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CLIMATE CHANGE IN THE ADIRONDACKS

JERRY JENKINS, NOVEMBER 2008
THE WILD CENTER & THE WILDLIFE CONSERVATION SOCIETY

Mountain forest, Keene Valley

This document is a brief survey of how climate change may affect the Adirondacks. It assumes that the reader knows that climate change is a formidable world problem. It ask how much that problem may affect the Adirondacks, and what we can do in response.

Climate change may be approached in many ways. We chose to approach it scientifically and graphically. We try to tell story as exactly as possible, with numbers and diagrams. We assume that facts always help and hope that readers may find some reassurance in approaching a frightening subject calmly and quantitatively.

The document was commissioned by the Wild Center in Tupper Lake, New York, and prepared for their Adirondack climate change conference (*Land of Opportunity, The American Response to Climate Change)* in November, 2008. It was prepared by the Wildlife Conservation Society Adirondack Program in Saranac Lake, New York. Leslie Karasin managed the project. Jerry Jenkins wrote, illustrated, and designed the document and was responsible for the quantitative analyses. Elizabeth McKenna helped with research.

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This is the first edited draft of this document, 17 November, 2008. It has not been peer reviewed. We hope to place a peer-reviewed and revised version on the web in December and to have an enlarged version in print in summer, 2009.

We thank Stephanie Ratcliffe of the Wild Center for initiating the project, and Charley Canham, Howard Fish, Kate Fish, Kara Page, and Ross Whaley for advising us during its preparation.

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Units and Accuracy

All temperatures are in degrees Fahrenheit. One degree Celsius = 1.8 degrees Fahrenheit; a temperature increase of 5 degrees C is 9 degrees F.

Carbon can either be measured in tons of carbon (C) or tons of carbon dioxide (CO_2). When discussing fossil fuel reserves carbon is the more logical, since fossil fuels don't contain carbon dioxide. When discussing emissions, carbon dioxide is the more usual, since that is what is actually emitted. One ton of carbon is 3.67 tons of carbon dioxide; 1 ton of carbon dioxide is 0.273 tons of carbon.

Energy consumption, also called power, is the amount of energy used per unit of time, and is measured in watts. Because a watt is a small unit, we often use megawatts (million watts), gigawatts (billion watts) and terawatts (trillion watts).

To convert other measures of energy consumption to watts note that:

1 million BTUs per year = 33.3 watts

1,000 kilowatt hours per year = 122 watts

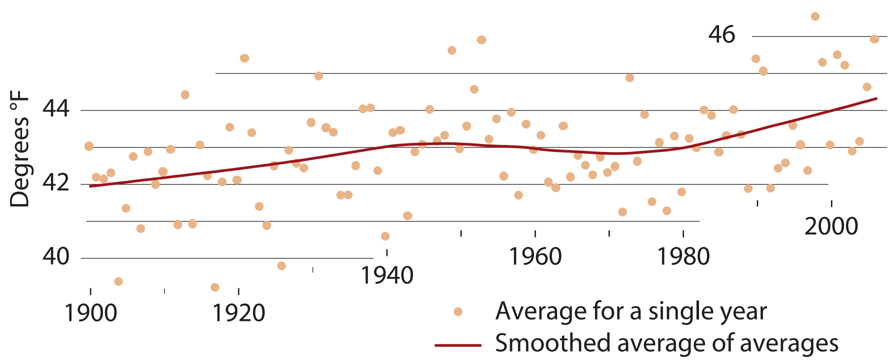
1,000 gallons gasoline per year = 4,300 watts

1 cord of wood per year = (very approximately) = 770 watts

Also keep in mind that when we say, for example, that a family's total energy consumption for heating is 5,000 watts, this is the average power that they use in the course of a year and not the power at any particular moment. When the stove is off they are not using any power at all. When it is on, they might be using 20,000 watts.

The numbers in this report are attempts to generalize about how much energy people are using and how fast the planet is warming in response. They sound accurate, but of course they are not. Be aware as you read that the numbers are estimates, and that different sources will give different estimates. We think that the estimates are consistent enough to be worth citing, and the story they tell seems to be true in broad outline, and independent of the details. But please note that we do not necessarily believe all the details, and neither should you.

AVERAGE ANNUAL TEMPERATURE, 19 NORTHERN NEW YORK HCN STATIONS



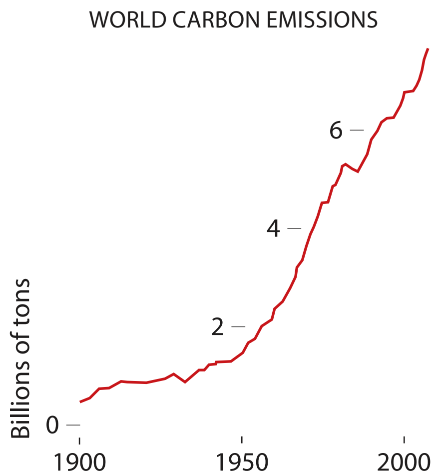
The yearly temperatures of northern New York, obtained by averaging the 19 stations of the United States Historical Climatology Network, vary within a six-degree band and do not show an obvious pattern. But when they are smoothed by averaging the averages, a clear pattern emerges. The smoothed temperatures rose slowly in the first part of the century, leveled off in the middle, and rose again, more rapidly, after 1970.

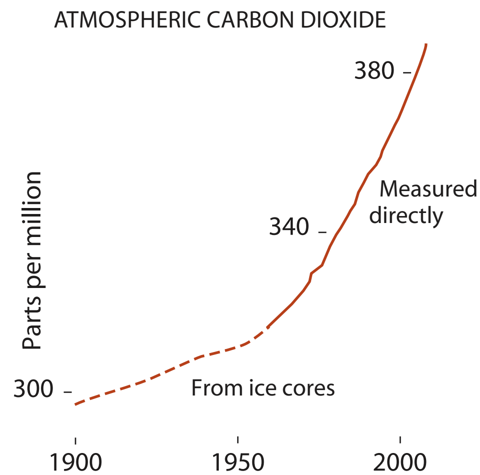
The Adirondack temperature increases are part of a world-wide temperature increase, and have the same cause: increased amounts of carbon in the atmosphere, from fossil fuels and land-use changes.

FLOWS OF CARBON INTO THE ATMOSPHERE

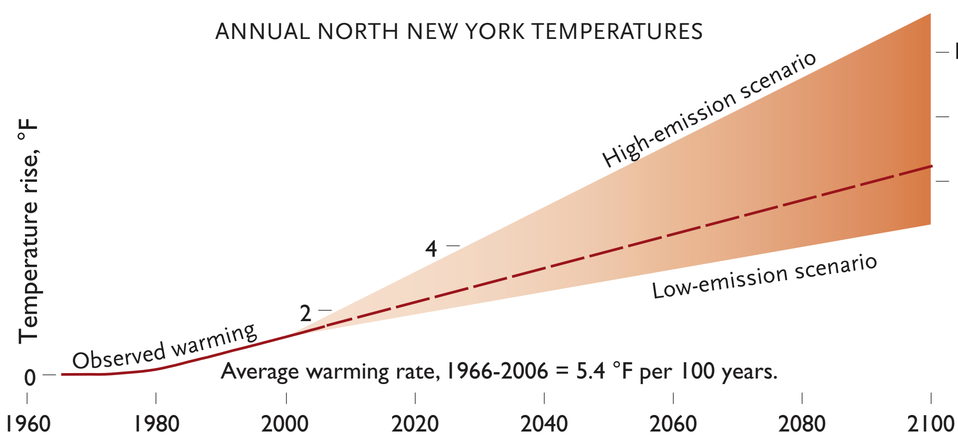
In the 1990s, humans released about 6.4 billion tons (GT) of carbon a year into the air by burning fossil fuels and another 1.6 billion tons by converting natural vegetation to farms and settlements. About half of the carbon was removed by forests and oceans. The rest stays in the atmosphere.

The carbon in the atmosphere is in the form of carbon dioxide, CO_2. Carbon dioxide acts as a blanket, trapping heat that would otherwise leave the earth. The more of it there is in the atmosphere, the hotter the earth will be.





World carbon emissions rose rapidly after 1950 as the human population grew and the world industrialized. Atmospheric carbon dioxide concentrations, which are the result of carbon emissions, rose with emissions. Adirondack and world temperatures, delayed because the climate system takes time to respond, lagged about 30 years behind carbon dioxide concentrations and now are rising rapidly.



Just how much they rise will depend on how much fossil fuel we burn. Computer models adapted by the Northeast Climate Impacts Assessment predict that if we lower world carbon emissions immediately, northern New York will warm about 5 degrees from 1960 levels in the coming century. If, on the other hand, we continue to use large amounts of fossil fuels to the middle of the next century or beyond, Northern New York will warm about 11 degrees from 1960 levels.

Since currently North New York temperatures are already rising at a rate of 5 degrees per century, and since the rate of rise will accelerate as carbon dioxide concentrations continue to rise, it seems likely that, even if we reduce world emissions immediately, we will see a rise of over 6 degrees in the next century.

The longer we delay in reducing emissions, the worse the prospects get (pp 18-19). If fossil fuel consumption rises for thirty years more before leveling off, we

Osgood River, March, 2008

could see a temperature rise of 10 degrees more in the next century. If it rises for 60 years more, we could add another 10 degrees more in the century after this one.

Because the Adirondacks are a northern landscape with a northern culture, temperature rises of this magnitude will change them greatly. With five to ten degrees of rise, we will lose much of our ice and snow. With them will go the cultures, human and wild, that need cold winters. Winter sports, and the winter economy based on them, will decline. Boreal landscapes, like these open meadows along the Osgood River, will turn to woods or thickets. Boreal animals like the marten and loon, and boreal plants like the bog aster and purple saxifrage, will decline or vanish.

With ten to twenty degrees of temperature rise, the Adirondacks will become unrecognizable. Ice and snow will be gone. Our winters will be warm, our summers subtropical. Over half of our birds and trees will be beyond their current climatic limits. Our forests will be in severe decline, and may have become carbon sources, adding carbon to the atmosphere rather than removing it.

Further, by the time Adirondack temperatures have risen 10 degrees , world temperatures will have risen 6 degrees, and the world will less habitable and more dangerous. Seas will be rising, storms and droughts intensifying, and human and natural ecosystems collapsing. The pace of change will be accelerating, and feedbacks in the climate system may make further change inescapable.

These predictions come from the Intergovernmental Panel on Climate Change. They do not come from an alarmist fringe, but rather from the consensus report of the largest international scientific body ever convened on our planet.

If they are even approximately correct, they suggest a simple conclusion: *For the sake of ourselves, the Adirondacks, and our planet, we must do everything that we can to keep the rise in world temperatures less than 6 degrees.*

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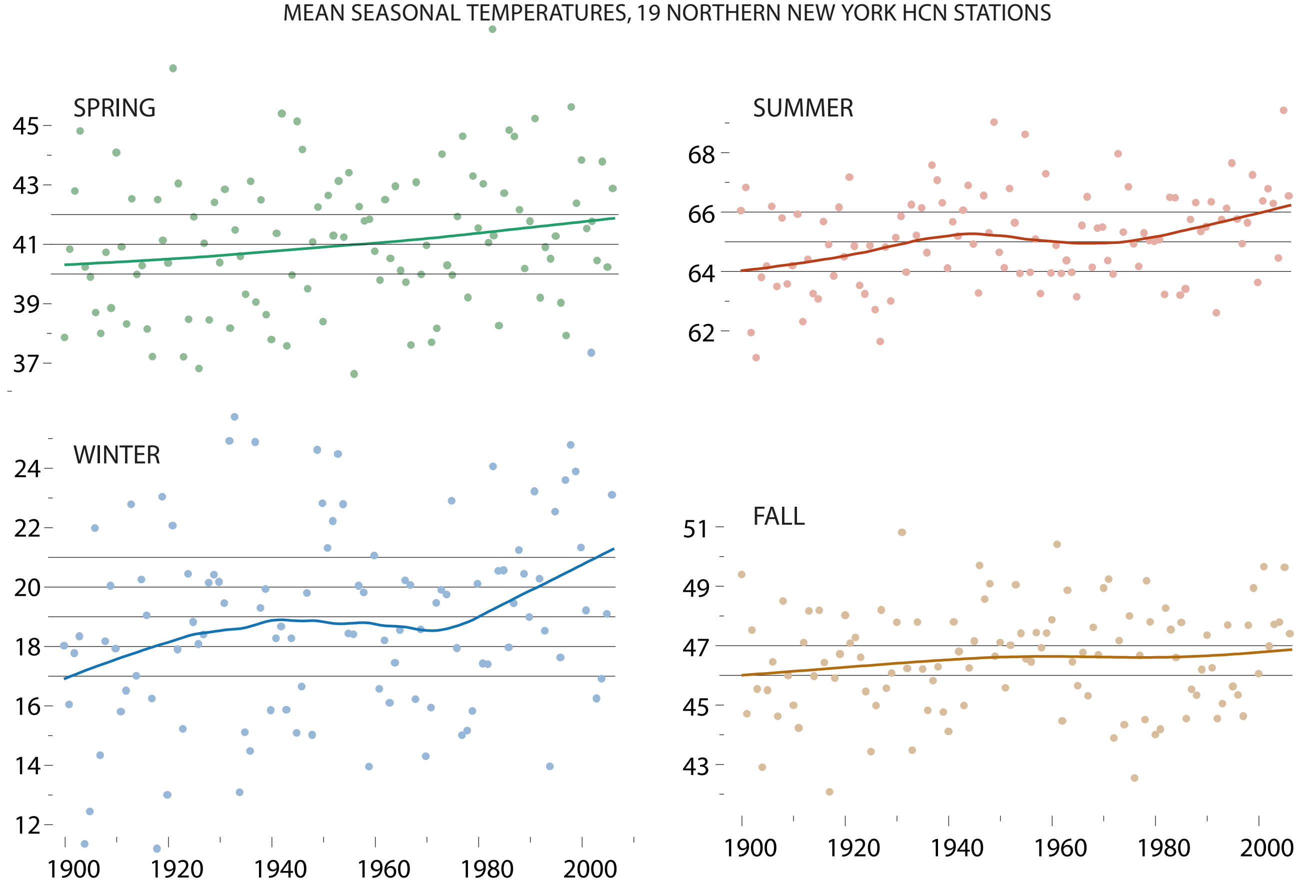
2 THE WEATHER IS CHANGING

Currently the Adirondacks are experiencing the beginnings of climate change: warmer summers and winters, earlier springs, longer growing seasons, and more rainfall. These changes, because of lags in the climate system, probably reflect the carbon emissions of several decades ago. Because emissions have increased since then, they are only a taste of the changes that are likely coming.

