, according to a report from the Clean Air Task Force. Millions of acres across 36 states have been dynamited for strip mining in the last 150 years (more than 60 percent of all coal mined in the United States today comes from strip mines). An estimated 750,000 to 1 million acres of hardwood forests, a thousand miles of waterways and more than 470 mountains have been destroyed in the southeastern Appalachians in the last 20 years from coal mining practices.

Methane: the Climate Change Supercharger

A lot is written about the greenhouse gas CO_2 (and with good reason - it accounts for around 85% of America's greenhouse gas emissions), but much less attention is given to methane in the general news media. This is beginning to change as Arctic permafrost (both subsea and continental) continues to thaw and new ways of extracting fossil fuels (i.e. fracking) could cause atmospheric levels to increase dramatically. Since 1750, methane levels have increased 158%, mostly as a result of cattle-rearing, rice planting, fossil fuel exploitation, and landfill off-gassing. Further increases in atmospheric methane would not be good news for our climate or for us - as a greenhouse gas, methane is about 25 times more effective at trapping heat than CO_2. Another way it differs from CO_2 is in its longevity in the atmosphere, lasting an average of 12 years versus between 50 to 200 years for carbon dioxide. After that decade or so it doesn't just go away however - it actually oxidizes *into* CO_2 and goes on warming the planet for a long time. Methane is also a prime suspect for causing rapid climate change events in the past where it helped to push the climate beyond certain tipping points and thresholds.

Many scientists are warning that continued thawing of Arctic permafrost could trigger massive methane releases and dramatically accelerate the rate of climate change. In Earth's past when this happened it coincided with major extinction events (see page 9). Research published in November 2011 by Rice University scientists suggests that the most likely cause of the huge carbon surge into the atmosphere during such an event 56 million years ago was the release of natural gas hydrates as the oceans warmed (hydrates contain methane trapped by freezing temperatures and high pressure in sea-floor sediment). Massive amounts of CO_2 were released and it took the planet about 150,000 years to recover while excess carbon was reabsorbed into the land and seabed sediment.

The Arctic has already warmed at about twice the rate of the rest of the planet, and in recent years studies of the world's largest continental sea shelf off the coast of Siberia have shown evidence that seabed methane release from warming hydrates has started and is accelerating. Last February, the National Snow and Ice Data Center stated that on present trends between 1/3 and 2/3 of Earth's permafrost will disappear by the end of the century.



University of Alaska researcher Katey Walter lights a pocket of methane on a lake in Siberia in March 2007. Photo by Sergey Zimov.

however, the tons of ash that is produced concentrates the uranium and thorium up to 10 times their original levels. A growing amount of coal ash is being produced each year due in part to an increased demand for electricity, but more so to improvements in air pollution controls. Contaminants and waste products listed above that are emitted through coal plants' smokestacks are and will increasingly be captured through filtration systems before they can become airborne. The new EPA rules will help clean the air, but also will increase the toxicity of power plants coal ash. The ash has to go somewhere, and 46 states across the country are holding huge quantities of it. Some is placed in landfills, some is used in concrete production, and a lot of it ends up in coal ash impoundment ponds. This is no small concern since coal fly ash remains mostly unregulated in the U.S. and contains all the previously mentioned toxins[5].

In the wake of a 2008 coal ash impoundment dam collapse in Tennessee in which 1.1 billion gallons of toxic coal slurry ash was released (a spill 100 times larger than the Exxon Valdez spill off the coast of Alaska in 1989), the EPA compiled a list of 584 coal ash sites spread across 35 states. Of these, 44 were listed under a "High hazard rating" - ash dump sites where, if a spill were to occur, it would likely lead to the direct deaths of nearby residents.

Heavy equipment hauls out ash at the point of the dam breach. Tennessean photo.

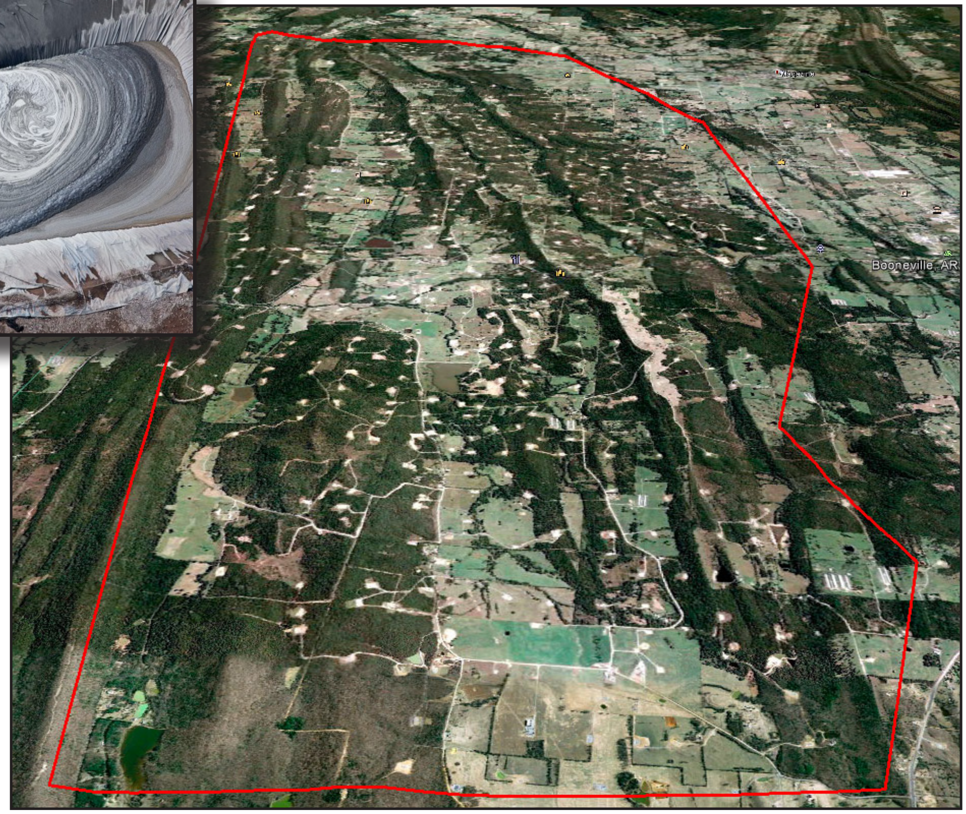
Kingston, TN before and after 1.1 billion gallons of coal slurry spilled across 300 acres from an accident on 12/22/2008. Clean up efforts are expected to top out at over 1.2 billion dollars. NASA images.

At our current pace and without efficiency/conservation programs put in place, demand for electricity is going to require 1,300 to 1,900 new power plants over the next 20 years in the U.S. If fossil fuel sources are used to fulfill our future energy needs, then billions of tons of ash, pollution, and CO_2 will be generated. A fossil fuel future would make our climate problems much worse and negatively

[5] Coal ash is currently considered an "exempt waste" under an amendment to the Resource Conservation and Recovery Act. As part of an EPA study of whether or not to regulate coal ash waste, they released a report that identified 63 sites in 26 states where drinking wells and surface water was contaminated from heavy metals by leaching from ash dumps or the use of ash. In 2010, the EPA proposed to either classify coal ash under hazardous-waste management law or let states regulate it as a non-hazardous waste. Senators from both parties introduced a bill in October 2011 that is similar to one recently passed by the House to completely block the EPA from regulating disposal of coal ash.

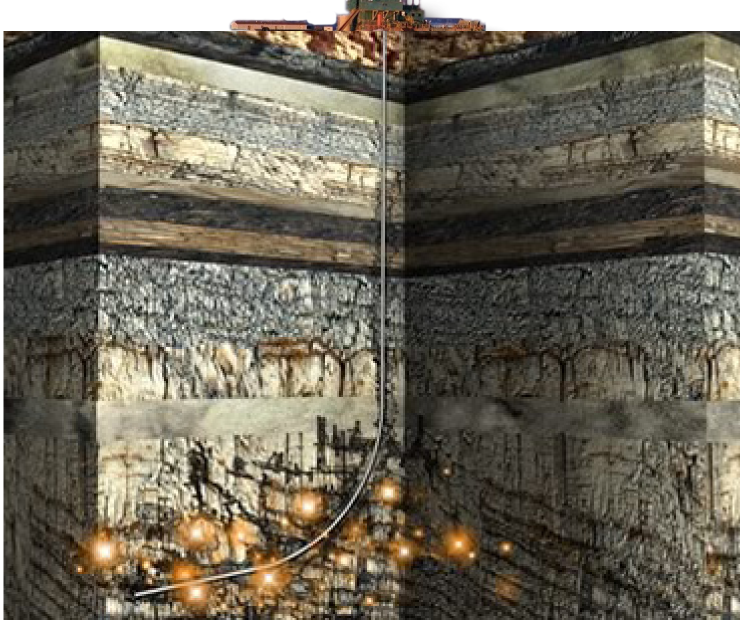
impact every portion of our lives: from the economy and society to the environment.

Do we want a fossil future? So far the answer has been yes. More fossil-fuel infrastructure—oil-burning cars, coal-fired power plants, and industrial factories consuming natural gas—are being added globally every day. Since 2000 the world has added 416 gigawatts of coal-fired power plants, 449 gigawatts of natural gas–fired power plants, and 47.5 gigawatts of oil-fired power plants according to an analysis in the journal *Science.*



The red line encompasses more than 40 square miles of fracked landscape near Boonesville, AR as viewed in Google Earth. The whitish clearings are drill pad sites. Fracking waste-water holding ponds can also be seen scattered throughout area. The inset shows such an open pit pond having slurry sprayed into it from an in-progress fracking operation. Photo by J. Henry Fair.