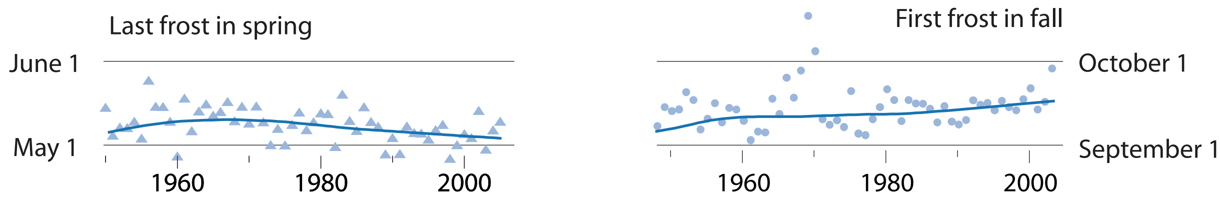
MEAN SEASONAL TEMPERATURES, 19 NORTHERN NEW YORK HCN STATIONS



Over the last century northern New York spring and summer temperatures have increased by about 2 degrees, and winter temperatures by about 5 degrees. Fall temperatures have shown a slight increase, but it is not statistically significant.

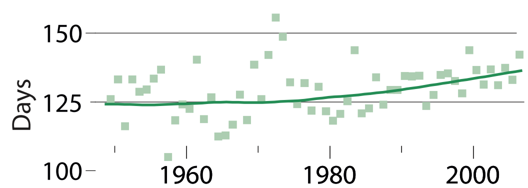
The warming has accelerated since 1970. The summer warming rate, from 1966 to 2006 is 3.5 degrees per century. The spring warming rate for this period is 4.4 degrees per century, and the winter warming rate is 8.8 degrees per century.

FIRST AND LAST FROSTS



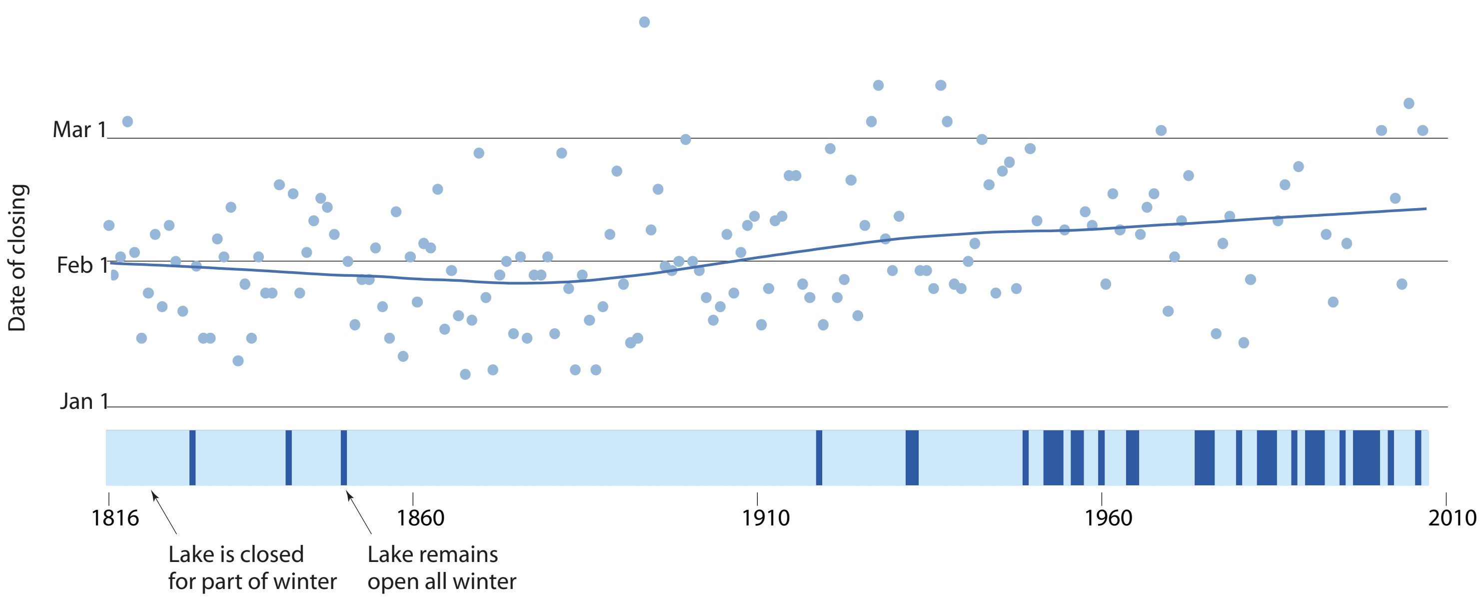
As a part of the general warming, the last frosts are coming about a week earlier in spring and the first frosts about a week later in the fall than they did fifty years ago. As a result, the average growing season has lengthened by two weeks.

GROWING SEASON



The freezing and thaw dates of lakes have also changed. Lake Champlain, which is large and so takes an extended period of cold weather to freeze, only remained open three times between 1816 and 1916. With the climate warming, its freeze-up date is 10 days later than it used to be, and it has remained open 20 of the last 47 winters.

YEARS WHEN LAKE CHAMPLAIN WAS CLOSED BETWEEN BURLINGTON AND PLATTSBURGH



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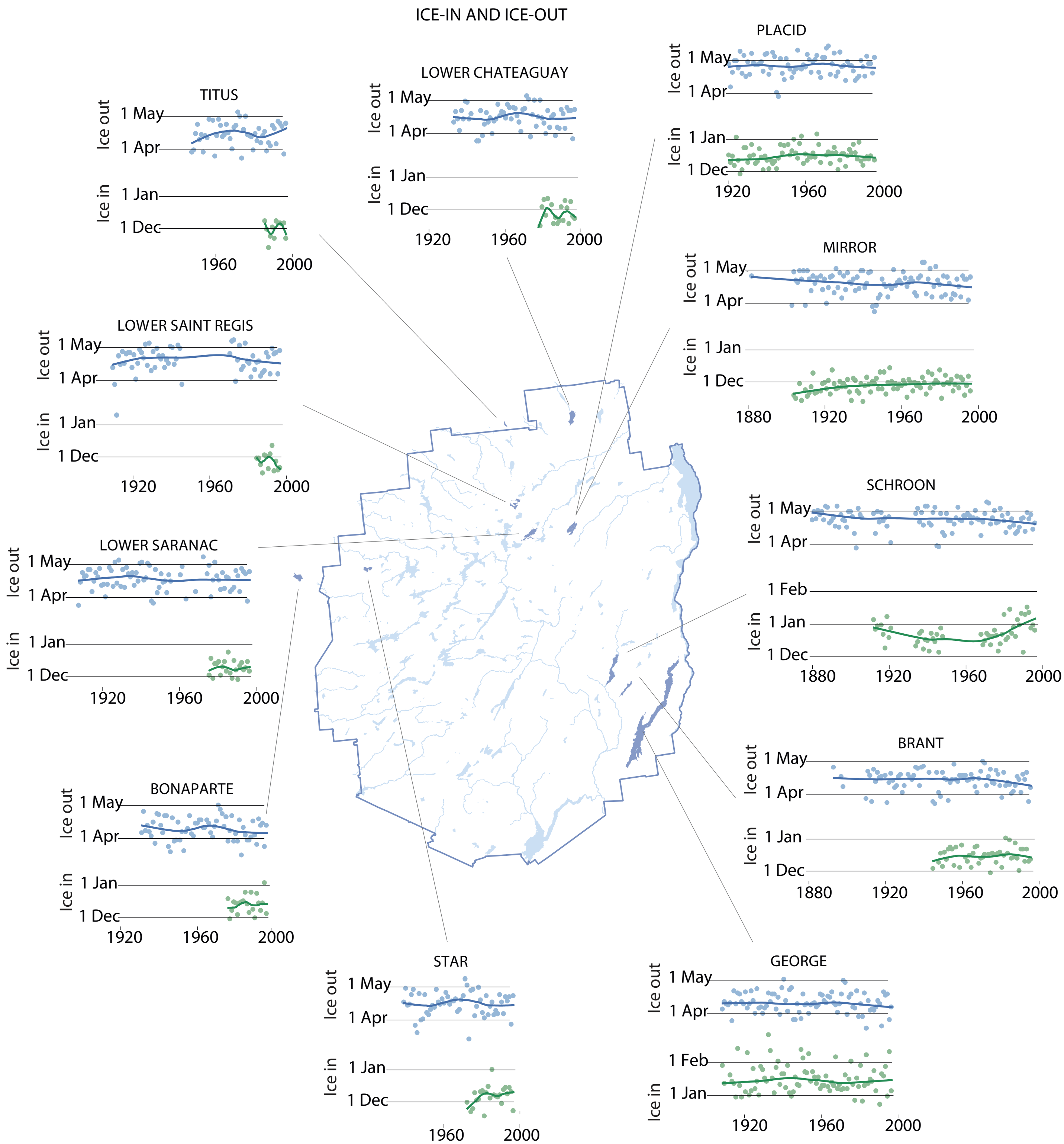

Other Adirondack lakes show similar patterns but, because they are smaller and easier to freeze, most still freeze every winter. The southern and peripheral lakes are tending to freeze later and thaw earlier. The northern and more interior ones have changed little.

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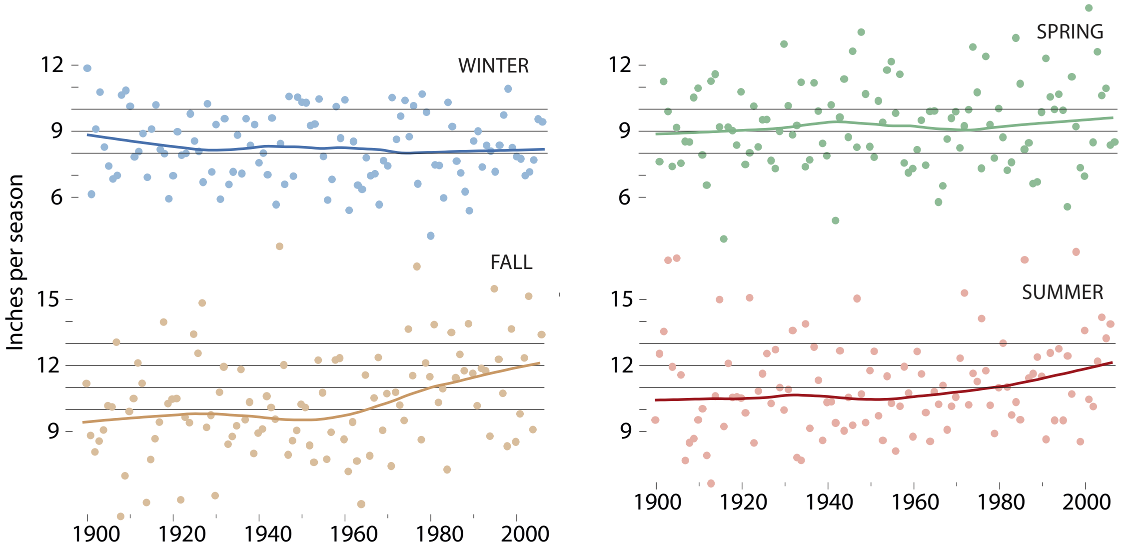
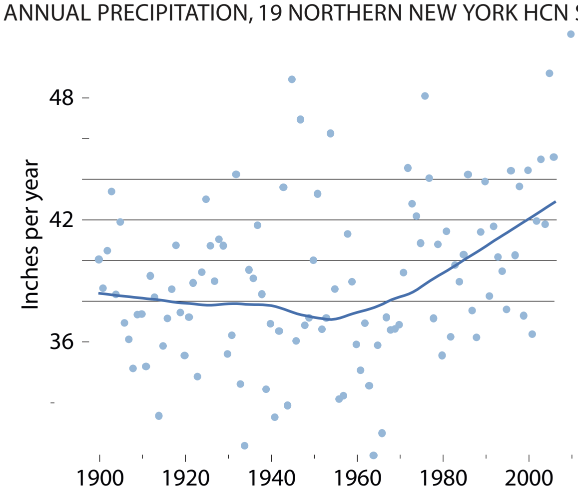
Changes in precipitation have been smaller than changes in temperature, and do not seem to accord with what regional climate models are predicting.

AVERAGE SEASONAL PRECIPITATION, 19 NORTHERN NEW YORK HCN STATIONS



Climate models suggest that we will have wetter winters and dryer summers. Instead, over the last fifty years, our summers and falls have gotten wetter and our winters have hardly changed.

AVERAGE ANNUAL PRECIPITATION, 19 NORTHERN NEW YORK HCN STATIONS



As a result, total precipitation has increased, and is about 13% greater than it was in 1960.

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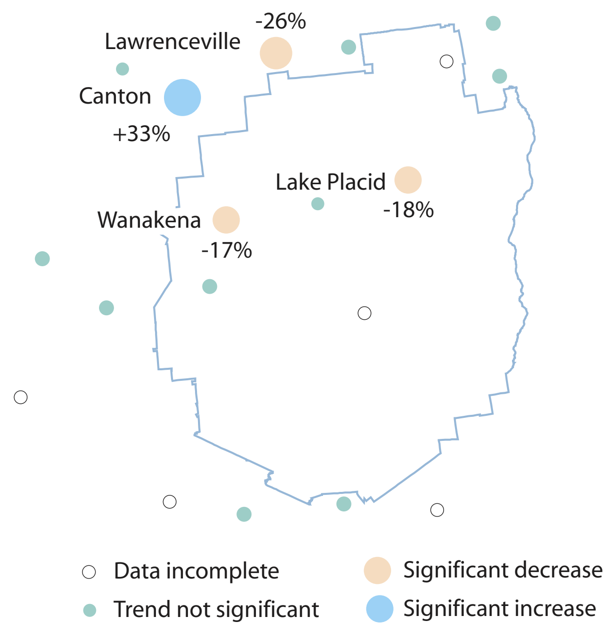
The records of snowfall are less complete than those of total precipitation and, because there are few stations in the interior of the park, are probably not representative of the Adirondacks. The average snowfall, for the stations for which we have reasonably complete data, shows no trend from 1948 to 2005. Three stations, shown on the map, have shown statistically significant decreases, and one has shown a significant increase.

CHANGES IN SNOWFALL AT HCN STATIONS, 1948–2005



Ice pack along the Hudson River in Warrensburg, March, 2008

Lake Champlain at ice-out, 29 March, 2008

Summarizing: Northern New York weather changed relatively slowly for the first two-thirds of the twentieth century, and much faster for the last third.

The greatest change has been in temperature. In the last forty years, winter temperatures have warmed at a rate of 8.8 degrees per century, which is what computer models predict for the coming century under a medium-emission scenario. Spring and summer temperatures have warmed at about half this rate, and fall temperatures have shown little change.

This warming has had conspicuous effects. Winters now come later and end sooner than they used to. The growing season is about two weeks longer. Some lakes, especially near the edges of the park, are freezing later and thawing sooner than they used to. Lake Champlain, which used to freeze almost every year, now remains open between Burlington and Plattsburgh two winters out of five.

Rainfall has also changed. Formerly we got roughly equal amounts of precipitation in every season. Now our summers and falls are definitely wetter, and our winters, if anything, slightly dryer. As a result, the average contrast between the seasons has increased. The total yearly precipitation has also increased by 5 inches, but the percentage increase—13%—is small and hard to notice.

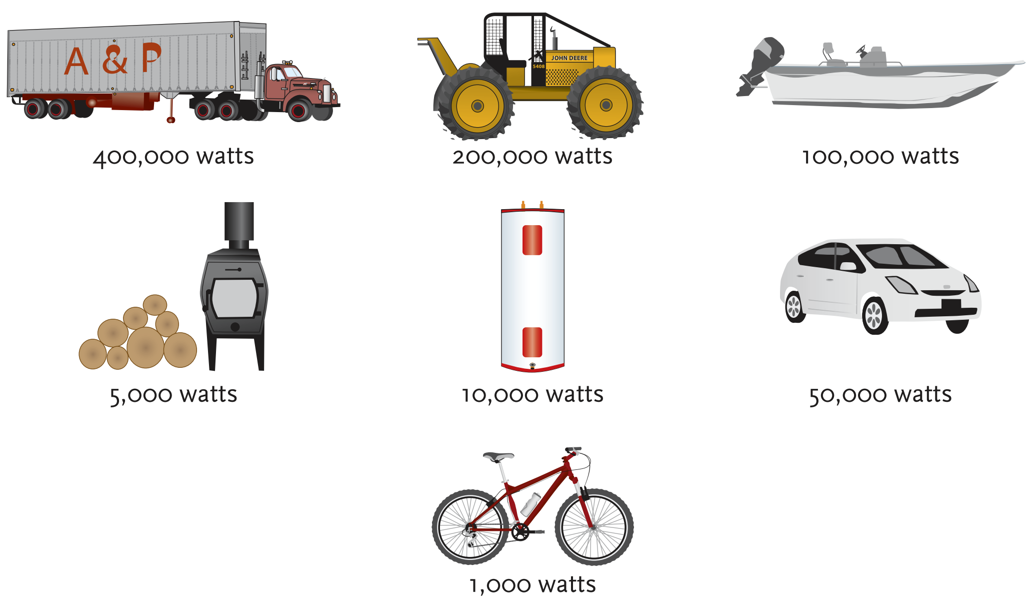
Overall snowfall, as best we can judge from the records we have, has not changed much since 1948. Three individual stations show significant decreases, one a significant increase, and 10 others show no clear pattern.

Taken together, the northern New York records show that the kind of warming we experienced in the last century—about 2 degree in 100 years—has had perceptible effects but does not represent a major shift in climate. The current warming rates is twice as fast as that of the last century, and may be five or ten times as fast before this century is over. The changes it causes will be correspondingly greater and, in all likelihood, much less benign.

3 THE CLIMATE PROBLEM IS AN ENERGY PROBLEM

The climate problem is caused by the carbon we are releasing into the atmosphere. Most of the carbon comes from the burning of fossil fuels, principally, coal, oil, gasoline, and natural gas. We burn these fuels to get energy, and the climate problem will only be solved if we can use less energy or produce energy without using fossil fuels.

MAXIMUM POWER USED BY HEATERS & VEHICLES



Getting rid of fossil fuels will not be easy. They are cheap and convenient and, used in engines and generators, supply us with a level of power that humans have never had before.

Our own bodies can generate a few hundred watts of power.* With draft animals we can extend this to a few thousand watts, and with small wind-powered and water-powered machinery to a few tens of thousands of watts.

Combustion engines allow us to much higher. A small car has a maximum power of 50,000 watts and a small boat or airplane a maximum power of around 100,000 watts Common heavy vehicles like trucks and skidders have powers of several hundred thousand watts. A Boeing 747, one of the most powerful machines in existence, uses something like 100 million watts to take off and half that to cruise.

Through machines like this, we have remarkable levels of power at our disposal. This power builds our buildings and highways, runs our farms, provides the goods we use, and keeps us healthy, warm, safe, and mobile. It is, in short, a necessity and a blessing.

But it is a blessing with a dark side. High-powered machines require concentrated fuels, and fossil fuels are the only concentrated fuels that are generally available. Our high-powered lives thus tie us to carbon-based fuels, and these, in turn, to the emissions that are changing our climate.

* This is the input power, the rate at which we burn food or the machine burns fuel.

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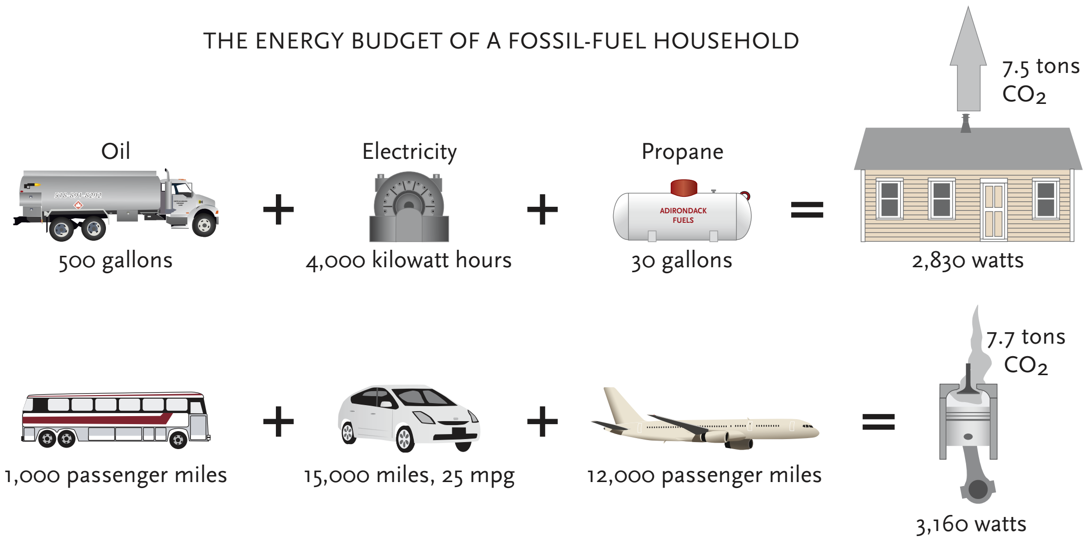
As an example of the pervasiveness of fossil fuels, consider the energy budget of an ordinary Adirondack household. The numbers are made up, but are similar to those we gathered from several Adirondack families.



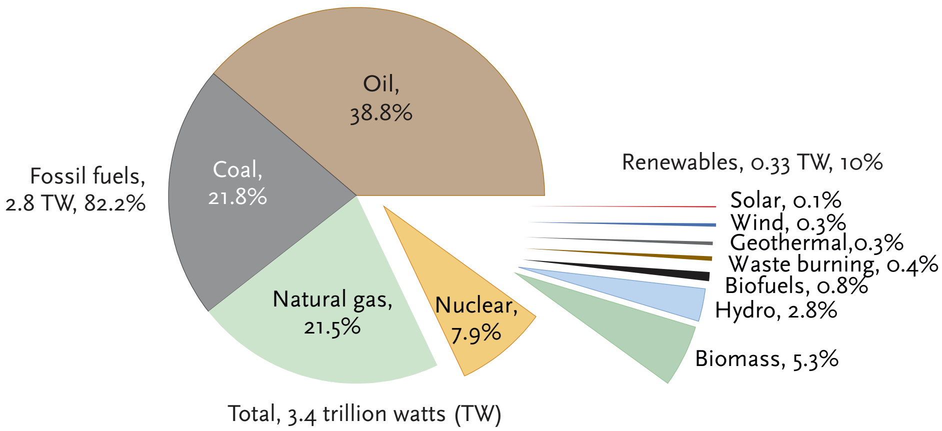
This household heats a medium-sized house and travels a total of 28,000 miles a year. To do this it uses a total of 6,000 watts of power, all derived from fossil fuels. This requires a total of about 4 tons (1,300 gallons) of fossil fuels, and generates about 15 tons of carbon dioxide. This does not include the fossil fuels used to produce and deliver their food and the other things they buy, which we have no way of estimating.

A striking feature of this energy budget, and of the Adirondack energy budgets on which it is based, is that half the energy is used for transportation. This would have been very different a hundred years ago. Adirondackers of a century ago, living in uninsulated houses and traveling by train or stage, would have used large amounts of energy for heating and very little for transportation. Probably no generation prior to our own traveled as far in their lives as we do, or emitted as much carbon doing it.

The United States is a Fossil Fuel Nation

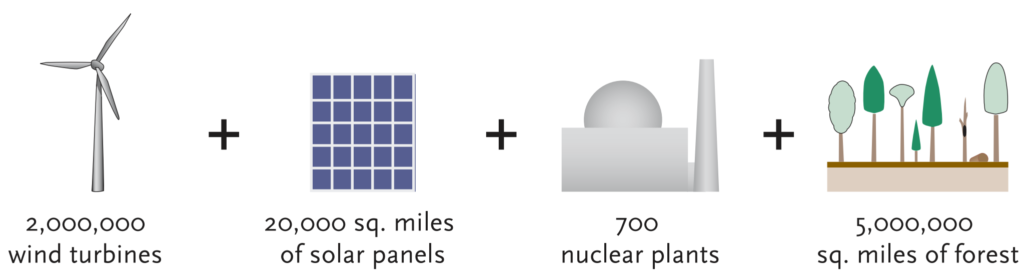
The United States is, from an energy point of view, a large collection of fossil-fuel households. Eighty-two percent of its energy comes from fossil fuels, 8% from nuclear (which is carbon-free but nonrenewable) and 10% from renewables. The largest renewables, hydropower and biomass fuels, are also the oldest. The modern renewables, solar, wind, geothermal heat and biofuels, are relatively small, and supply only 1.5% of our total energy consumption.

U.S. ENERGY SOURCES, 2006



Two of the reasons that the renewables are a relatively small part of our energy picture is that they are expensive and tend have large footprints. Solar, hydro, and biofuel energy are more expensive than fossil fuel energy. Biofuels and biomass require large areas of forest, hydro requires large reservoirs, and wind turbines and solar panels require more area than fossil-fuel generators of similar power.

RESOURCES REQUIRED TO REPLACE 2.8 TRILLION WATTS OF FOSSIL FUELS



If we are thinking about what a low-emission future might look like, we have to take the issues of footprint and cost very seriously. Suppose we imagine a thirty-year plan to replace the 2.8 trillion watts of U.S. fossil fuel use with an equal mixture of nuclear, solar, biofuels, and wind. We would need space for 2,000,000 wind turbines, which would cover the United States (including Alaska) with two wind turbines on every three square miles of land. We would also need an area a bit smaller than West Virginia for solar panels. We would need to site 700 new nuclear plants (currently there are 104 in the United States.) And we would need to harvest 5,000,000 acres of forest, which is more than the forest area of the United States and Canada combined. The total cost would be in the tens of trillions of dollars.

None of this except the forests is impossible. But it is large scale. Fossil fuels are deeply entrenched in our lives and economy. Ending our dependence on them will require a generation or more of focused national and individual effort. It will change our lives and landscape, and not necessarily in ways that those of use who are advocating this course find it comfortable to think about.

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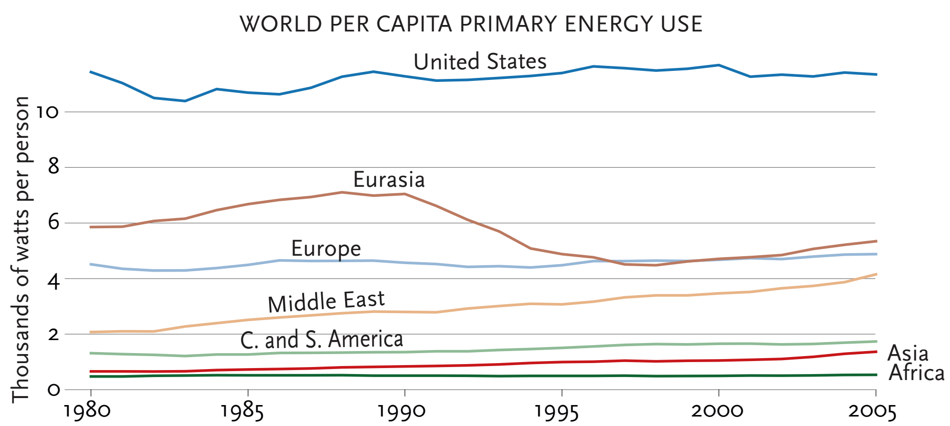
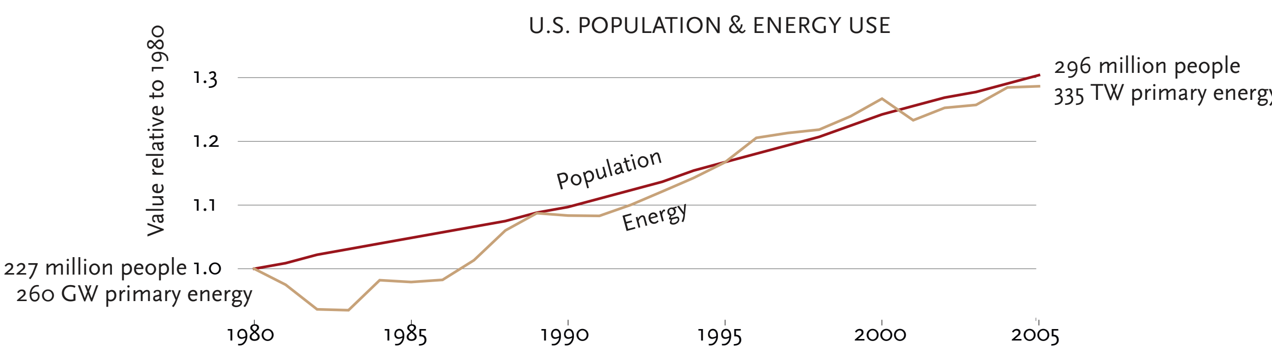
Energy Use is Driven by Population and Consumption

World energy use is increasing, and with it world carbon emissions. The increase has two causes, population and consumption per person.

Consumption per person is the less important. In much of the world, consumption per person is nearly constant. It is increasing in Asia and the Middle East. In the Middle East this is not very important because there are not many people there. In Asia it is because there are.



Population is much more important. In the United States and many other countries, population and energy have been rising together for much of this century.



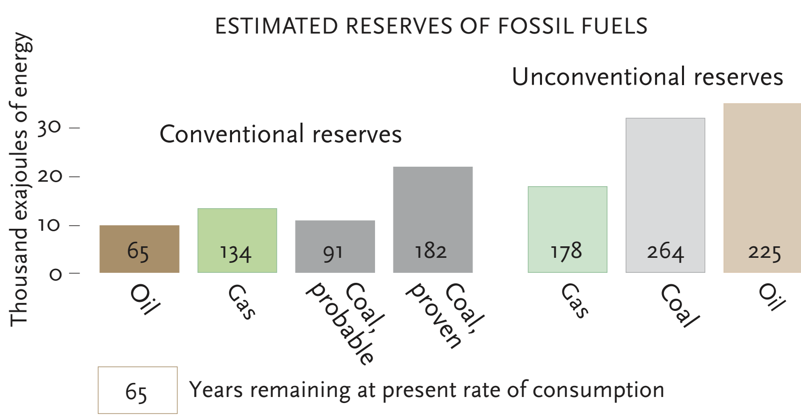
The continuing increase in population makes the climate problem, like many other problems, more difficult. At present rates, the world population will grow by 2.5 billion people in the next 40 years. Most will be in Asia, and most will, by American standards, not use very much energy. But they will use some, and that some, if it requires fossil fuels, will release billions of additional tons of carbon and accelerate the pace of climate change.