The greenhouse-gas creating prowess of oil and coal are well known, but natural gas has it's hidden dangers as well. While it is true that the *combustion* of natural gas emits almost 30 percent less CO_2 than oil, and just under 45 percent less than coal, if it is extracted through high-volume hydraulic fracturing (aka "fracking") of shale, it may actually be responsible for creating more greenhouse gases than both of the others do, according to a 2011 paper in the journal *Climatic Change*. The technique of fracking — injecting water, sand and chemicals at high pressures to fracture hard rock — has been around for decades. But now it is being combined with the new technology of horizontal drilling (horizontally guiding a drill bit through a shale reservoir, as opposed to conventional vertical drilling) making possible the exploitation of gas fields that were viewed as practically useless only a decade or so ago. Though it is often billed as the "clean fossil fuel", the problem with natural gas stems from the fact that it is largely made up of methane (see inset on previous page), and the *Climatic Change* study shows that over the lifetime of a typical well, 3.6% to 7.9% of its methane escapes into the atmosphere through venting and leaks. Factoring in these methane leaks, the carbon footprint of "shale gas is at least 20% greater and perhaps more than twice as great on the 20-year horizon" when compared to coal. So while the up-front burning of natural gas emits fewer greenhouse gases than coal or oil, the combined impact of fracking with burning natural gas actually causes more warming than either other fuel.



Fracking involves drilling deep into the earth and injecting a high pressure mix of water, sand and chemicals to fracture shale rock in order to release pockets of trapped gas and oil. Image from electrictreehouse.com.

"But we are, even now, breaking up the floor and wainscoting and doors and window frames of our dwelling, for fuel to warm our bodies and seethe our pottage, and the world cannot afford to wait until the slow and sure progress of exact science has taught it a better economy."

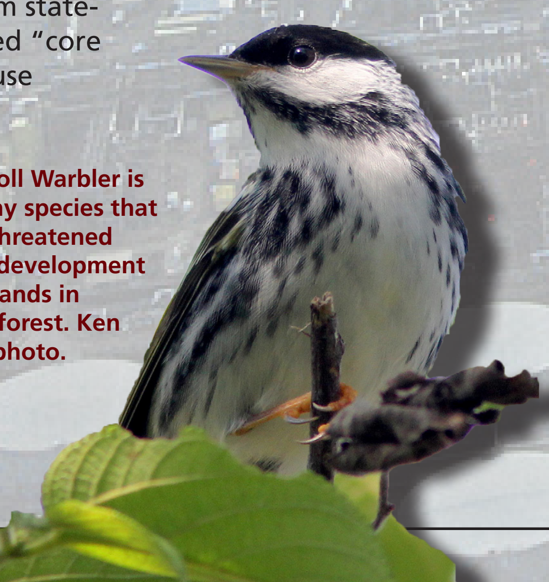
George Perkins Marsh
Man and Nature, 1864

This is especially important and timely news as the shale gas production industry in the United States is now more than 5 times as large as it was in 2006 and continues to grow. A variety of groups oppose its growth, citing among other

A Fossil Future or Winds of Change? A Tale of Two Proposed Energy Projects

The climate of the future will be a direct reflection of the energy choices we make today. Perhaps there is no better example of the choices we have than two proposed energy projects. By sheer coincidence, they would both have almost exactly the same start-up costs ($7-8 billion), but one option will decidedly lead the U.S. energy market further down the path towards a fossil future, and the other towards a solution that produces no greenhouse gases. They are not mutually exclusive - it is entirely possible both will be approved, but the long-term consequences of each project would be vastly different.

The first project is an large-scale renewable energy proposal, the TransWest Express (TWE) Transmission & Sierra Madre Wind Energy Project. The wind farm would deliver power generated by 1,000 2-3 MW turbines spread across about 100,000 acres of ranch land located in the wind-rich (Class 7-10 winds – some of the highest wind power potential in the world) and ironically named Carbon County, Wyoming. If constructed, it would produce 9 million megawatt-hours (MWh's) of CO_2 and toxic waste by-product free electricity per year. Enough to supply 600,000 to 800,000 homes each year. The project would also create about 18,000 new jobs (though only about 130 of them would be permanent jobs directly related to the project). The estimated cost per MWh (about $80) is significantly lower than existing coal power (about $90) even without any federal or state renewable subsidies. The project is not without its environmental concerns however, and one of the most immediate is the protection of the Greater Sage Grouse, a candidate for federal Endangered Species Act protection. Wyoming is home to about half of the world's remaining Sage Grouse, and federal and state leaders in Wyoming and neighboring states are trying to preserve those that remain by steering development away from the most sensitive habitat areas. Former Wyoming Gov. Dave Freudenthal issued an executive order in 2010 charting out a transmission corridor to aid in the siting of power lines away from state-designated "core sage grouse areas".



The Blackpoll Warbler is one of many species that would be threatened by further development of the tar sands in the boreal forest. Ken Schneider photo.

If constructed the wind project will no doubt have other unforeseen environmental costs associated with it, but in both the short and long-term, they would likely never approach the costs of another proposed energy project - the Keystone XL pipeline. This is also a $7-8 billion project, but rather than being spent locally, it would largely benefit one foreign-owned company, and the U.S. would have to pay a premium for what the industry calls "heavy" oil because it requires significantly more refinement than typical crude oil, costing about $30 a barrel to produce versus about $5 a barrel for Saudi oil.

The proposed 1,711-mile pipeline would flow across 1,904 rivers, streams, and waterways in the U.S., including the Yellowstone and Missouri rivers, and the Ogallala Aquifer (which supplies 30 percent of the nation's agricultural freshwater) putting millions of people at risk when the inevitable leaks and spills occur. Even the safest and best maintained pipelines eventually leak some oil, whether through accidents, tampering, or the aging of equipment. The proposed Keystone XL would be more prone to leaks and spills than most current pipelines because the shale oil it would be pumping is thicker than its drilled-out-of-the-well counterpart. To keep it flowing, TransCanada plans to thin it with other petroleum condensates and use internal pressures higher than typical pipelines, making leaks and failures more likely. The first, already constructed Keystone pipeline has so far had 12 spills ranging from 2 gallons to 21,000 gallons since it began operation in 2010.

Like the TWE wind project, the Keystone XL would also create employment. Cited numbers range wildly from 5,000 to over 100,000, though the U.S State Dept. estimates the number to be around 6,500, mostly temporary, jobs. An analysis performed by the Cornell Labor Institute calculated the number of permanent jobs created by the pipeline to be about 50. And though it would reduce our dependence on some foreign oil, the pipeline would only provide about an extra 700,000 barrels of crude per day – which is about 3.5% of the U.S.'s current daily needs and amounts to small impact on foreign oil dependence. As an example, if the average U.S. smoker, who puffs about 16.90 cigarettes a day, reduced their cigarette intake by 3.5% to 16.31 a day - it would be hard to argue that they were any less addicted to smoking. Several independent analysis also show that the more expensive oil, pumped in at 700,000 bpd, would increase oil prices by about $6.00 a barrel.

The extraction and refining of the heavy oil would also decrease migratory birds seen throughout North America, including some NETN parks, according to the peer-reviewed policy and science report - *Danger in the Nursery: Impact on Birds of Tar Sands Oil Development in Canada's Boreal Forest*. In Alberta, current tar sands mining and drilling already causes significant habitat loss and fragmentation. Toxic tailing ponds result in 8,000 to 100,000 oiled and drowned birds annually when the birds land in the pollution-filled water storage lakes.

Canada's Boreal forest is a globally important breeding habitat destination for birds, and about half of America's migratory birds nest there. The rapidly expanding tar sands oil extraction industry increasingly puts many of these birds at risk. Each year 22–170 million birds breed in the area that could eventually be developed for tar sands oil. The report projects that the cumulative impact over the next 30–50 years could be as high as 166 million birds lost, including future generations.

The threat to birds is not contained exclusively in Alberta. Resulting decreases in air and water quality and increasing temperatures from climate change already affecting boreal birds are only exacerbated by the tar sands development, which now account for Canada's fastest growing source of greenhouse gas emissions.

Tar sands production is also highly resource intensive, requiring three barrels of freshwater for every one barrel of oil produced and uses enough natural gas to heat 3 million Canadian homes, making it vastly more carbon polluting than domestic crude oil. According to the EPA, carbon emissions from tar sands crude are approximately 82% higher than for average crude oil refined in the U.S.

When climate scientists tell us we need to take action now to prevent the worst climate change has to offer, they are talking about decisions like this one. It is these kinds of choices that we make today that will both affect and reflect our climate tomorrow.


Existing Wyoming wind farm.

Alberta tar sands. NWF photo.

The Deepwater Horizon drilling platform in its final moments in April of 2010. It was the largest accidental marine oil spill in the history of the petroleum industry, releasing about 4.9 million barrels of crude oil into the Gulf of Mexico. New York Times photo.

reasons the belief that the undisclosed chemicals in fracking fluids can pollute water supplies. Temporary or permanent fracking bans have been put in place in New York, New Jersey and Maryland, and other states are toughening drilling regulations. The EPA is expected to complete a study on fracking sometime this year.

In recent years, engineers have found ways of extracting oil from shale rocks as well. The Bakken field, spread across North Dakota and Montana, now produces about 400,000 barrels a day up from a few thousand in 2007. Oil executives predict production could reach a million barrels a day by 2015. The first well of this type was drilled in the Eagle Ford shale field in south Texas in 2008, and now it produces more than 100,000 barrels a day, with 420,000 expected by 2015. There are 20 other shale and similar tight rock fields across the U.S. that if drilled could make states like Ohio and Michigan major fossil fuel producers.