Crane Mountain, Johnsburg

4 HOW MUCH COULD THE ADIRONDACKS CHANGE?

The Adirondacks are already warming, and will certainly warm more over the next century. The graph on p. 4 suggests that 5 to 11 degrees of warming may occur by 2100. Here we look at that prediction in more detail, asking what determines the range of temperatures and how far temperatures will rise before they eventually stabilize.

Because temperatures will only stabilize when we stop adding fossil fuel carbon to the air, this question is equivalent to asking how long we will continue burning fossil fuels.



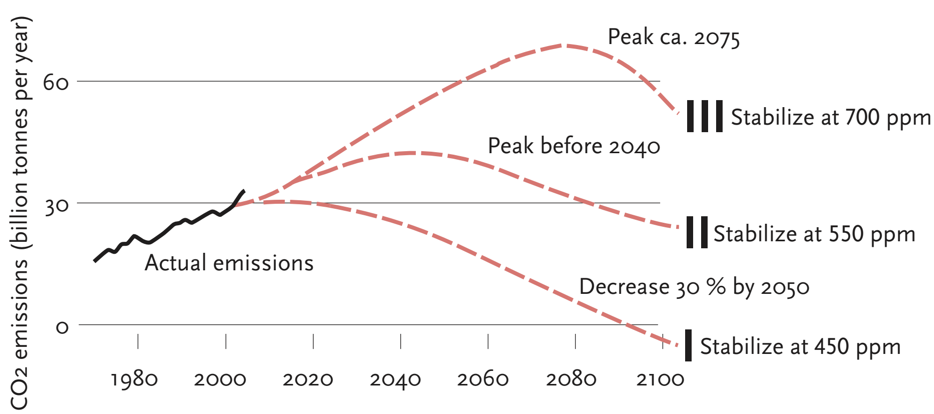
Conventional reserves are those that can be mined economically with standard techniques. *Unconventional* reserves, like oil shales, need special and hence more costly extraction methods.

If geology and economics were the only considerations, the answer might be for a century or more. The conventional reserves of all fossil fuels except oil will last for over a century at the present rates of consumption. Adding the unconventional (= less accessible, more expensive) reserves, there is enough for three centuries.

Thus if fossil fuel use declines in the following century, it will be because the human race has chosen to get its energy from other sources, and not because the supply of fossil fuels has run short. Since another century of uncontrolled fossil fuel use may be very dangerous for the Adirondacks and for the planet, we hope this is what happens.

The final warming that we will get depends on *stabilized CO_2 level*, which is the amount of CO_2 in the atmosphere when we stop adding to it. This in turn depends on how soon we start to reduce CO_2 emissions. Here are three scenarios, among many possible ones. They span the range from **I**, which near the best that we might reasonably hope for, to **III**, which was the worst that the scientists of the Inergovernmental panel on climate change were willing to think about in 2002.

THREE SCENARIOS FOR STABILIZING CO_2



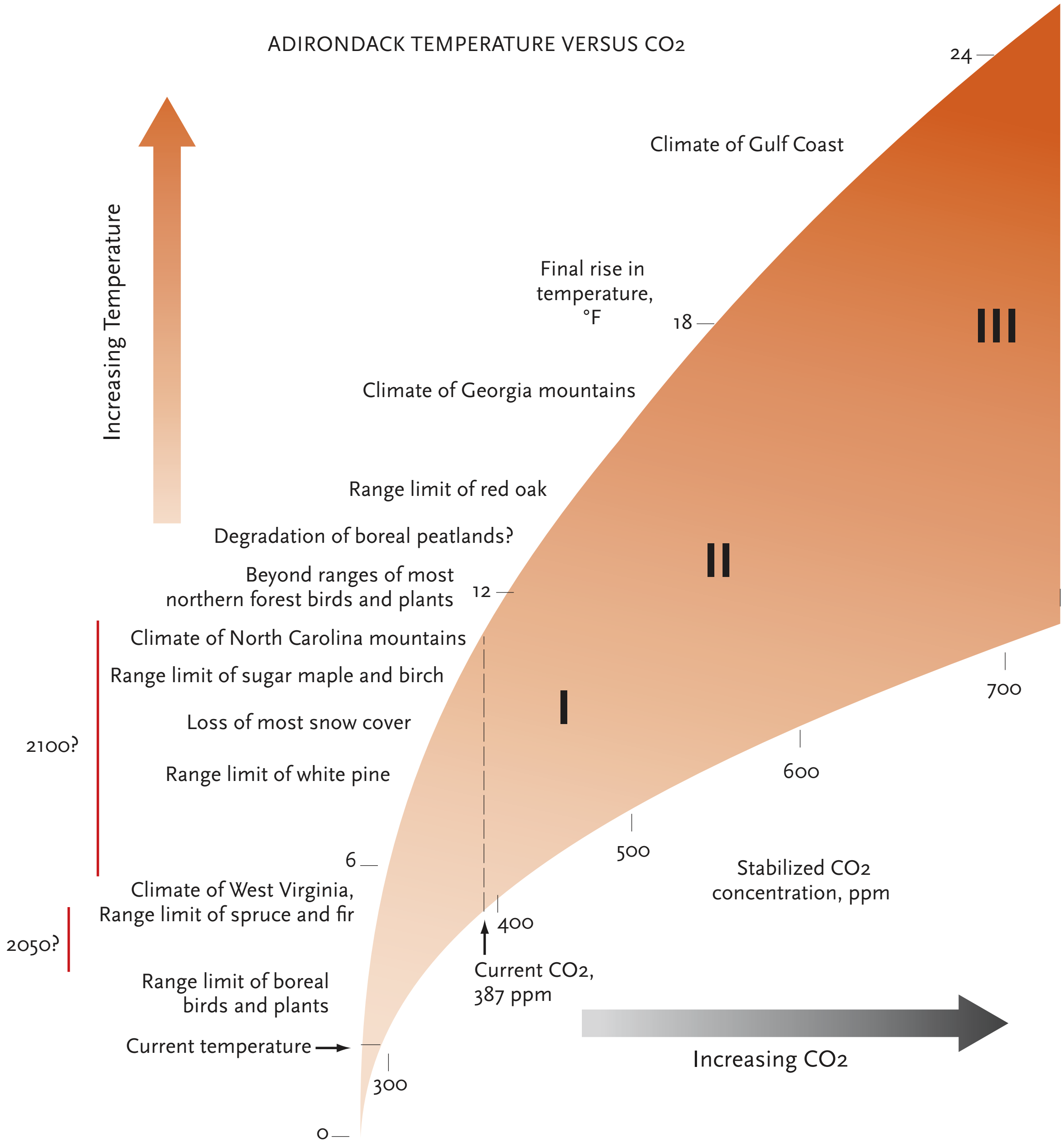
It may, unfortunately, not be the worst that we need to think about in 2008. The black line shows the world CO_2 emissions. They have increased rapidly for the last five years, and are now several billion tons above that the IPCC considered its worst-case scenario in 2002.

The graph on p. 19 translates stabilized CO_2 levels into Adirondack temperature rises. The colored figure represents the range of estimates from different climate models. It says, for example, that if we stopped emitting CO_2 today, the current CO_2 level of 387 ppm (dashed vertical line) will result in an eventual warming of 4 to 11 degrees.

Since the current warming is only about 2 degrees, this is cautionary. The climate system, it appears, has momentum and will continue moving in the direction it is going for a considerable time, even after we stop pushing it.

Combining the graphs, we have three versions of future Adirondack temperatures:

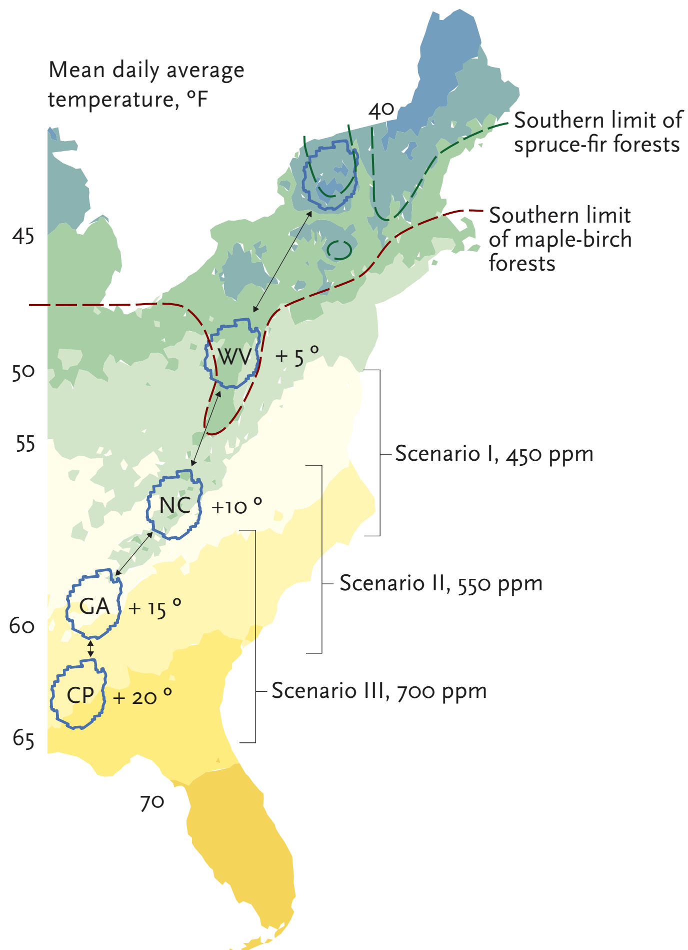
If we	The stabilized CO_2 will be	And final temperature rise will be
Do all we can fast	450 ppm	6°–14°
Reduce emissions by 2040	550 ppm	8°–18°
Reduce emissions by 2075	700 ppm	11°–24°



Bear in mind that these are the final temperature rises that will occur *after* CO_2 emissions have stopped and temperatures have stopped rising. For Scenarios **II** and **III**, this will take well over a century. If we are only concerned with how climate change will affect us, they are not something we need to worry about. But if we are concerned, as moral citizens of the planet, with how our actions will affect the future of the world, they are exactly what we should be worrying about.

The labels to the left of the graph suggest that as temperatures rise our climate will become progressively more southern, and our northern animals and place will become progressively more out of place in it. The analogy is only approximate. A temperature warming of 6 degrees will give us temperatures something like those West Virginia, but will not give us Virginian day-length, sun-angles, or rainfall. A warming of 10 degrees will take us to the climatic limits of sugar maple and yellow birch, but it doesn't mean that all the maples and birch die when we reach that tem-

CLIMATE ANALOGS FOR A WARMER ADIRONDACKS



perature. Some will persist after we reach it. Others, perhaps many, will die before we reach it.

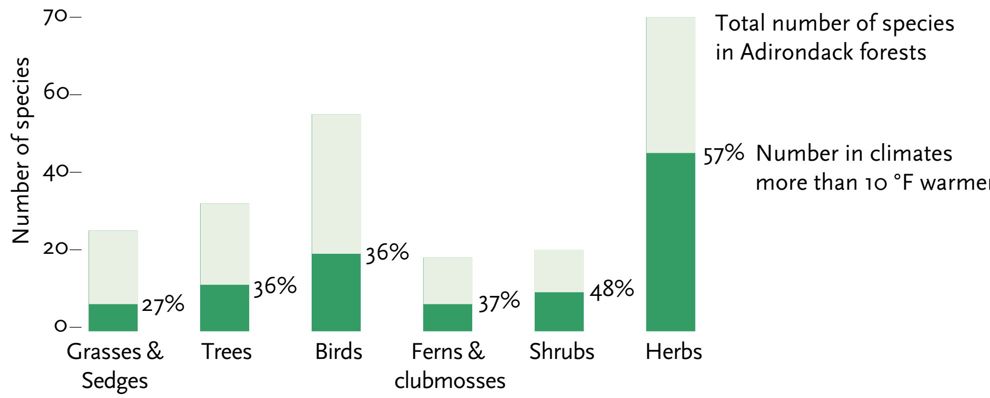
With these caveats, we can translate the graphs on pp. 18-19 to a map like the one above, in which successive warmings of 5 degrees move the Adirondacks southward down the Appalachians.

A warming of 5 degrees gives us a climate like that of West Virginia. A warming of 10 degrees or more takes us to a climate something that of highland North Carolina. A warming of 15 or 20 degrees takes us to highland Georgia or the Gulf coastal plain.

The importance of this map is not just what it says about temperature change, but what it says about the biological and cultural effects of temperature change. The Adirondacks are a region of boreal and cool-temperate forests. They have big bogs, spruce-covered mountains, and snow and ice for much of the winter. They are a place where people ski, snowmobile, climb, snowshoe, and ice fish in the winter, and where the winter economy is built around outdoor recreation.

None of these will survive the kind of climate changes the map suggests. In climates 5 degrees warmer than ours there are no big bogs, or spruce-fir forests, or mountains with continuous snow cover. Snowmobiling and skiing are limited, and snowshoeing and winter climbing almost nonexistent.

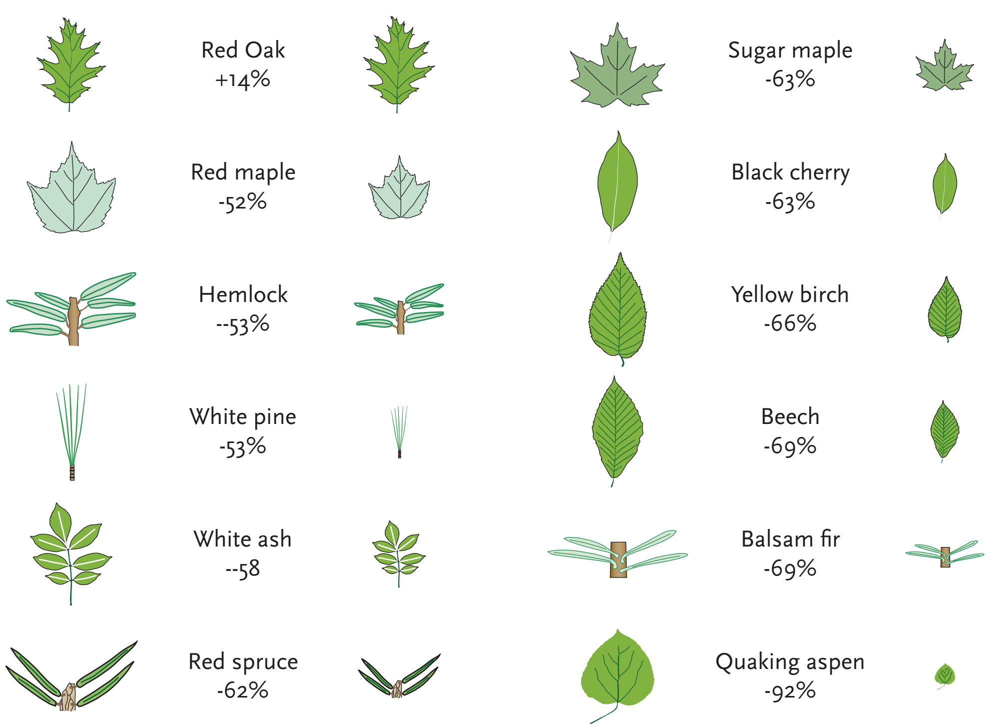
NUMBER OF ADIRONDACK FOREST SPECIES FOUND IN THE SOUTHERN APPALACHIANS



Climates 10 degrees warmer than ours are even more different. Southern Appalachian forests are oak and hickory dominated, and have little in common with Adirondack forests. Few of our common forest animal and plants live in them at all, and even fewer prosper there. The graph shows that of 246 common Adirondack forest species, only 84 (34%) are found in the southern Appalachians at temperatures 10 degrees or more warmer than ours.

If we could simply exchange our forests for southern Appalachian ones, which are equally lovely, climate change might not be so menacing. But there is no way we can do this. Most of the trees of southern Appalachian forests are hundreds of miles from us. Trees migrate very slowly, only 10 or 20 miles per century, and so it may be hundreds of years before they get to us.

CHANGES IN NEW YORK TREES FOR A 6-DEGREE FINAL WARMING



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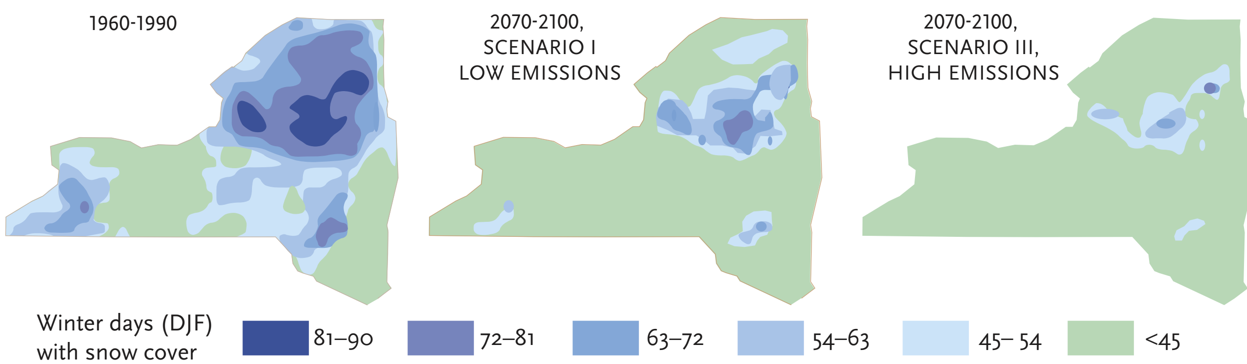
Instead of an exchange, what we are likely to see is a gradual, long-continued, dying of our forests. The figure on the bottom of p. 21, based on a model by Iverson and his colleagues, shows what may happen. With a warming of 6 degrees, roughly equivalent to moving the Adirondacks to the central Appalachians, every major Adirondack tree except red oak declines by 50% or more.

PREDICTED CHANGES IN WINTER SNOW COVER



As temperature changes, rainfall and snowfall will also change. The Northeast Climate Impacts Assessment models suggest that total Adirondack precipitation will increase by a third or more, especially in the winter. Snowfall, on the other hand, will fall by third or more. Under Scenario **I**, with immediate emission cuts, the number of winter days with snow cover in most parts of the Adirondacks will be cut by a third to a half. Under Scenario **III**, with emissions rising until 2070, most parts of the Adirondacks lose most of their snow cover.

Summing up, all the climate models predict a significant warming of 5 degrees or more in the coming century. The amount will depend the amount of fossil fuel we use. Under moderate and high emission scenarios there will be an additional warming, which could amount to a total of 20 degrees or more, before the temperature finally stabilizes.

The models also predict moderate increases in rainfall and total precipitation and great decreases in snowfall. Under high emission scenarios, most of the Adirondacks will have less than 45 winter days with snow on the ground.

These changes will move the Adirondacks to a different climate zone, comparable to that of the central or southern Appalachians, where summers are hotter and dryer, winter thaw days are common, and ice and snow do not persist through the winter.

This may change the Adirondacks greatly. Neither winter sports nor boreal forests like those in the Adirondacks exist in the central Appalachians. Deciduous forests like those of the Adirondacks do not exist in the southern Appalachians.

We will be moving, in other words, to a climate that will support neither Adirondack biology nor Adirondack culture. The results in the long term may be replacement and transformation. But in the short term—which may be a century or more—they will be decline and loss.

5 WE ARE NORTHERN AND THEREFORE VULNERABLE

The climate models suggest that, unlike in many other places in the world, climate change in the Adirondacks will be gradual and nonviolent. We will not have to contend with rising sea levels or thawing permafrost. We will probably not suffer violent storms, extended droughts, or gigantic fires. Our water supplies are probably secure, and our farms are capable of feeding us if farms elsewhere fail.

None the less, climate change may change us greatly. To repeat the conclusion of the previous chapter, climate change has the potential to move us to a place where cultures like ours do not exist.

As this happens, we will lose the elements that make up our landscape. The northern ones will go first. We will lose river ice first, then lake ice, and then the ice and snow in the mountains. We will lose the deep cold, the boreal forests and wetlands that depend on it, and the boreal animals and plants that depend on them. We will lose the recreationists that use snow and ice and cold, and then the businesses and facilities that support them.

As the elements go, the communities that depend on them will become simpler and less vital. A natural community, like Spring Pond Bog, may contain a hundred or more plant and vertebrate species, and many hundreds of fungi and insects. When its major species vanish or decline, the habitat will change, and when the habitat changes the minor species will go as well.

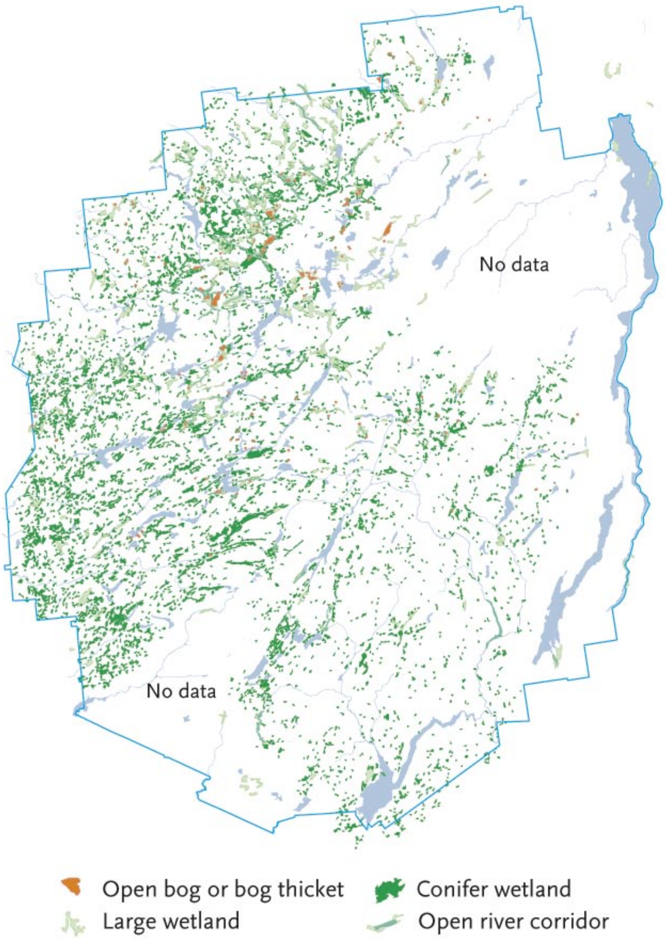
Similarly, a major recreational center like Old Forge may contain a hundred or more businesses that support recreation, and which in turn require thousands of people to support them. As recreation decreases the businesses will close. As the businesses closes, recreation will decrease further.

Ice-climbing route, Chapel Pond

Once they start, losses of this sort are hard to reverse. Natural communities may take hundreds or thousands of years to assemble their characteristic species and attain their mature form. Cultural communities develop faster, but still may take many decades to accumulate the economic strength and human resources that a complex community requires. Thus community-scale losses, either in towns or in the wild, will be long-lasting, and so particularly damaging.

The human and natural communities of the Adirondacks, because they are northern, could easily be lost to warming temperatures. In this section we look at two areas—boreal natural communities and winter recreation—where the losses could be severe.

THE ADIRONDACK LOWLAND BOREAL



Boreal forests and wetlands, here used very generally for any forest and wetland communities dominated by northern conifers, are the signature natural communities of the Adirondacks.

Even though deciduous forests are more common, it is the boreal habitats—the evergreen forests, the mountain summits, the open rivers, the great bogs—that are the most characteristic Adirondack landscapes. And it the boreal plants and animal—the moose, the loon, the tamarack, the spruce—that are the icons of these landscapes.

The boreal animals and plants are special for many reasons, not least because they are symbols of deep snow and the north and at the southern edges of their natural ranges here. The Adirondacks are the southernmost place where they occur in quantity and in their characteristic associations. The lowlands around us and the mountains to your south do not have them at all, or have only small remnant populations.

Because the boreal animals and plants are at their southern range limits, they are vulnerable to climate warming. The same factors that make them special—their intolerance of warmer climates and snowless landscapes—make it likely that we will lose them if our climate warms much more than 5 degrees.

Much the same is true of the boreal landscapes themselves. The map above, showing the distribution of conifer swamps and open bogs, shows that the largest examples occur in the western and northwestern parts of the park, where the lowest temperatures and greatest snowfall occur. The illustrations on the right show six distinctive communities that are largely confined to areas as cold or colder than the Adirondacks. Of these, montane forests, open alluvial wetlands, and black spruce tamarack swamps occur south of the Adirondacks, but only in small isolated examples. Open river shores and large open peatlands, both relatively common in the Adirondacks, do not seem to occur south of us at all. And ice-meadows (see p. 11 for a winter photograph of the same shore) are a high-northern habitat, rare in the Adirondacks and unknown elsewhere at our latitude.

Montane forests: High peaks from Giant Ridge

Open alluvial wetlands: confluence of Goodnough and Hudson

Black spruce-tamarack swamps and open shores:

Open Shores: Oswegatchie River

Ice meadows: Hudson River in Warrensburg

Large open peatlands: Spring Pond Bog

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Bog Rosemary


Pod-Grass


White-fringed Orchid


Hare's-tail Sedge

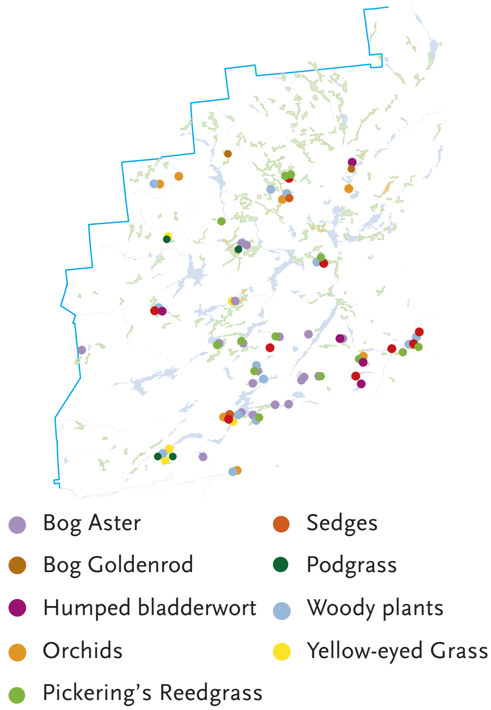

Tamarack


Green Alder

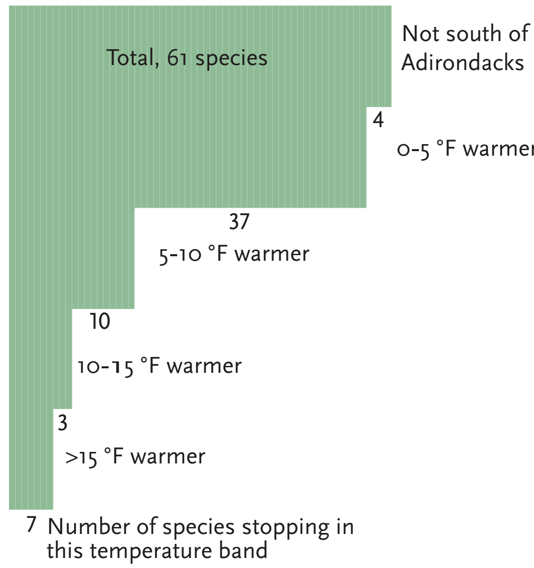

Canadian Burnet


Kalm's Lobelia

RARE AND UNCOMMON PLANTS
IN THE LOWLAND BOREAL



SOUTHERN TEMPERATURE LIMITS
OF ADIRONDACK BOG PLANTS



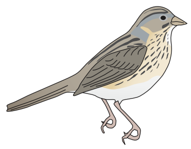
Boreal Plants

Several hundred species of vascular plants and mosses occur in boreal habitats in the Adirondacks. Of these a smaller number, perhaps 100 species, are boreal specialists in the sense that they do not occur in nonboreal habitats as well.

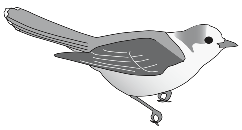
The boreal specialists are an interesting group. All are, by definition, cold tolerant and heat intolerant. Most are slow-growing, and either evergreen or small-leaved or both. Many are restricted to wet peaty soils, and many others to exposed rock faces, habitats common in the Adirondacks and to the north of us and much rarer to the south of us.

The heat intolerance of the boreal specialists is shown in the right hand graph above, which shows the temperature limits of 61 widespread Adirondack bog plants. Each species is represented by a slender vertical bar. Forty-one species (67%), the true boreal specialists, are limited to habitats within 5 degrees of Adirondack temperatures. Another 10 (16%) are northern but not truly boreal, and are found in habitats up to 10 degrees warmer than the Adirondacks. The remaining 10 are wide-ranging species that at a wide range of temperatures, and in many different sorts of habitats.

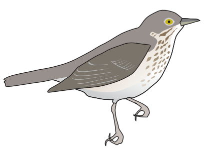
Because boreal habitats are ecologically unusual, they contain many species that are regionally uncommon. The map above shows the distribution, by species groups and a few isolated species, of 24 such species from the Adirondack lowland boreal. Interestingly, only about half of these are true boreal species. The remainder are wide-ranging but uncommon species that favor the specialized habitats found in the boreal.