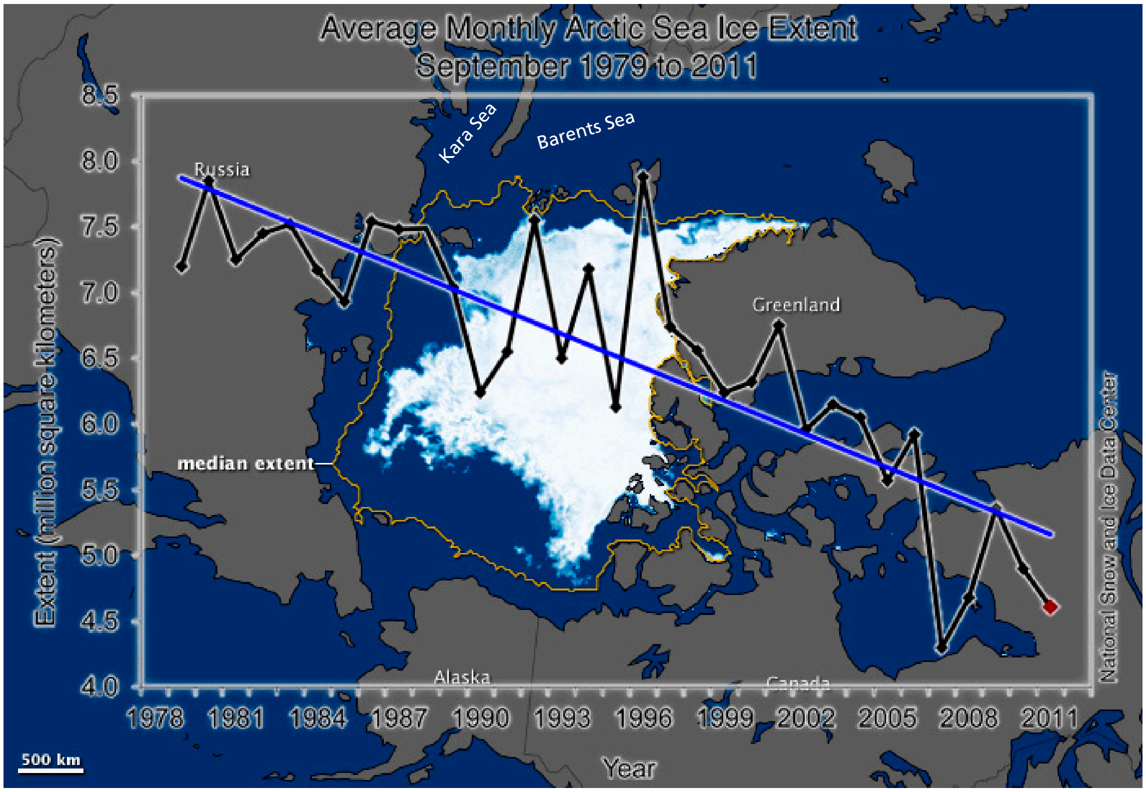
> Action of man upon nature... is often followed by unforeseen and undesired results, yet it is nevertheless guided by a self-conscious and intelligent will...
>
> George Perkins Marsh
> *Man and Nature*, 1864

The fracking phenomenon highlights a growing trend in world energy companies of finding and extracting fossil fuels in difficult to reach places through new technologies and unconventional means. An October 2011 New York Times article, *New Technologies Redraw the World's Energy Picture*, outlines many of these trends and technologies. Reserves are being found and exploited in new locations around the world as well as in places that they were known to exist, but were considered inaccessible either economically or technologically. Places like the high Arctic waters north of Norway, Argentine Patagonia, northwest boreal Canada, the deep ocean off the shores of Angola, and many other areas are yielding giant oil and gas reserves that are being mined, steamed, and drilled with new technologies.

If the current pace of expansion continues, these new fossil fuel sources will bring hundreds of billions of barrels to world markets in coming decades and add billions upon billions of tons of greenhouse gases to the atmosphere. This decided shift in energy supplies began in the 1990's when the first deep ocean wells were drilled in the Gulf of Mexico and Brazil, but has really expanded in the last 10 or so years because of declining conventional supplies, rising energy prices, and jumps in technology. Today, deep-sea rigs can reach down 40,000 feet, twice as deep as a decade ago, plunging their drills through 10,000 feet of seawater and then 30,000 more feet of seabed.

Deep ocean offshore drilling has already measurably increased world oil supplies and is now around 7 million barrels a day, providing about 8% of the world's supply. In 2000, fewer than 20 vessels existed in the world that could drill deep ocean wells, now there are nearly 200 with more being built almost every month. Though advances in technology have made deep ocean drilling possible, many risks still remain as the April 2010 Deepwater Horizon disaster demonstrated. In the aftermath, regulations have become somewhat tougher worldwide but caused only a brief pause in drilling and the U.S. back to almost pre-Horizon drilling levels.

Canadian oil sands are another growing new energy source. Current estimates of how much oil is in the sands tops Iraq's total reserves. Knowledge of oil sands has been around for decades, but they were deemed too expensive to produce oil at a large scale. Rising oil prices have shifted the economics in their favor however and multibillion-dollar investments from international oil companies have been made in Canada. Since 2000, production has expanded from 600,000 to more than 1.5 million barrels a day of synthetic oil. Combined with the conventional oil Canada already exports to the U.S., the oil sands make the country the most important source of oil for America.



In September 2011, sea ice covering the Arctic Ocean declined to the second-lowest extent on record. Satellite data from NASA and the National Snow and Ice Data Center (NSIDC) showed that 2011 continued a steady downward trend in ice extent over the past 30 years. The opening of Arctic waters is making it easier for fossil fuel companies to explore the region for more oil sources. NASA image and NSIDC graph.

One thing holding back further development of Canada's oil sands are the many environmental concerns associated with development. Much of the oil sands come from the removal of large sections of boreal forest to create mining sites. The forests are important carbon sinks and provide breeding grounds for many bird species. Refining the oil is also a much more carbon intensive process than conventional crude.

The search for more oil has even reached high up into the Arctic waters off Norway all the way across to Alaska in places that as recently as the late 1990's were inaccessible because of sea ice. The recent thinning and receding of Arctic ice (primarily due to the burning of fossil fuels) sounds off alarm bells in the scientific community, but it has also opened the doors to fossil fuel companies to explore for more oil in the region. A 2008 assessment by the USGS estimated that a quarter of the world's remaining undiscovered conventional oil and gas is in the Arctic, more than 80 percent of it in difficult to reach, though now less frequently ice-clogged offshore areas.

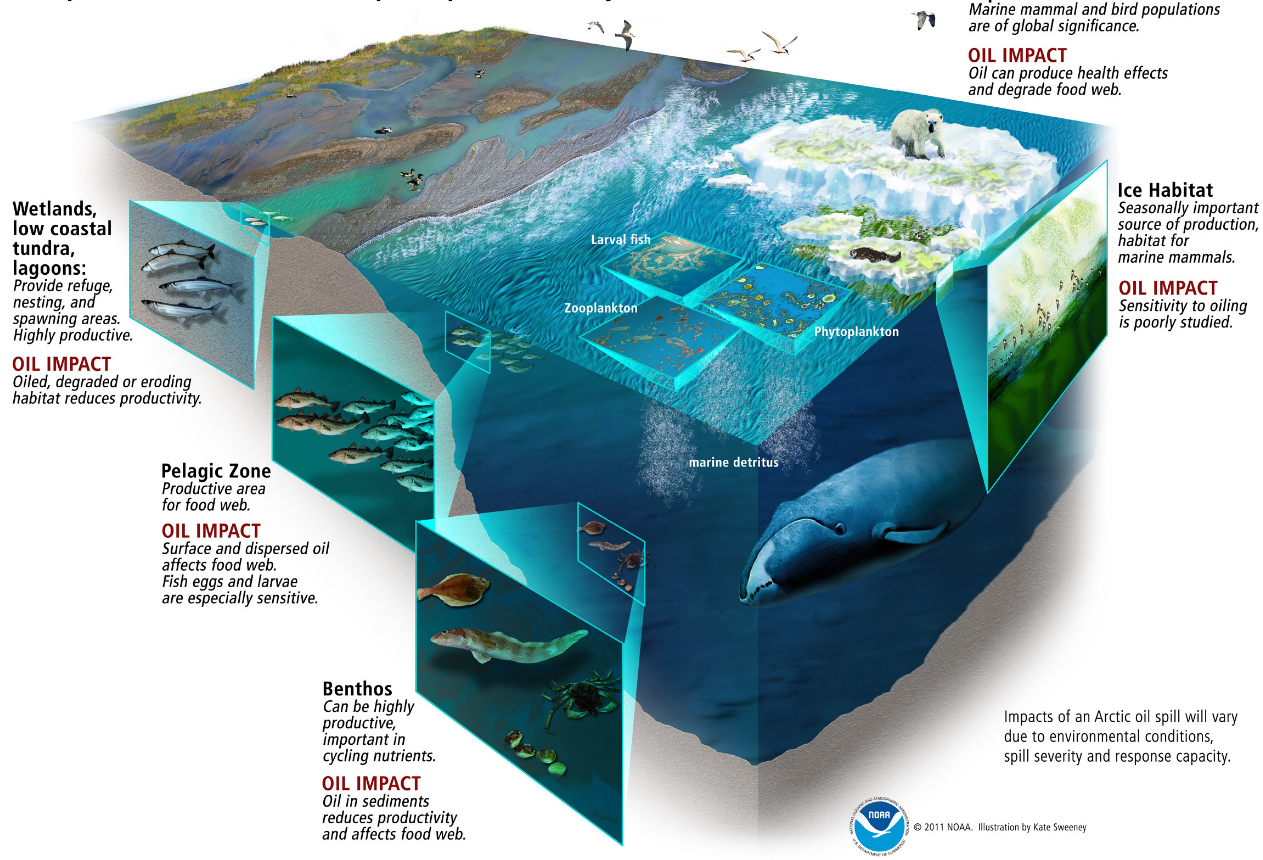
Oil companies are right now doing seismic work in Canada's Arctic waters, have drilled exploratory wells off Greenland's coast, and invested billions of dollars in the exploration of the icy Kara Sea north of Siberia. In the far northern waters off Norway (which stay ice-free because of warm Gulf Stream waters) there is already a gas field, called Snow White, some 340 miles north of the Arctic Circle in the Barents Sea. Several fossil fuel companies are currently drilling oil wells in the Barents after operations accelerated with the discovery of an estimated 250 million barrels of high-quality sweet crude oil (sometimes referred to as "champagne" by oil companies) in the Skrugard field in April 2011. As big as this discovery was, it is only the seventh-largest oil or gas find in the world in 2011.