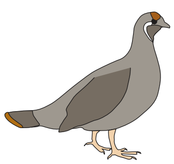
Lincoln's Sparrow



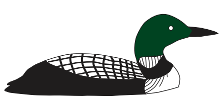
Gray Jay



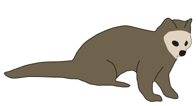
Bicknell's Thrush



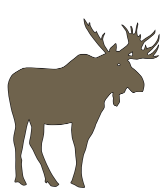
Spruce Grouse



Common Loon

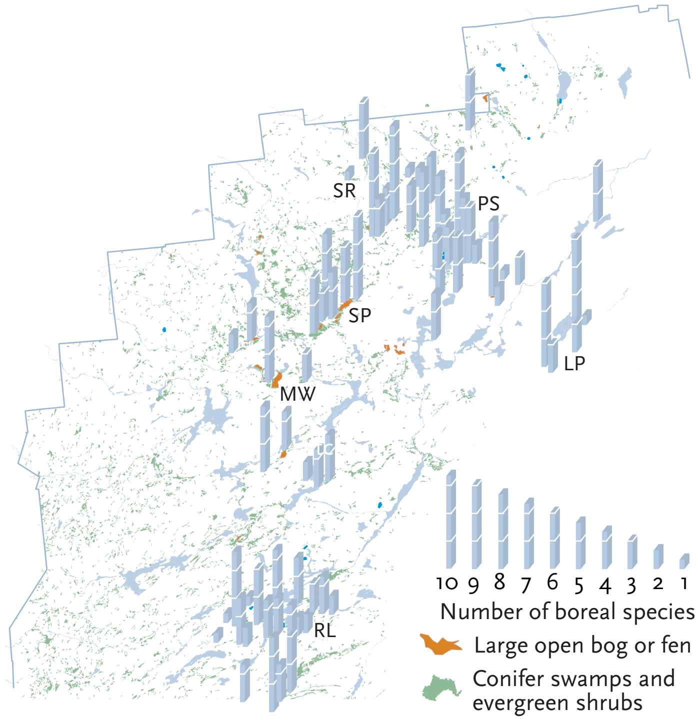


Pine Marten



Moose

WCS BOREAL BIRD SURVEY RECORDS, 2003–2007

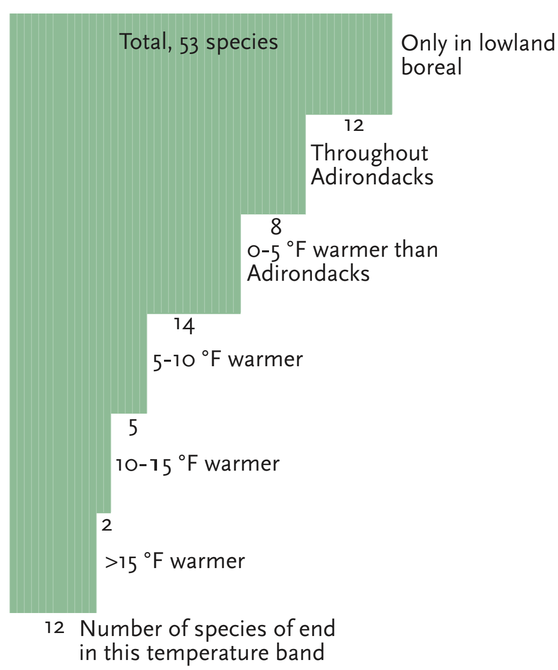


Boreal Mammals and Birds

Mammals tend to be wide-ranging, and the Adirondacks probably have only one boreal species, the pine marten, and one near-boreal species, the moose. Birds are more specialized in their habitat preferences and the Adirondacks have 45 boreal and near-boreal species. This is especially true of the birds of boreal wetlands. Thirty-four Adirondack wetland birds are restricted to habitats that are 5 degrees or less warmer than the Adirondacks. Twenty of these are true boreal specialists and barely occur outside of the Adirondacks at all.

This last group is strongly associated with the large lowland boreal habitats in the western Adirondacks and includes some species that may be bellwethers of climate change. WCS researchers are currently monitoring them. Some of their results are shown in the map above. Other results from the Breeding Bird Atlas Project, are shown on p. 37.

SOUTHERN TEMPERATURE LIMITS OF
OF ADIRONDACK WETLAND BIRDS



Ice climbers on the Chapel Pond Slab

Winter Recreation

Winter recreation, including hiking, climbing, snowshoeing, bobsledding, snow tubing, alpine and nordic skiing, snowmobiling, and ice fishing, is relevant to the climate change story for several reasons.

First, it is the major winter industry of the Adirondacks. Taken in the aggregate, it uses several thousand square miles of land and an elaborate infrastructure of shelters and trails, including over a thousand miles of groomed ski and snowmobile trails. It is served by some fifty to a hundred business that operate these facilities and provide equipment and services, and several hundred additional businesses that provide food and lodging. It has an annual user base of tens of thousands of participants, many of whom are Adirondack residents or own Adirondack property, and so contribute to local economies in other ways as well.

Second, the community of participants and service-providers is complex and interdependent. Compared to summer recreation, which can involve things as simple as walking in the woods or floating in a tube, winter recreation tends to involve specialized facilities and often specialized user-groups. These in turn require an equally specialized service community. to support them.

Third, it is embedded deeply into Adirondack history and Adirondack culture. For over a hundred years Adirondackers have participated and competed in winter sports. The ski, the snowshoe, and the snowmobile are as much Adirondack symbols as the guideboat or the paddle. Their users helped bring winter sports to America; the towns that first hosted them are now our main winter resorts.

And fourth, and most important, all winter sports except bobsled (which takes place on an enclosed, refrigerated track), and ski jumping (which can be done year round on plastic tiles) are climate-dependent. Downhill skiing on artificial snow is the least so, and snowmobiling, which requires both trail systems with natural snow and sound ice for lake and river crossing, perhaps the most so. But all require snow or cold to some extent, and so all will be vulnerable to warming climates.

The U.S. Olympic bobsled team, 1936

Lake Champlain, 1920s

The two photos with captions are from the New York State archives and are used with permission. The remaining photos are courtesy of the Adirondack Colledction at the Saranack Lake Free Library and are also used with permission.

An Adirondack Winter Chronology

Above, as evidence of the cultural roots of winter sports, early photos of bobsledders, curlers, sledders, skiers, and ice fishing. At right, a chronology of Adirondack firsts and competitions. The Adirondacks were central in the development of winter sports in the United States. Some of the first ski jumping, bobsled, speed-skating, downhill, and slalom races in the country were held here. The Adirondacks hosted the first and third of the country's four winter Olympics, had one of the first ski tows and ski schools in the country, and were among the first places to develop large, lift-serviced, downhill ski areas. "Powered sleds" (early snowmobiles) were used here in the 1930s. The Adirondacks were one of the places where American winter mountaineering began a hundred years ago, and one of the places where the modern techniques for climbing vertical ice were developed and taken to world-class levels.

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ADIRONDACK WINTER SPORTS, 1890–1980

1893 First known winter ascent of Mount Marcy.

1897 The Pontiac Club inaugurates The Saranac Lake Winter Carnival.

1912 Fridtjof Nansen, the Norwegian arctic explorer, climbs Mt. Marcy on skis.

1914 First Mid-Winter Sports Festival in Lake Placid.

1917 Lake Placid Club builds a ski jump for its members.

1918 First eastern speed skating championships on Mirror Lake; ski jumping contests at Blood Hill at Saranac Lake.

ca. 1920 Herman "Jack Rabbit" Johanssen lays cross country ski trails around Saranac Lake and Lake Placid; the Lake Placid Club hires Henrik Jacobsen as the first paid ski instructor in the United States.

1921 First winter sport championships for women.

1922 The first meeting of Adirondack Mountain Club.

1924 The Sno Bird's Club ski tournament has 3500 spectators.

1925 Earle Brinsmade skis 300 miles to Lake Placid to participate in the Sno Birds club tournament; first Adirondack slalom competition; first Lake Placid-Saranac Lake race.

1926 First Adirondack downhill race.

1927 Lake Placid Club builds a 60 meter Olympic ski jump at in North Elba.

1930 First race at the Mt. Van Hoevenberg bobsled run.

1931 Volunteers from the American Legion cut ski trails on Gore Mountain; Charles Martin and Otis King drive dogsleds to the top of Whiteface Mountain.

1932 Governor Franklin Roosevelt opens the third Olympic Winter Games at Lake Placid.

1934 Carl Schaefer installs a ski tow and starts a ski school ar Gore Mountain.

1936 The Van Hoevenberg hiking trail is widened and becomes the Marcy Ski Trail; Jim Goodwin and Bob Notman make the first winter ascent of the Chapel Pond Slab.

1941 The New York State Constitution is amended to allow ski trails on Whiteface Mountain; in 1947 it is amended again to allow ski trails on Gore Mountain.

1947 Oak Mountain Ski Center in Pleasant Lake opens with two rope tows and a T-bar .

1949, 1969, 1973, 1978 World bobsled championships held at Mount Hoevenberg.

1950 World ski jumping championship held at Lake Placid.

1952 David Bernays and his partner ice climb Rainbow Falls at Lower Ausable Lake.

1954 The first Appalachian Mountain Club winter mountaineering school.

1958 Whiteface Mountain Ski Center rebuilt.

1966 Gore Mountain Ski Center rebuilt.

1968 First Roger Ranger's Run cross-county ski race on Lake George.

1968 First Long Lake 100 Snowmobile Race.

1972 World University Winter Games at Lake Placid.

1975 John Bragg and John Bouchard climb *Positive Thinking* on Poke-o-Moonshine, the first Class 5 ice climb in the Adirondacks.

1977 First Alpo International Dogsled Races in Saranac Lake.

1978 Cross-country ski trails and biathlon range built at Mount Van Hoevenberg.

1979 International luge competition at Mount Van Hoevenberg.

1980 The thirteenth Winter Olympics are held at Lake Placid.

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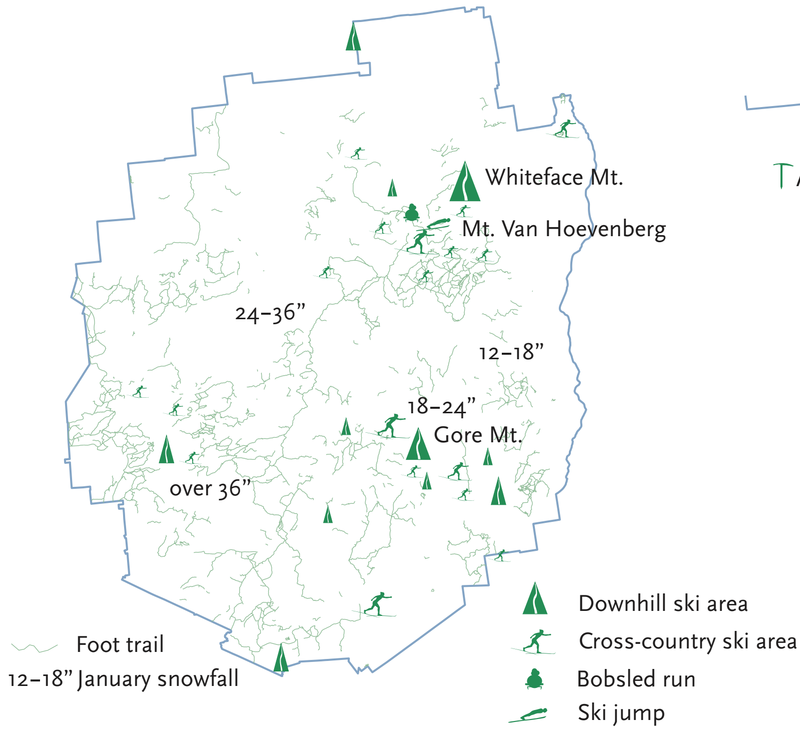
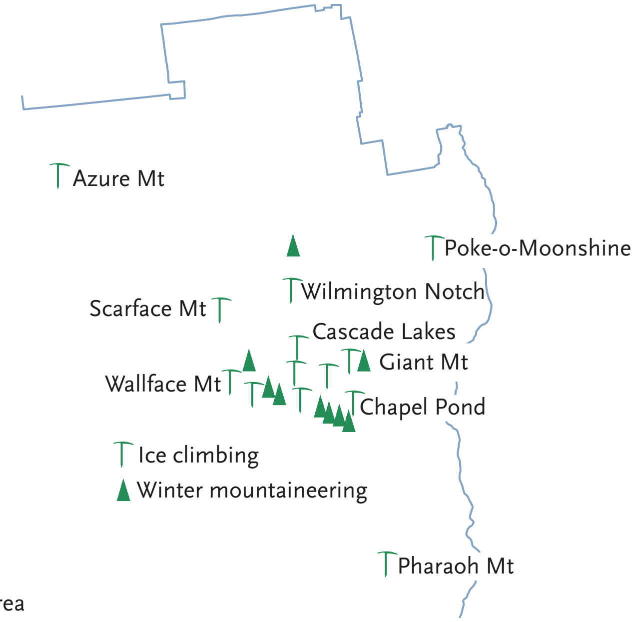
WINTER RECREATION

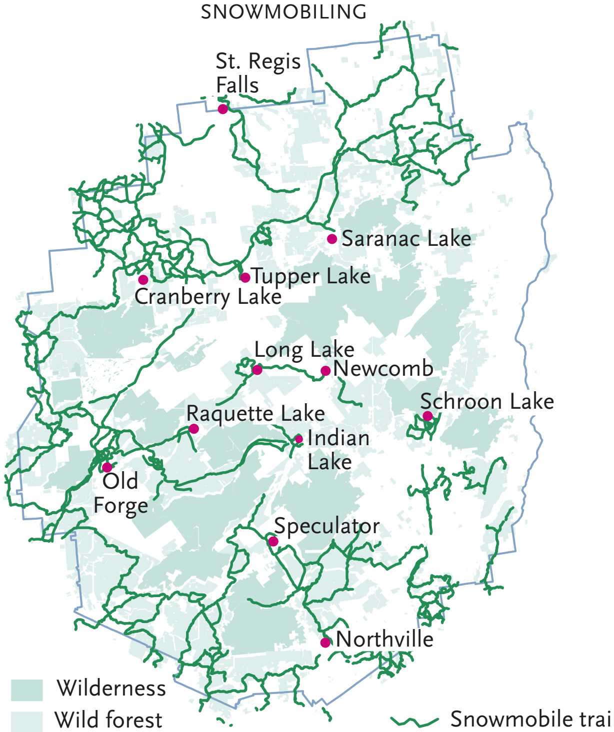
SKIING AND SNOWSHOEING



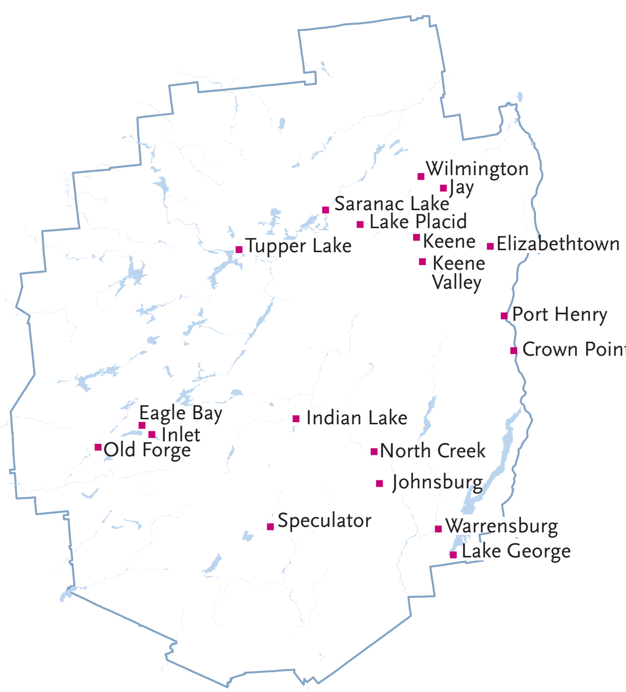
WINTER CLIMBING



SNOWMOBILING



WINTER DESTINATIONS



The winter economy is extensive, interdependent, and at risk.

The maps suggest the physical extent of the winter economy. Commercial skiing takes place at 29 different ski areas and involves over 300 miles of groomed trails. Snowmobiling uses 800 miles of groomed trails on state land, and several hundred miles of trails on private land. Ice climbing takes place on over a hundred routes on thirteen major cliffs.

Not visible in the maps are the business that run the facilities and feed and house the participants. Old Forge, the snowmobiling center of the Adirondacks, operates its own trail system and sells 10,000 trail passes a year. Its winter season is as busy or busier than its summer one. Seventy-eight of its 94 restaurants and inns stay open year around; 6 businesses sell, repair, or rent snowmobiles. Since service businesses are labor intensive, and since other business have to supply them, this suggests that there may be over 500 people in the winter economy in Old Forge alone.

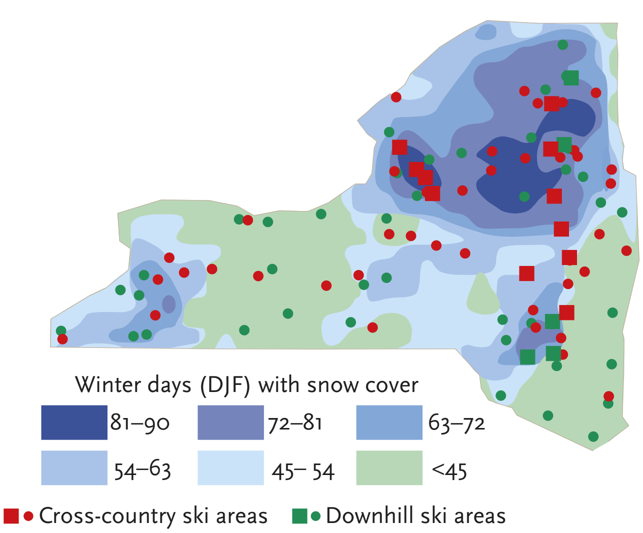
Besides the facilities and the service providers, the winter economy involves many user groups. Snowmobilers belong to clubs and are represented by snowmobile organizations. Nordic skiers are competition-oriented, and have teams and youth leagues and regional and national racing associations. Even climbers and snowshoers, the most solitary winter groups, have clubs and schools. All of these organizations need to be staffed and represent significant investments of human and economic capital.

Because the winter economy is elaborate, it is also interdependent. The users come not only because the cold and the snow are there, but because there are facilities for them, events for them to go to, and services in the towns where the events were. If the snow becomes unreliable there will be fewer users and events; without the users and events the service businesses will close, and without the service business there will be even fewer users.

This has not happened in the Adirondacks yet, but it is happening not far to our south. Western Massachusetts, which formerly had reliable snow and a strong winter sports culture, now has increasingly brown winters and a noticeable decrease in winter sports and in the organizations and businesses that support them.

The map suggests that this could easily happen in the Adirondacks. Small ski areas occur all over New York, even in areas where the snow is intermittent. Large ones, which have full programs are mostly in the areas with continuous snow cover. As the climate warms and the snow cover becomes intermittent, the major areas will not be able to offer the services their users expect; their user base will shrink and their programs will vanish. They may continue for many years with gradually shortening seasons, but they will not have the vitality they now have or support the communities they now do.

SKI AREAS AND SNOW COVER



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The High Peaks from Bristol Mountain

6 BIOLOGY AND RECREATION ARE ALREADY CHANGING

Compared to thirty years ago, the Adirondacks are warmer and wetter, with longer springs and falls and shorter winters. The changes are not big, but they have come quickly.

When the climate changes, we expect culture and biology to respond, though not immediately. A warmer climate may bring new birds and kill boreal trees, but the birds will take time to arrive and the trees even longer to die. Winter recreation will eventually suffer as cold and snow decrease, but in the short term it may prosper if we have snow and other places don't.

Two conclusions follow from this, one encouraging and one cautionary. The encouraging one is that if culture and biology lag far enough behind climate, we may be able to stop climate change before its effects are irreversible. The cautionary one is that, because of the same lag, the small changes that we see now in, say, boreal birds or days of skiing, may be a warning of larger changes to come.

Either way, to prepare for the changes that are coming, we need to understand the changes that have already happened.

This turns out to be a surprisingly difficult job. In only a few areas, like bird distribution, are the Adirondack data both reasonably complete and publicly accessible. In some, like snowmobile use, they are accessible but incomplete. In others, like expenditures for snowmaking, they are inaccessible. And finally, in many particularly interesting areas, like river ice and school snow days, there seem to be almost no data at all.

In this section we give a brief review of the kind of changes that seem to be occurring, starting with those for which we have the best evidence and then dealing, briefly and unsatisfactorily, with those for which the evidence is incomplete or anecdotal.

What May be Changing

As the climate warms, we may expect changes in eight areas:

The seasonal timing of biological and cultural events.

The arrival of new southern species and the loss of northern species.

The openness of boreal natural communities like bogs and ice meadows.

The number of days with suitable conditions for winter recreation.

The number of people participating in winter recreation.

The energy used for winter heating and summer cooling.

The energy used for snowmaking and icemaking.

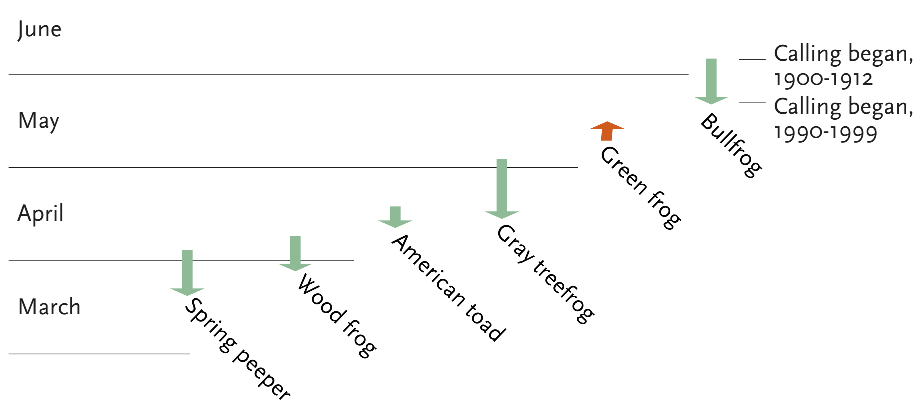
The number of days when school are closed or snowplows are out.

We can present at some information on four of these. We have looked for but thus far not found information on three others, and are still researching one.

Seasonal Timing

Many biological events are tied to seasonal cycles, and there is now a considerable literature showing that different creatures are budding, flowering migrating, singing, or breeding early in the spring. The graph gives an example from the Finger Lakes. The springs there are about 3 degrees warmer than they were in 1900, and 5 out of 6 frog species are calling early than they used to. The average shift is about two weeks.

CHANGES IN AVERAGE DATES WHEN FROGS BEGIN CALLING NEAR ITHACA, N.Y.



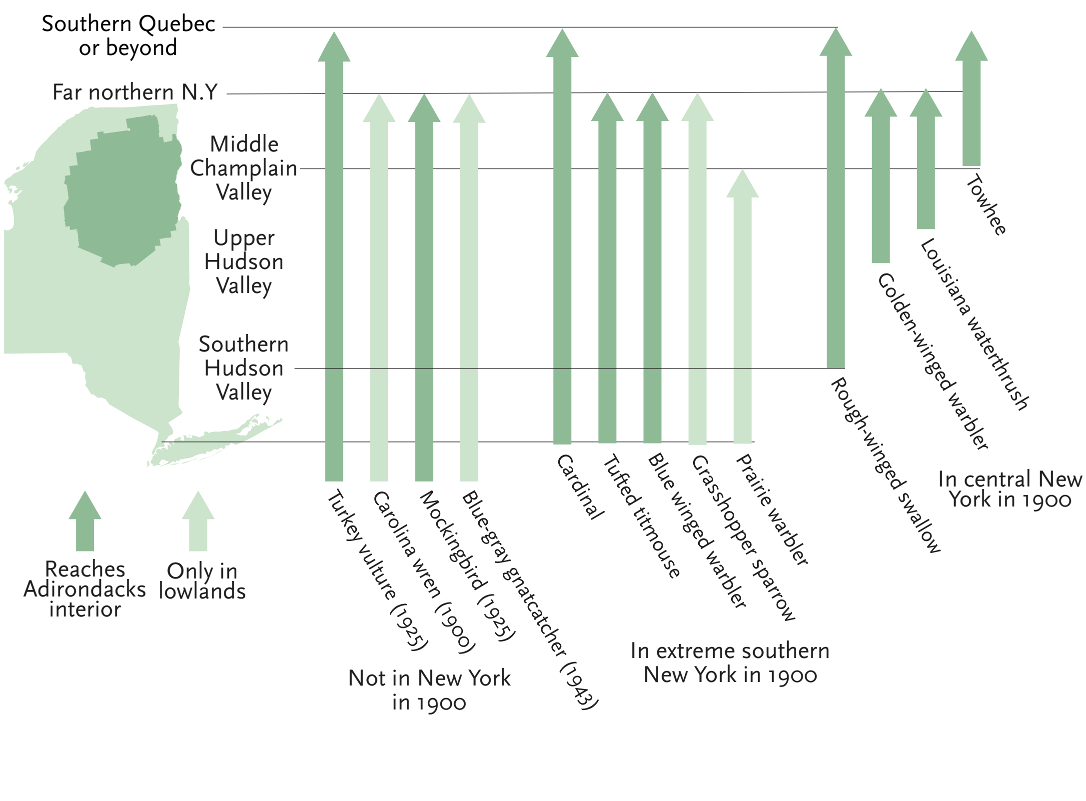
It is reasonable to expect similar changes in the Adirondacks, but thus far there is very little data to go on. Curt Stager and his collaborators have reviewed several existing data sets, and found a statistical correlation between warmer springs and earlier flowering in white water lilies, but no correlation for bird arrivals or the flowering of other plants.

Cultural events are also tied to seasonal cycles and seem to be changing as well. Skiers, snowmobilers, ice climbers, and ice fishermen all report that they are starting later in their year, though (because snow and ice linger) apparently not ending earlier. Hunters reports less snow, or no snow at all, in deer season. Gardeners, at least in the lowlands, are planting somewhat earlier and expecting frosts to come a week to two weeks later in the fall.

Expansion of Southern Species and Retreat of Northern Ones

There is clear evidence, now from all over the world, that birds, fish, butterflies and a few other insects are expanding their ranges northward with the warming. The shifts are dramatic but only found in the most mobile groups. Few, if any, similar shifts seem to have been found in plants, mammals, or other relatively sedentary groups.

EXPANSION OF SOUTHERN BIRDS INTO NORTHERN NEW YORK, 1900-2007

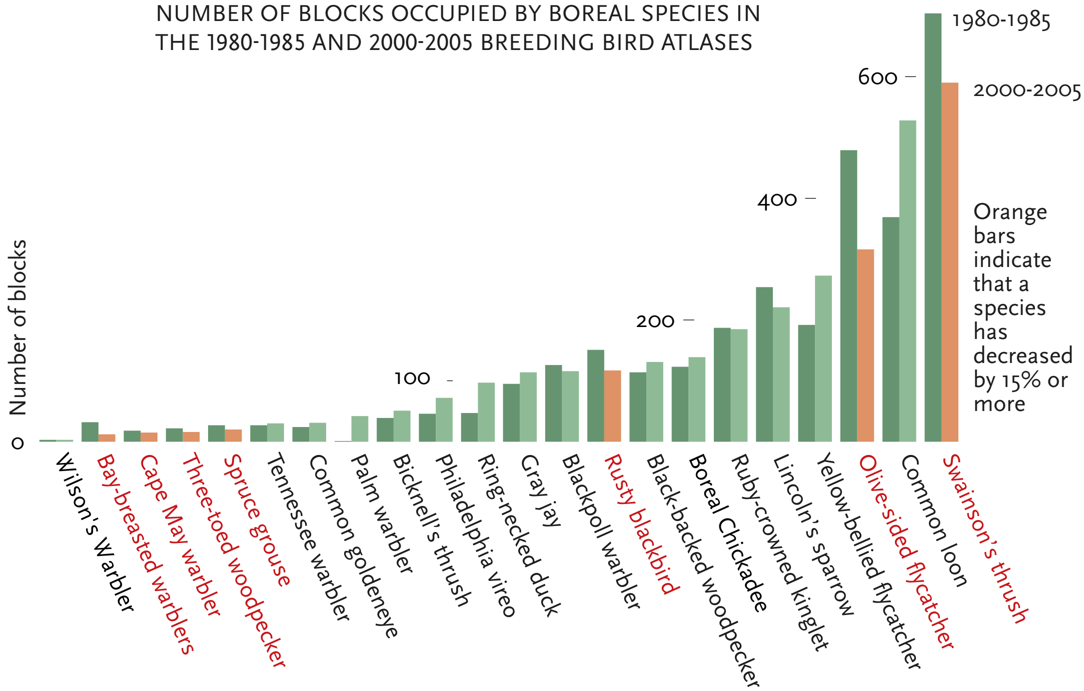


Similar changes are happening in New York state. About 25 new breeding birds have arrived New York in the last century; 13 new breeding birds have spread into northern New York, and 9 into the Adirondack interior. The distances the birds have moved correspond to the amount that the temperature has changed, and suggest that birds are tracking climate change and moving with it.

Much less is known about movements in other groups. Weeds like garlic mustard, pests like the hemlock adelgid, and disease vectors like the deer tick have all spread northward in the last thirty years and seem at least in part controlled by climate. But how much of their spread is due to climate change and how much by their other ecological relations is impossible to say.