Large oil and gas discoveries began in Russia and Alaska in the 1960's, and more than 40 fields are now in production across Alaska, Russia, Norway, and Canada. Oil companies have been trying for years to drill in Alaska's Chukchi and Beaufort Seas and have invested billions on leases. So far, U.S. regulatory agencies or courts have delayed drilling efforts because of concerns that the Arctic waters are vital breeding grounds for many bird, mammal, and aquatic species that are endangered or at risk.

Another concern is that an arctic well blowout would be difficult or impossible to stop or clean-up. A paper released by the national commission on the Deepwater Horizon disaster warned that a leak of that nature in the high Arctic would be difficult to clean and contain because skimmers could become clogged in ice and spilled oil is unlikely to degrade in the frigid water. Even with the risks, in August 2011 the Department of the Interior gave approval to at least one oil company to begin drilling exploratory wells there in the summer of 2012. The industry estimates that 25 billion barrels of oil are in the Alaskan Arctic, mostly in the Chukchi Sea. Looking at it another way, burning 25 billion barrels of oil would add at least 20 *trillion pounds* of CO_2 to the atmosphere.

As these unconventional sources for fossil fuels continue to be explored and extracted, they only make addressing climate change and the development of renewable energy more difficult. The industry trend of moving into developing fossil fuels that are even dirtier and release more carbon pollution in the process of extracting, refining, and using is the prelude to a hot "climate movie" that will feature the degradation of ecosystems, wild weather extremes, loss of biodiversity, and the harming of human health and quality of life for all people planet wide.

Conceptual Model of Arctic Oil Spill Exposure and Injuries



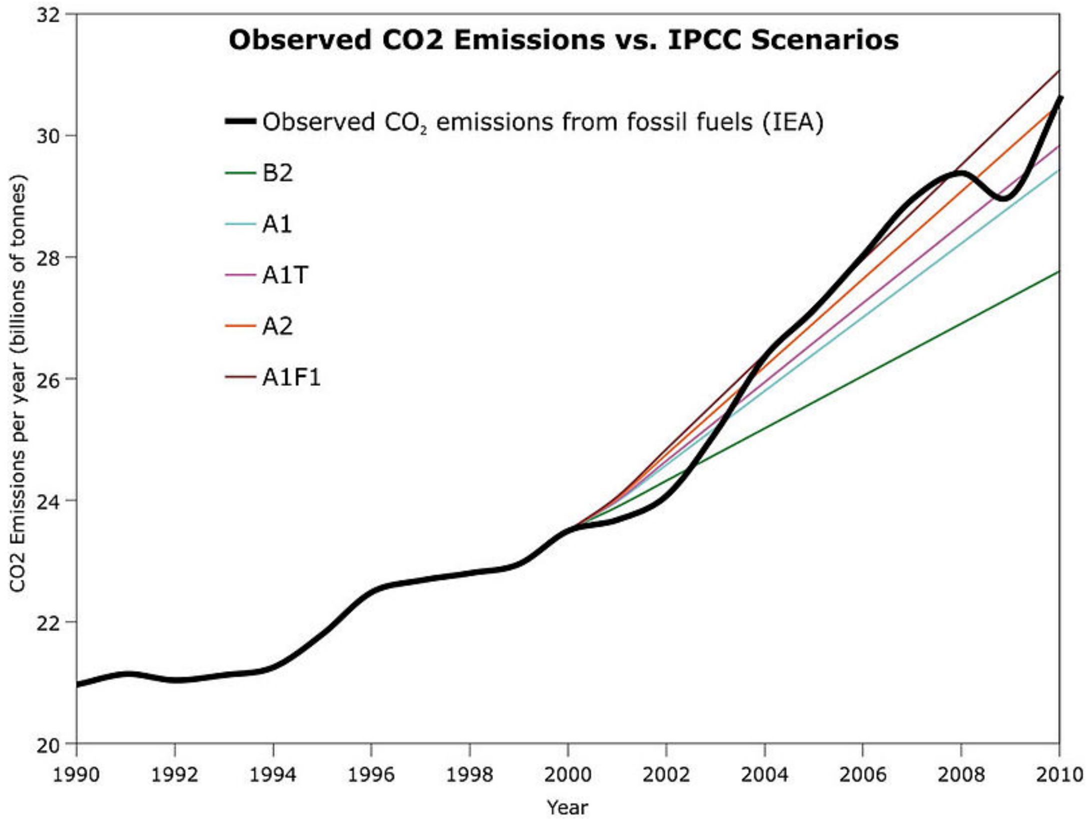
because of the fact that there is this extra water vapor lurking around in the atmosphere than there used to be say 30 years ago. It's about a 4% extra amount, it invigorates the storms, it provides plenty of moisture for these storms and it's unfortunate that the public is not associating these with the fact that this is one manifestation of climate change. And the prospects are that these kinds of things will only get bigger and worse in the future."

They will certainly get worse if energy-related CO_2 emissions continue on the track that they are on. As with multi-billion dollar storm events, emission levels have also reached record levels and threaten to continue breaking records for years if all the previously mentioned fossil fuel options are exploited. In 2010, total CO_2 emissions were the highest in human history, according to the latest estimates by the International Energy Agency (IEA), topping out at a record 30.6 gigatons (Gt), an

According to an IPCC report released in early November 2011, weather extremes are already becoming more frequent around the world because of the exploitation of fossil fuels and human caused warming. The report states that continuing climate change will only worsen certain extreme weather events like heat waves, floods, droughts and storms. This would no doubt be very costly for the U.S., both economically and environmentally. The powerful October 29th, 2011 snow storm in the Northeast brought the tally of U.S. billion dollar-plus weather disasters in 2011 to 14, resulting in economic losses of almost $50 billion. This beats by a longshot the previous record of nine set in 2008. The 30 year average for billion-dollar weather disasters in the U.S. is 3.5 events per year. As noted early on in this paper, not all of those events can be directly attributed to climate change, but a warming atmosphere almost certainly contributed to the power of most of them. Kevin Trenberth, head of the Climate Analysis Section at the National Center for Atmospheric Research, puts it this way:

"[many climate scientists will say] 'Well you can't attribute a single event to climate change.' But there is a systematic influence on all of these weather events now-a-days

Flooding in Vermont from Hurricane Irene in August 2011. It was one of 14, billion-dollar weather related disasters that year. USFWS photo.



CO_2 emissions are at record levels, surpassing the IPCC's "worst case" scenarios from just a few years ago. If more unconventional and traditional sources of fossil fuels are exploited in the coming few years, it will be extremely difficult to prevent the most severe effects of climate change.

incredible 6% increase from 2009 worldwide emission totals. The numbers for 2010 greenhouse gas emissions are now higher than the worst-case scenario outlined by the IPCC climate experts just 4 years ago.

In terms of fuels, 44% of the estimated 2010 CO_2 emissions came from coal (an 8% increase from 2009), 36% from oil, and 20% from natural gas. While the IEA estimates that 40% of global emissions came from European and North American countries, they only accounted for 25% of emissions growth compared to 2009. Countries such as China and India saw much stronger increases in emissions as their economic growth has accelerated. European and North American countries still lead all other parts of the world on a per-capita basis however, collectively emitting 10 tons per capita, compared with 5.8 tons for China, and 1.5 tons in India.

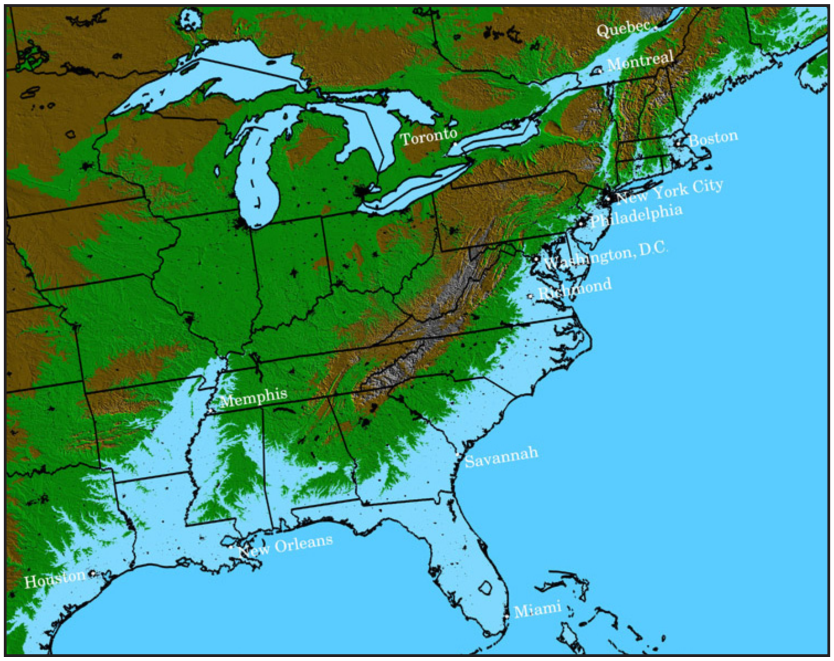
"This significant increase in CO_2 emissions and the locking in of future emissions due to [fossil fuel] infrastructure investments represent a serious setback to our hopes of limiting the global rise in temperature to no more than 2ºC [~3.6ºF]," according to Dr. Fatih Birol, Chief Economist at the IEA who oversees the annual *World Energy Outlook*, the agency's primary publication.

> The Earth is fast becoming an unfit home for its noblest inhabitant, and another era of equal human crime and human improvidence... would reduce it to such a condition of impoverished productiveness, of shattered surface, of climatic excess, as to threaten the depravation, barbarism, and perhaps even extinction of the species.
>
> George Perkins Marsh
> *Man and Nature*, 1864

Global leaders agreed to a target of limiting temperature increase to ~3.6 °F at the UN climate change talks in Cancun in the fall of 2010. It is believed that for that to happen, the long-term concentration of greenhouse gases in the atmosphere must be limited to around 450 parts per million of CO_2. These numbers have been at the heart of global negotiations on carbon dioxide emissions for years because they were considered to be the threshold after which the worst climate change has to offer will commence. However, as climate science and studies of Earth's past climate continue to improve, more and more scientists agree that 450 ppm and a 3.6 degree warming could be too much. Among others, Dr. James Hansen (director of the NASA Goddard Institute for Space Studies and whose data has been central to setting the 450 ppm benchmark since the 1980's) now warns that a rise that much could be "a prescription for disaster" because of what it would mean for the planet, human health, and many of the world's major cities and islands.

Dr. Hansen came to the conclusion after reviewing averages and extreme ups-and-downs of Earth's paleoclimatic record, which shows that 50 million years ago the Earth was free of ice (the time when alligators and palm trees called the Arctic Circle home), and sea level was over 200 feet higher on average than it is today. This was a result of higher global temperatures due to changes in the sun's output and Earth's orbit over geological time scales. Rising temperatures during the "Anthropocene", however, are happening over far shorter time scales for which neither the sun nor the orbit can be blamed. The latest analysis shows that a level of 450 ppm would likely be enough to melt a significant portion of the world's ice, largely because of feedback loops and methane emissions from thawing permafrost that will accelerate warming.

If the number reaches 560 ppm, a doubling of preindustrial values, sea level globally could eventually rise over 80 feet, which would inundate the dozens of islands and large cities worldwide that lie lower than that elevation (parts or all of



An interpretation of what the East and Gulf Coasts could look like if all of the world's ice melts

London, Boston, Miami, New York, New Orleans, Mumbai, Cairo, Amsterdam, Tokyo, etc.) This scenario is easily achievable and is not some distant future event. At the current CO_2 accretion rate of about 2.4 ppm a year and assuming that rate won't increase (though if the fossil fuel industry continues its current growth the rate will certainly increase) we would be at 558 ppm by 2080. Well within the lifetimes of almost 2 billion people alive today (26% of the global population is aged under 15). In all likelihood, we could achieve a doubling of CO_2 sooner than that even. It is by no means a foregone conclusion that the exact same scenario would unfold, but if the paleoclimatic record is any guide, 560 ppm is enough to eventually melt all the ice in the Arctic, and later the Antarctic. If that were to happen, sea levels could rise by a truly Water World-like 195 to 230 feet. According to Dr. Hansen, "If governments keep going the way they are going, the planet will reach an ice-free state."

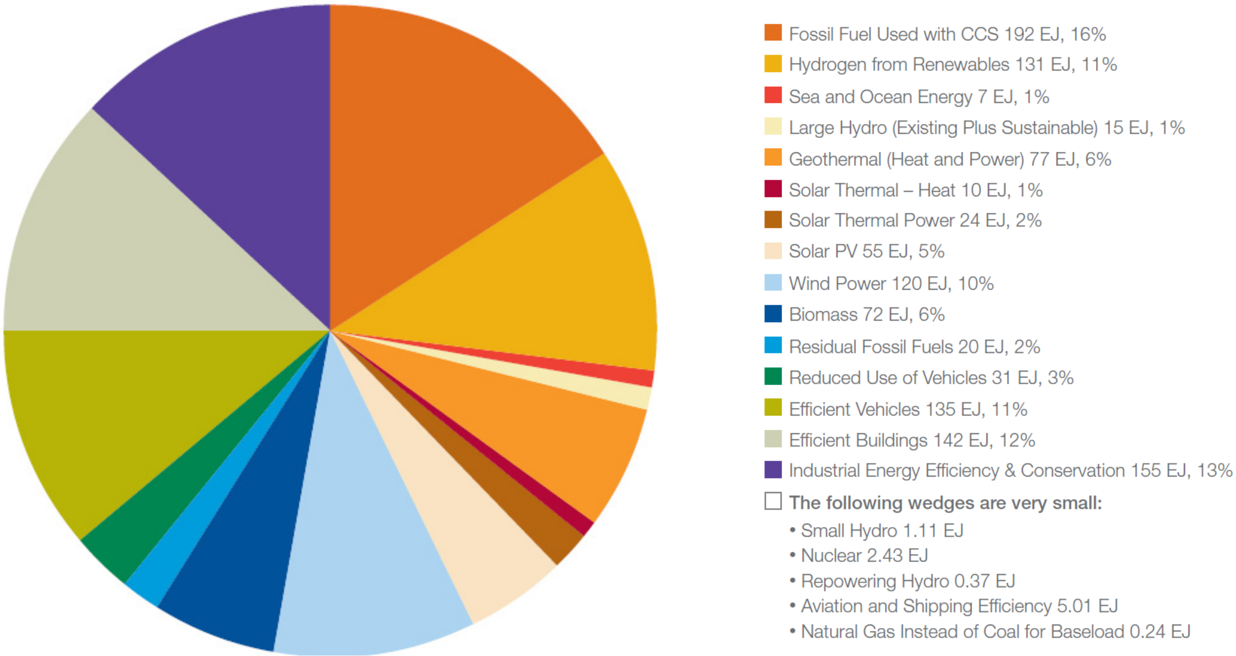
However, if we begin to reduce CO_2 build-up now, it will save a whole lot of lives, infrastructure damage, and billions in expenses. If the world reduces CO_2 emissions by 6 percent a year starting in 2012, atmospheric levels can return to the "safe" level of 350 ppm that Dr. Hansen and many other scientists have long called for. If the world waits until 2020 to take any real action, a position favored by some of the world's nations during the recent Durban climate talks in December 2011, nations will need to reduce CO_2 by a much more costly and difficult 15 percent a year in order to reach 350 ppm.

The *World Energy Outlook 2011* report agrees: "On planned policies, rising fossil energy use will lead to irreversible and potentially catastrophic climate change … we are on an even more dangerous track to an increase of 6°C [11°F] … Delaying action is a false economy: for every $1 of investment in cleaner technology that is avoided in the power sector before 2020, an additional $4.30 would need to be spent after 2020 to compensate for the increased emissions."

ENERGY ALTERNATIVES

Renewable energy sources are not perfect by any means, and each one presents its own complications and challenges, whether they be financial, cultural, environmental - or all three. The trade-offs are of course that the majority neither emit any greenhouse gases nor do they have the pollution and problems associated with extraction. What seems to hold back the further development of many clean energy sources is their perceived costs. But when the full costs of fossil fuels are factored in (not just price per watt, but human health, environmental, disaster clean up costs, etc.) many renewables are shown not only to be competitive, but actually more economical. Today, due to its widespread abundance and low market price, coal power is the largest single source of energy production worldwide. A major problem with the way the current cost is calculated for coal (and other fossil fuels as well) is that its full costs are not truly reflected in its market price. While it

When completed in 2013, the Mojave Desert-based Ivanpah Solar Electric Generating System will send approximately 2,600 megawatts of power to the grid, doubling the amount of solar thermal power produced in the U.S. and generating enough electricity to power 140,000 California homes. The plant is not without its controversy however, and a compromise over care and relocation of the state-threatened Mojave desert tortoise was needed to allow it to move forward.



One possible energy solution for the year 2050 put forth by the World Wildlife Fund, presented first in Exajoules and then as a percentage of energy supplied or avoided, compared with the energy demand projection in the IPCC's *SRES A1B* scenario (high energy demand). Efficiencies reduce demand by about 40%; of the remaining demand, about 70% can be met by low-carbon technologies, and about 26% by fossil fuels operating with carbon capture and storage. Nuclear, conventional fossil-fuel use without carbon capture, and other small sources make up the last 4%.

appears coal can be purchased and burned cheaply, the actual cost of coal is much higher in the long run. In "economist speak" the impacts on human and environmental health which are not directly reflected in a commodity's price is called an "externality". Those who benefit from the seemingly cheap electricity made from coal don't pay for these externalities up front, but eventually do pay in the form of medical bills, environmental cleanups, climate change and so on.

In a recent study published in the *Annals of the New York Academy of Sciences*, a group of researchers attempted to do a full cost accounting for the life cycle of coal by taking many of its externalities into account, an impressive list which includes:

- increased illness and mortality due to mining pollution
- climate change from greenhouse gas emissions
- particulates causing air pollution
- loss of biodiversity
- government coal subsidies
- cost to taxpayers of environmental monitoring and cleanup
- decreased property values
- infrastructure damages from mudslides resulting from mountaintop removal
- infrastructure damage from mine blasting
- impacts of acid rain resulting from coal combustion byproducts
- water pollution

Note that most of these external factors do not apply to renewable energy sources. The report found that the total cost of these externalities ranged from approximately 9 to 27 cents per kilowatt-hour (kWh) of electricity generated, with an average of approximately 18 cents per kWh. The authors made clear that this is a conservative estimate because they could not account for every associated impact.

To find out what this means, we need to look at the U.S. Energy Information Administration's comparison of levelized costs for different power generation sources. "Levelized cost"

Energy Source for Electricity	Minimum	Average	Maximum
Conventional Coal	8.55	9.48	11.08
Advanced Coal	10.07	10.94	12.21
Advanced Coal with CCS	12.63	13.62	15.45
Natural Gas-fired :			
Conventional Combined Cycle	6.00	6.61	7.41
Advanced Combined Cycle	5.69	6.31	7.05
Advanced CC with CCS	8.08	8.93	10.40
Conventional Combustion Turbine	9.92	12.45	14.42
Advanced Combustion Turbine	8.71	10.35	11.82
Advanced Nuclear	10.97	11.39	12.14
Wind	8.19	9.70	11.50
Wind – Offshore	18.67	24.32	34.94
Solar Photovoltaic	15.87	21.07	32.39
Solar Thermal	19.17	31.18	64.16
Geothermal	9.18	10.17	11.57
Biomass	9.95	11.25	13.34
Hydro	5.85	8.64	12.14

U.S. Energy Information Administration table of levelized costs in cents per kilowatt-hour for several sources of electricity generation, before externalities are factored in. CCS stands for Carbon Capture and Sequestration. Data from *Annual Energy Outlook 2011.*

An innovative way for a coal power plant to simultaneously add jobs, stimulate the economy, and reduce its CO_2 emissions. The Pratt Street Power Plant mall, Baltimore, MD. Andrew Horne photo.

represents the present value of the total cost of building and operating a generating plant over a period of time, and reflects overnight capital cost, fuel cost, operation and maintenance costs, financing costs, and an assumed utilization rate for each plant type.

Looking at coal power's levelized cost, adding the list of previous externalities are sufficient to triple its cost if they were reflected in its market price (the December 2011 EPA ruling requiring coal plants to remove mercury and other pollutants from their emissions by 2015 will likely raise the market price of coal and help to highlight some of the true costs of coal). Externalities included, coal's levelized cost increases to approximately 28 cents per kWh - more than hydroelectric, wind (onshore and offshore), geothermal, biomass, solar photovoltaic, and on par with solar thermal (whose costs have been falling each year). Even without adding most of the externalized costs to coal with unproven Carbon Capture and Sequestration (CCS) technology, it is already significantly more expensive to produce than many other forms of renewable energy - with externalities, there is no contest, renewables win every time.

No one-size-fits-all single solution or source of renewable energy could be the answer to everyone's energy needs across the globe, but a mix of efficiency, renewables, and even a small amount of fossil fuels can drastically reduce our greenhouse gas emissions. Solar and wind power are two well-known examples of renewable energy, and more details on both of those rapidly expanding industries follows, but there are also a surprising amount of other very innovative and small scale renewable energy projects out there that are all helping to reduce fossil fuel consumption. Lengthy articles could be written about each one, but here are a few short descriptions of the incredible variety of renewable energy projects around the world:

- Some commercial passenger jets in the U.S., China, and Mexico are beginning to burn a biofuel mix derived partially from algae and waste cooking oil. The fuel is converted from inedible natural oils and wastes into a more environmentally friendly jet fuel that offers as much as an 85% reduction in greenhouse gas emissions than petroleum-based jet fuel.
- An inventor in the U.K. has created a paving slab that generates electricity every time someone steps on it. They are already being used in a college in England, but the first large-scale commercial use of them will be when they are placed between London's Olympic stadium and the Westfield Stratford City mall during the 2012 Olympics. It is estimated that only twenty "PaveGen" tiles will be needed to generate enough electricity to power at least half of the mall's outdoor lighting needs - just from people walking around it.
- Microbial fuel cells (MFCs) are being developed by a number of researchers who are trying to utilize specialized bacteria to break down natural waste products (such as

Kinetic energy generating Pavegen tiles will help power the lighting system in one of Europe's largest shopping areas during the 2012 Olympic games. Pavegen image.


Ireland's SeaGen turbine takes advantage of the swift tidal current of Strangford Lough to create electricity for about 1,000 homes in the region.

urine from cows, and even people) and in the process create energy that can be stored for future use.

- Methane from decomposing landfill garbage is being used to power 85 percent of the University Of New Hampshire's heat and electricity needs. The "EcoLine" project makes UNH the first school in the nation to source a majority of its power from landfill gas. The system is expected to pay for itself within 10 years and has lowered the school's CO_2 emissions to 57% *less* than its 1990 levels.
- More than 30,000 MW of electricity a year are being generated in dairy rich states like Vermont, Pennsylvania, New York, and Wisconsin through "Cow Power" manure-to-methane recapture projects that sends power to tens of thousands of homes and businesses.
- Many coastal countries of the world are getting thousands of megawatts of clean energy from tidal movement and wave energy installations.
- A surprising statistic is that next to oil, coffee is the most traded commodity on the planet. Normal coffee production and preparation creates a lot of waste in the form of used grounds, but researchers at the University of Nevada are finding ways to use this by-product and convert it into biofuel. Coffee grounds contain a significant percentage of oil in the form of biodiesel, and the natural anti-oxidants in coffee oil helps to extend its shelf life. Leftover grounds can be compacted and burned as pelletized fuel. Major coffee retailers could realize huge benefits by changing the ways they treat waste grounds. It's estimated that *Starbucks* generates 210 million pounds of coffee grounds annually. Processing these grounds could provide nearly 3 million gallons of biodiesel fuel and about 90,000 tons of fuel pellets.
- Energy carried by high-altitude wind streams in the troposphere has been estimated to be over 800 terrawatts (TW). Humanity's *total* annual energy budget amounts to a relatively trifling 17 TW. Even at heights of only 1,000-2,000 feet, there is a large amount of wind energy that could be tapped. Companies around the world are evaluating designs for high-flying, multi-winged kites that supports arrays of wind turbines and can produce enough electricity to supply from 10 to 1,000 homes - from a kite.

A quick Google search for "unconventional renewable energy" will return literally dozens more examples of innovative energy projects around the world. While the aforementioned examples may never be adapted on as wide a scale as oil and coal, they serve to highlight the amazing amount of human ingenuity available when it comes to problem solving our energy needs. Taken cumulatively, these unusual energy initiatives are helping to prevent millions of tons of greenhouse gases from getting into our atmosphere and warming the planet.

THE FUTURE OF WIND & SUN: LOOKING BRIGHT AND BREEZY

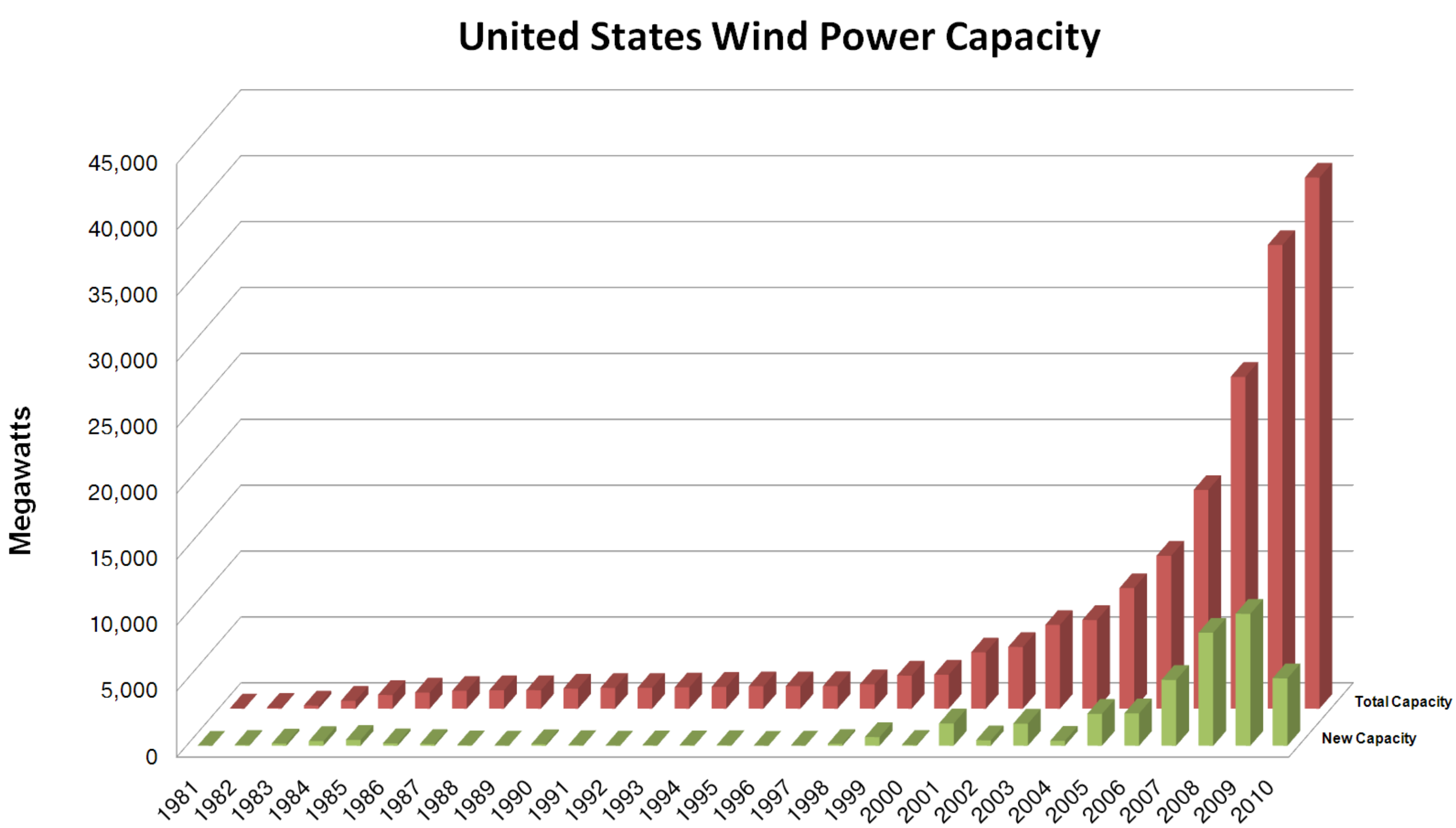
More traditional renewable energy sources are also benefiting from leaps in technology and hold even more promise for adaptation on a widespread scale. Both the wind and solar industries are in a state of rapid growth, even during the recent economic downturn. The U.S. wind industry currently employs around 85,000 people (there are 80,600 coal miners working in the U.S., according to the Bureau of Labor Statistics) and adds more "green-collar" jobs every year. Wind capacity is quickly increasing as well. In the year 2000, the U.S. had 2,578 MW of total installed wind power capacity. Just over 10 years later, the U.S. wind industry now stands at 42,432 MW of cumulative wind capacity, powering 10 million homes and preventing 100 million metric tons worth of CO_2 emissions every year that would otherwise be produced if coal powered those same homes. Of new electrical generating capacity installed in America over the past 4 years, 35% has been with wind power – more than coal and nuclear combined. Since the start of the recession in 2007, the wind industry has actually experienced a 41% growth rate. That growth is projected to continue according to a 2011 report from Pike Research. Total installed wind capacity in North America is expected to almost triple over the next 6 years, increasing to about 126 GW by 2017 (China plans on having 100 GW of wind by 2015). The global growth rate of wind has also been

Wind turbines themselves take up relatively little space and 'wind farm' land can still be utilized for a variety of other purposes. This is a wind farm in Minnesota that also has plenty of room for grazing cattle. Windimages photo.

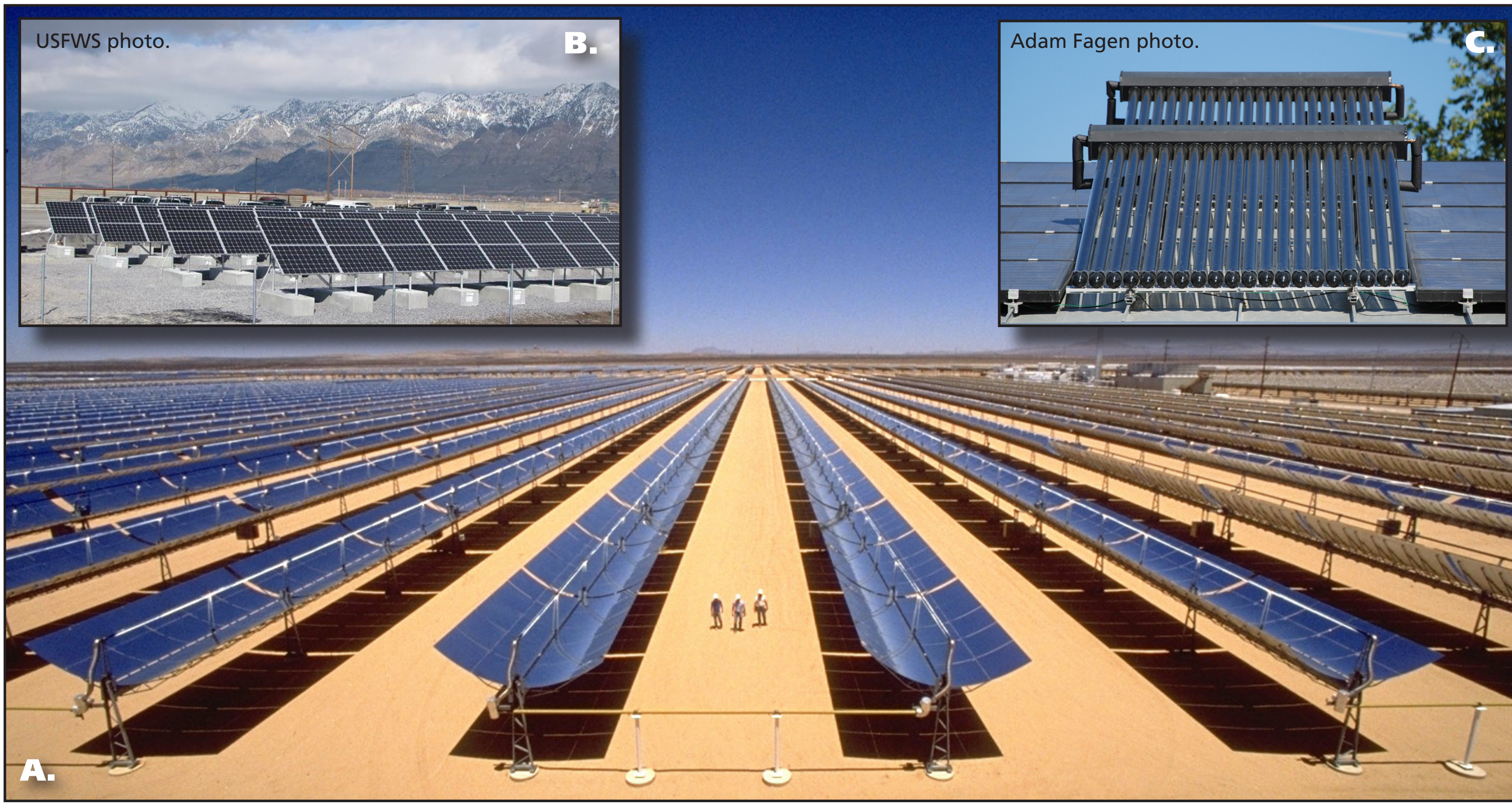
expanding rapidly. As of June 2011, worldwide capacity of wind-powered generators was 215 gigawatts. Several countries have already achieved relatively high levels of wind power penetration, such as 21% of stationary electricity production in Denmark, 16% in Spain, and 9% in Germany as of 2010. Closer to home, Iowa and South Dakota have achieved 20% of their electricity coming from wind power in 2011, - a first for the U.S.- and more projects are in the works. A utility system in Colorado even set a wind world-record on October 6th, 2011 when an Xcel Energy subsidiary, Public Service of Colorado, met 55.6% of the electricity demand of its 1 million customers solely from wind power, as reported in the Denver Post.

The American Wind Energy Association estimates that wind energy could provide 20% of America's electricity with turbines installed on less than 1% of the nation's land area. Within that area, less than 5% of the land would be occupied by wind equipment—the remaining 95% could continue to be used for farming, ranching, or other activities.

The solar power industry is also growing rapidly. *The National Solar Jobs Census 2011: A Review of the Solar Workforce* report contrasts a 2 percent net job loss in the fossil fuel power generation sector with a solar industry growth rate of 6.8 percent. The number of Americans working in the solar industry more than doubled to over 100,000 from 2009 to 2011, according to the Solar Energy Industries Association (SEIA), and now symbolically employs more workers than the U.S. steel production sector. Almost half of the solar firms in the report said they planned to hire more workers in the next



Wind power capacity has increased rapidly in the U.S. over the last decade Wikimedia graph.



People can harness power from the sun in three primary ways. Solar thermal power plants (A) essentially boil water or other liquids by concentrating the sun's energy. The resulting steam is used to turn a turbine to generate electricity. Solar photovoltaics (B) directly convert the sun's energy into electricity, and solar hot water systems (C) eliminate or reduce the need to heat water through the use of fossil fuels.

12 months, which should create an additional 24,000 new jobs. Through the third quarter of 2011, the U.S. solar market installed more than 1,000 MW of solar capacity, surpassing total 2010 installations of 956 MW, according to U.S. Solar Market Insight. This includes a record 449 MW installed in the third quarter alone (more new solar electric capacity than was added in all of 2009), and represents 140 percent growth over the same quarter last year. Even more growth is expected when numbers for the fourth quarter are released.

The U.S. solar market has grown to a $6 billion industry, up 67% from $3.6 billion in 2009. As a result of growing awareness about reliable, off-the-shelf solar technology, a recent renewable energy tax break program (Department of Treasury's 1603 grant program), and concerns about rising costs of conventional energy, deployment of solar energy has expanded greatly since 2005. Technological advances in the solar industry are happening every month or two in recent years. From thin solar films and solar paints to exploring the photovoltaic potential of materials like pyrite (fool's gold) and organic plastics, discoveries are being made that could potentially double solar panel electric output while simultaneously bringing down the cost of making panels. Technological feats such as these serve to highlight a recent study from Queen's University in Ontario that found cost estimates for solar technology used by energy analysts tend to be incorrectly high. With the technology changing so fast, many studies aren't reflecting the newest realities. For instance, the cost of solar panels has dropped 70% just since 2009, and panel productivity only declines 0.1% to 0.2% per year, not the 1% per year as used to be the case. Many commonly referenced studies have listed dollars-per-watt of electricity as high as $7.61, when according to the Queen's University study, the real cost in 2011 dollars is under $1 per watt.

The Department of Treasury's 1603 grant program has been integral to much of the growth in both the solar and wind industry, but Congress let it expire as of December 31st, 2011. Its expiration highlights a trend in declining federal support for renewable energy programs. The record shows that government support for new energy sources is much lower today than it has been at any other point in U.S. history, according to a September 2011 report analyzing U.S. energy incentives[6].

When it existed, the 1603 program supported more than 22,000 projects with an average cost of $65,000, and helped leverage $30 billion in private financing according to the SEIA. If extended, the 1603 grant program would not require new funding, as it relies on existing tax breaks extended to renewable energy through 2016, money that's already been accounted for in the federal budget. As of the time of this

[6] During the early growth of what would become the U.S. oil and gas industries, federal subsidies for producers averaged half a percent of the federal budget. The current support for renewables is about one-tenth of one percent of federal spending. Average annual support for the oil and gas industry has averaged $4.86 billion/yr between 1918 and 2009, compared to $3.50 billion/yr for nuclear (1947-1999) and $0.37 billion/yr (1994-2009) for all renewable energy sources combined. More can be found in the report: *What Would Jefferson Do? The Historical Role of Federal Subsidies in Shaping America's Energy Future.*

article, Congress is expected to reconvene the week of January 23, 2012 and will possibly take up the issue of the grant program again.

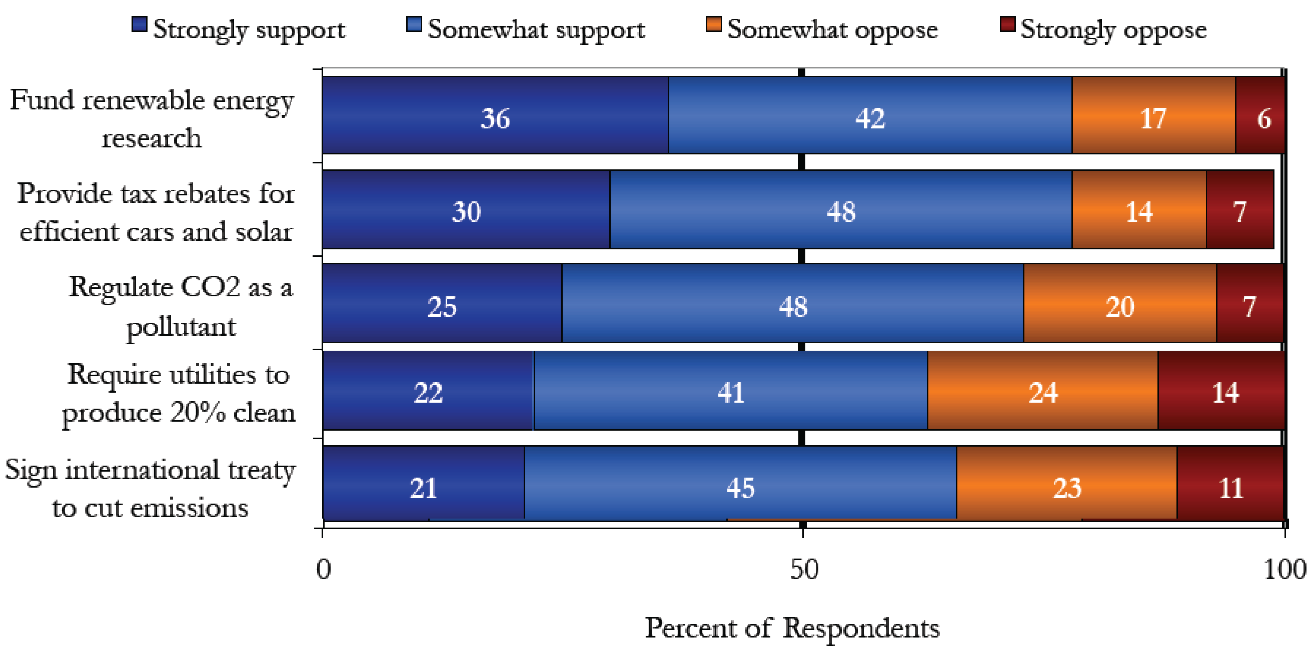
AN OUNCE OF PREVENTION: TAKING ACTION

As this article has clearly illustrated, the challenges surrounding climate change are many and can appear daunting at times. But climate scientists are clear: human activities are the leading cause of climate change, and we have yet to reach the tipping point when it comes to the direst of changes. This is good news. If climate change was being caused by some other phenomenon there would be little or nothing we could do to slow its progress. As the news about the incredible innovation in and the rapid growth of the renewable energy sector shows, even in spite of an overall drop in economic growth and an entrenched fossil fuel energy system, we are capable of making thoughtful choices about where our energy comes from. A recent survey entitled *Public Support for Climate & Energy Policies in November 2011* even shows that despite the ongoing concerns about the economy, 66% of Americans think that the U.S. should undertake a large (26%) or medium-scale efforts (40%) to reduce climate change, even if it has large or moderate economic costs. That same survey showed that most Americans are more willing than ever before to address climate issues head on. Public support for a variety of climate change and energy policies is high, even across party lines. Below are a few examples from the survey results:

- 70% of Americans think global warming should be a very high (12%), high (25%), or medium (33%) priority for the president and Congress.
- 90% of Americans say developing sources of clean energy should be a very high (30%), high (35%), or medium (25%) priority for the president and Congress.
- 60% of Americans support a $10 per ton carbon tax if the revenue were used to reduce federal income taxes, even when told this would "slightly increase the cost of many things you buy, including food, clothing, and electricity." This policy is supported by 48 percent of registered Republicans, 50 percent of Independents, and 74 percent of Democrats.
- 69% of Americans oppose federal subsidies to the fossil fuel industry, including 67%t of registered Republicans, 80% of Independents, and 68% of Democrats.
- 78% support research into renewable energy sources and tax rebates for people who purchase energy-efficient vehicles or solar panels.

Public support is also high for regulating CO_2 as a pollutant (73%), signing an international treaty to cut emissions (66%), and requiring electric utilities to produce at least 20% of their electricity from renewable energy sources, even if it costs the average household an extra $100 a year.

Scientists cannot be more clear that the time to act is now, and with public support at very high levels it is the perfect time to do just that. Today, the U.S. still generates half of its electricity via coal burning plants and is one of the world's largest emitters of greenhouse gases per person. How we and other countries around the world choose to get our energy over the coming years and decades will undoubtedly be the primary factor in determining the ultimate degree of global climate change we and future generations will have to cope with.



Results of recent national polls clearly show that Americans are ready to take large steps in order to reduce our impacts on climate change. Poll results are from *Climate change in the American Mind: Public support for climate & energy policies in November 2011*.

The Forest Center is a program facility building at Marsh-Billings-Rockefeller NHP that is solar powered, heated with sustainably grown park wood, and U.S. Green Buildings Council Platinum LEED certified. The building is part of an impressive sustainability portfolio that helps the park achieve Climate Friendly Park status. The park also won several awards in March 2011 from the Sustainable Operations and Climate Change (SOCC) Branch of the Park Facility Management (PFMD) division. Ed Sharron photo.

THE NATIONAL PARK SERVICE RESPONSE TO CLIMATE CHANGE

The National Park Service is striving to lead by example with its response to the climate change challenge, which involves re-examining policies and long-range planning, implementing sustainability practices, and preparing for adaptation. The Inventory & Monitoring program is just one of the many service-wide initiatives the NPS has that will help it reach its goals. The Park Service recognizes that climate change is a complex issue, and responding to it requires coordinated action in long-term planning and policy, and that collective action should promote national and global leadership. With that in mind, the NPS response to climate change is coordinated around four main pillars of emphasis that include:

- **Science** to help parks manage climate change
- **Adaptation** to an uncertain future
- **Mitigation** and reduction of the carbon footprint of Parks.
- **Communication** to the public and NPS employees about climate change.

The I&M program is a core part of the first pillar, and parks will continue to use the information they receive from monitoring activities to help guide their adaptation strategies. Field measurements from National Parks are significantly contributing to the detection of ecological changes attributed to climate change. Examples include studies showing the winter ranges of numerous bird species having shifted an average of 0.3 ± 1.5 miles per year northward from 1975 to 2004 in 54 National Parks across the country. Conifer tree background mortality has increased in Mount Rainier (Washington), Olympic (Washington), Sequoia (California), and Yosemite (California) National Parks. Boreal conifer forests have shifted into the tundra environments in Noatak National Preserve (Alaska) and into the alpine biome in Yosemite National Park.

For mitigation, the Climate Friendly Parks program (CFP) is one component of the forthcoming NPS Green Parks Plan, an integrated approach to address climate change through implementing sustainable practices in park operations. The plan will set ambitious goals for greenhouse gas emission reductions, much of which can be accomplished through energy conservation and reduction in energy use, recycling, composting, technology upgrades and other actions that CFP Member Parks address in their climate action plans. Through demonstrating how they are reducing their own carbon footprints, National Parks are ideally positioned to educate visitors about climate change and sustainability. Fossil fuel emissions inventories from the first 18 parks in the CFP program showed that their emissions mostly came from park visitor vehicle emissions, and many parks now offer alternatively fueled visitor buses and shuttles. Several NETN parks have either already become, or have taken the first steps to becoming climate friendly parks. Acadia and Saint-Gaudens are in the process, and Boston Harbor Islands and

The CCRP website contains details on the programs initiatives and goals.

Marsh-Billings-Rockefeller have both become fully certified CFP parks. Take a look at their pages on the CFP website (http://www.nps.gov/climatefriendlyparks) to learn more about their sustainability goals and strategies.

The CFP program is part of the NPS's overall Climate Change Response Program (CCRP) which "works to foster communication, provide guidance, scientific information, and recommendations that support stewardship actions to preserve our natural and cultural heritage from the detrimental impacts of global climate change".

The CCRP is helping to implement the Department of the Interior's climate change response initiative with a strategic, adaptive, and collaborative response to climate change that supports the mission of the parks and the values of the public.

The cultural and natural resources the NPS watches over are among the most valuable and vulnerable in the country, and they also possess the ability to teach the parks themselves and the public about a changing planet. In the past, many parks have strived to recreate and preserve "natural" or "historical" conditions, but these goals may be more difficult or impossible to maintain under many climate change scenarios. For example, Glacier National Park's glaciers are expected to disappear over the coming decades, Joshua Tree National Park's Joshua Trees are also threatened, and even the shapes of coastal parks like Boston Harbor Islands and Acadia will be modified with rising sea levels. The whole concept of "naturalness" becomes unclear in the Anthropocene era where human activities play the primary role in shaping global climate and ecology.

Monitoring resources in National Parks helps answer the basic management question of whether or not a resource is changing, while attribution can guide resource management toward the predominant factor that is causing change. Whereas in the past resource managers have developed measures that address urbanization, invasive species, grazing, fire, timber harvesting, and other factors, changes from climate change will require new adaptation measures.

This article began with a George Perkins Marsh quote, so it is fitting that it should end with one as well. Marsh had a keen and piercing insight into the unintended consequences of humanity's actions upon the Earth. He looked beyond the obvious and up-front and saw some of the possible outcomes, both negative and positive. He once said: "Sight is a faculty; seeing, an art." Anyway you look at it, with climate change the National Park Service faces challenges ahead. But a different perspective shows that the NPS also has the chance to embrace an equally as large opportunity to lead by example, to educate their visitors about climate change causes and effects, and to provide for the enjoyment of its entrusted resources for current and future generations.

NETN Science Communication Specialist Ed Sharron may be available to come to network parks, communities, or schools to talk with park staff, the public, and students about climate change. He can offer a customized 45 minute to 2 hour presentation on climate change and what the NPS/NETN are doing on the mitigation/monitoring front. Plenty of time for questions and discussion are also built into the program. Please contact him at **ed_sharron@nps.gov***, or 802-457-3368 ex 23 to discuss the details or set up a possible visit.*

NETN Staff includes:

Brian R. Mitchell
Program Manager
Brian_Mitchell@nps.gov

Fred Dieffenbach
Environmental Monitoring Coordinator
Fred_Dieffenbach@nps.gov

Adam Kozlowski
Data Manager
Adam_Kozlowski@nps.gov

Kate Miller
Plant Ecologist
Kathryn_Miller@nps.gov

Aaron Rinehart
Biological Science Tech
Aaron_Rinehart@nps.gov

Kevin Morris
Assistant Data Manager - Biologist
Kevin_Morris@nps.gov

Jonathan DeDell
Data Technician Intern
Jonathan_DeDelli@nps.gov

Ed Sharron
Science Communication Specialist
Ed_Sharron@nps.gov

Bill Gawley
Biologist (Air / Water / Data Mgmt)
Bill_Gawley@nps.gov

Brian Schuetz
Hydro Technician
Brian_Schuetz@nps.gov

Beth Arsenault
Physical Science Tech
Beth_Arsenault@nps.gov

Jesse Wheeler
Biological Technician / Crew Leader
Jesse_Wheeler@nps.gov

Northeast Temperate Network
54 Elm Street
Woodstock, Vermont 05091
802-457-3368
http://science.nature.nps.gov/im/units/netn/