Surprisingly and reassuringly, there is much less evidence for the decline of northern species than there is for the spread of southern ones. This is true both in the northern hemisphere as a whole and in the Adirondacks in particular. Trees like the white spruce and quaking aspen, mammals like the moose and marten, and birds like the boreal chickadee and loon, though northern and therefore at risk, still appear to be doing well.

NUMBER OF BLOCKS OCCUPIED BY BOREAL SPECIES IN THE 1980-1985 AND 2000-2005 BREEDING BIRD ATLASES



This is not, however, universally true. The graph shows the changes in the number of 5 km × 5 km survey blocks in which boreal birds were found in two New York breeding bird surveys twenty years apart. There is no overall pattern of increase or loss, and many of the changes may represents normal population fluctuations or the uncertainties of observing secretive species. But still, four of our most widely distributed boreal species showed big losses. The olive-sided flycatcher apparently vanished from 163 blocks, Swainson's thrush from 114, Lincoln's sparrow from thirty four, and rusty blackbird from 33. Declines of this size in relatively common species are unlikely, and suggest a pattern of some kind. We have no evidence that climate change is responsible, but it is certainly a possible or contributing cause and so something we need to watch closely.

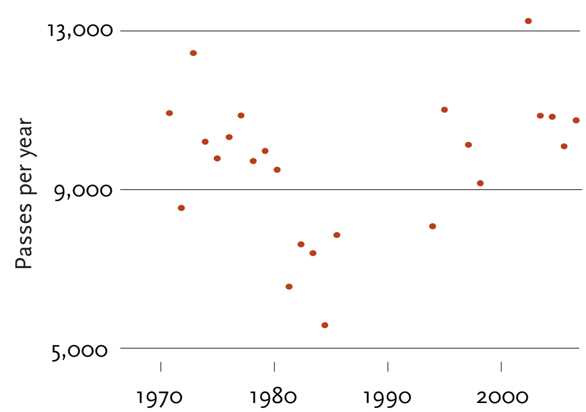
Changes in Winter Recreation

Winter recreation has always been dependent on the weather, especially in early winter. Natural snow comes and goes, lakes freeze later or earlier, the ice on climbing routes forms or doesn't form, migratory fish populations do or do not show up.

Against this background variability, individual warm years and the cancellations of events that result from them do not count for much. In 2002–2003, the warmest Adirondack winter on record, snowfall was low, and many events were cancelled. On January 10, 2007, it was 60 degrees in the Adirondacks and there was no snow or ice anywhere. In 2006 and 2007 the Lake Champlain Ice Fishing Championship was cancelled for lack of ice. The pond hockey tournament in Lake Placid has been held on artificial ice in two of the last four Januaries because Mirror Lake was not been frozen. All these are interesting, and may someday be seen as early warnings, but as yet they are not a trend.

Likewise, anecdotal information from participants is valuable but hard to evaluate. We have been told for example, that rivers are freezing less than they used to and that snowmobile crossing are correspondingly more dangerous; that rainbow smelt, a coldwater fish, are no longer making their winter migration to the shallow parts of Lake Champlain where they were traditionally fished; that no major ice-climbing routes in the Keene Valley area have passed out of use in the last decade; and that the total number of skier-days at Mt. Van Hoevenberg has not changed much in the last 15 years. All these are interesting, and none have been verified.

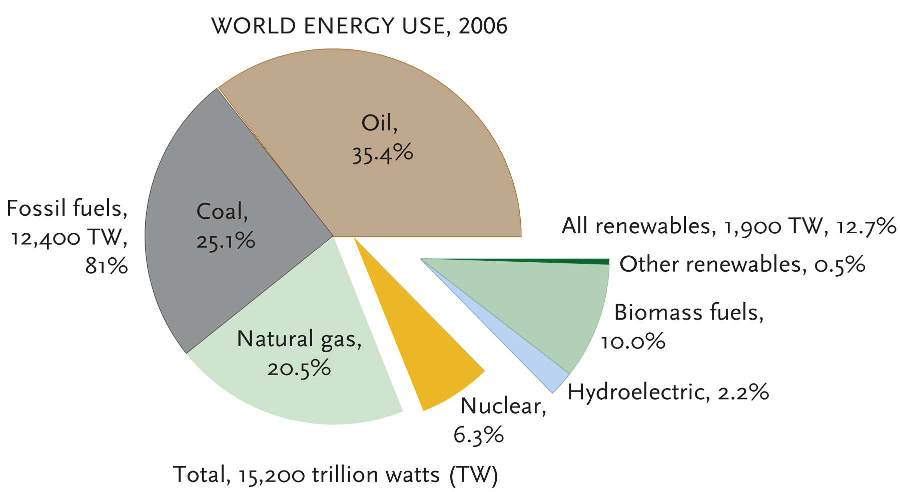
SNOWMOBILE TRAIL PASSES SOLD BY THE TOWN OF WEB



Our only quantitative example is, like the anecdotal ones, incomplete but interesting. The Town of Webb, a major snowmobiling destination, maintains its own trail system and sells passes to users. We have incomplete data on the numbers of passes, which seem to show a high number in the 1970s, a decline in the 1980s, and a recovery (after a data gap) after 1995. Why the decline occurred and what happened between 1985 and 195 we don't know; in any event there is no long-term trend.

7 THERE IS MUCH THAT INDIVIDUALS CAN DO

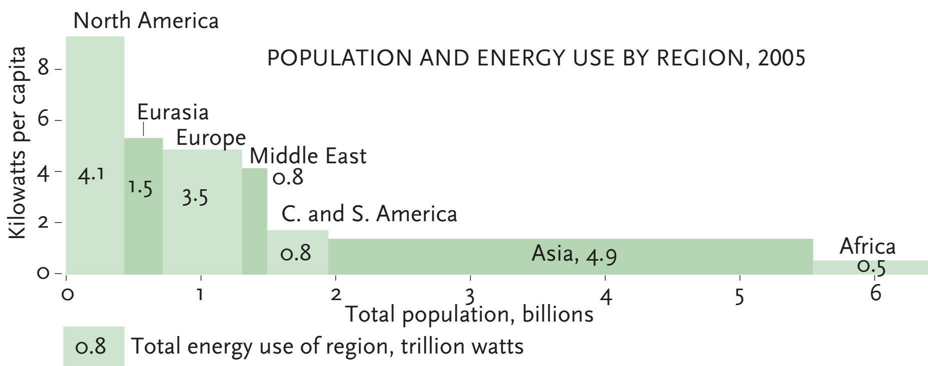
To prevent damaging amounts of climate change, we have to reduce the world use of fossil fuels. Further, we have to do it quickly. As the scenarios on p. 18 show, the longer we wait the harder it will be do and the more climate change we will be committed to.



At present fossil fuels supply about 12 trillion watts, which is 80% of the world's energy. There are two paths to reducing their use: either we can reduce the total amount of energy we use, or we replace fossil fuels with other sources of energy,

In countries like the United States, where per-capita energy use is currently high, reducing the amount of energy we use is our cheapest and quickest way of reducing fossil fuel use. It costs no money to turn a light off or not drive a car, and it can be done immediately. It does cost money to re-insulate a house, but it can still be done quickly, and the cost can often be recovered from the energy savings.

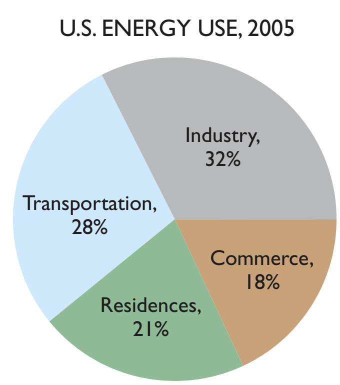
In contrast, replacing fossil fuels with other sources of energy is slow and expensive. To replace the 12 trillion watts of fossil fuel power the world currently uses with nuclear power would require around 12,000 new nuclear plants. To replace it with wind power would require 36 million windmills.



Unfortunately, using less energy can only go so far. The developed countries, at the left of the graph, may be able to cut their energy consumption in half, but that will still leave them using too much energy. The developing countries on the right of the graph don't have enough energy as is and need more energy to meet the needs of their people and provide for their growing populations. The only way the developing countries will be able to get the energy they need and the developed ones cut emissions as much as they need to will be to switch to low carbon sources of energy.

Thus, if the world is to reduce fossil-fuel emissions, it will have to follow both the conservation and the alternative energy paths. The developed countries can and should cut emissions—the fast path— immediately. Then they and the developing countries can develop low-carbon energy sources—the slow path but the lasting one—more gradually.

Reducing U.S. Fossil Fuel Use Means Reducing Our Own Fossil Fuel Use



Our concern here is with how the United States can reduce its fossil use, and what role the Adirondacks could play in that.

The quick answer is that the United States can best reduce its fossil fuel use by a national program of energy conservation and new energy technologies, and we, and everyone else in the country, will have to be part of it. The program will have be national, because no one but the federal government will have the ability to create the economic incentives it will require. But it will also involve individuals, because much of our energy consumption is consumption by individuals.

Traditional graphs of energy use, like the one shown here, hide the extent of individual consumption. Residential energy use is clearly individual consumption. But so is perhaps of half of transportation (which sells us the things we buy) and industry (which makes them). Taking these together, it seems likely that individual consumption of fuel and good account for at least half of the energy used in the United States

If this is true, then the only way that the United States will reduce its total fossil fuel consumption is if every one in the United States reduces their individual fossil fuel consumption. This will not be enough—farms and businesses and the government itself will have to reduce consumption too. But it will be essential. We are the ones who use much of the fuel, and so we are the ones who will have to do something about it.

How does a household reduce its fossil fuel consumption?

We focus on households from now on, because the people in a household share resources, and so the household is the natural unit for measuring energy consumption.

If a household wants to make a serious attempt to cut its fossil fuel consumption, it will have to do three things.

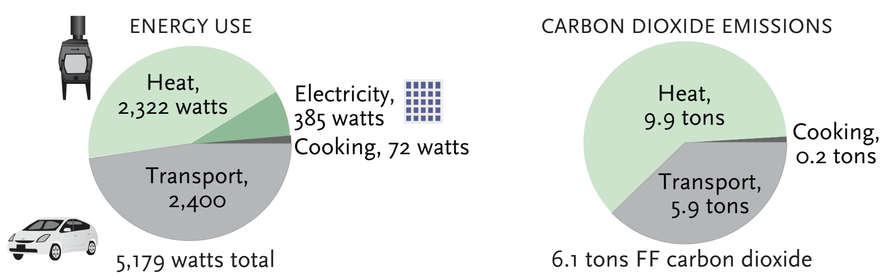
First it will need to figure out how much energy it uses and how much fossil fuel carbon it emits.

Second, it will have to reduce its carbon emissions, either by using less energy or switching to energy sources that emit less carbon.

And third, if it has emissions that it can't reduce, it should consider offsetting these emissions by subsidizing emission reductions elsewhere.

We consider each of these in turn, using Adirondack households as examples.

ANNUAL ENERGY & EMISSIONS OF A HOUSEHOLD WITH RENEWABLE HEAT AND POWER



How do we determine how much energy a household uses and how much carbon it emits?

The best way is by taking the actual consumption—the fuels used, the mileage traveled— and multiplying it by conversion factors. Thus every gallon of gasoline burned in a year represents an annual power consumption of 4 watts, and an average CO_2 emission of 0.01 tons. The results give an energy and carbon budget.

The graphs show the author's budget. He lives in an old house that has been rebuilt with modern windows and insulation, heats with wood, cooks with propane, and gets his electricity from solar panels. He travels for work in a car that gets 25

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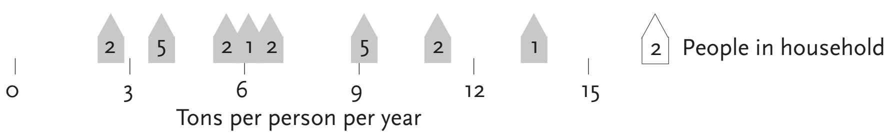
miles per gallon. His total power use is 5,200 watts of which 48%, shaded gray in the figure, comes from fossil fuels. His total CO_2 emissions are 16 tons, of which 9.9 (shaded green) come from wood and 6.1 come from fossil fuels. The carbon released from the wood is offset by carbon taken up by other trees in his woodlot and so is carbon neutral, and thus his net carbon emissions are 6.1 tons.

This calculation does not include the energy used to grow food and produce the other goods (in the author's case mostly books and beer) that the household buys. These are important, but at present there is no good way of calculating them. The author buys about 80% of his food from organic producers within a hundred miles of where he lives. This still represents carbon emissions: a ton of CO_2 might be a reasonable guess. If he were buying prepared foods from the supermarket or energy-intensive food produced on farms farther away, it might represent several tons more.

How much carbon do Adirondack households emit?

We have prepared carbon budgets for about 20 households. Eight are shown at the right. They differ greatly in total emissions, but this is partly because there are different numbers of people in different households. On a per capita basis the emis-

PER CAPITA CO_2 EMISSIONS OF EIGHT HOUSEHOLDS



sions cluster more, and are mostly between 3 and 10 tons per capita. The lowest per-capita emissions are from a family two in a small, efficient, off-the-grid house. The largest, ironically, are from a single person who lives in a cabin of only 280 square feet but travels a lot.

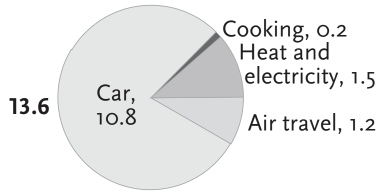
The budgets show several common features. Heating is significant in all budgets. Six out of eight have wood heat, and for five of these wood is the major source of heat, greatly reducing fossil fuel emissions. Electricity is less significant, and doesn't contribute more than an eighth of the carbon emissions in any budget. (This is because electricity in New York is relatively green, with much nuclear and hydropower and few coal-fired plants.) Transportation is very significant, and accounts for over half of the fossil fuel carbon emissions in every household.

Carbon budgets like these are valuable planning tools. They suggest, for example, that most of these households should concentrate on reducing emissions from transportation and heating first and electricity second. They are also valuable as benchmarks. They show what the emissions have been, and whether they have been decreasing.

We give charts for preparing energy and carbon budgets on pp. 58-59 of this report, and hope every reader will make one for her or his household. If you are reading this, it is because you want to become a better citizen of the planet. Energy and carbon budgets are your first step.

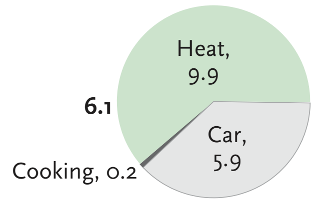
CARBON DIOXIDE EMISSIONS OF EIGHT NORTHERN NEW YORK HOUSEHOLDS

SMALL BATCHELOR CABIN



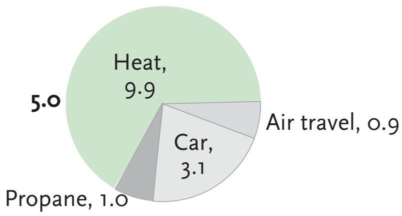
Single professional, small, electrically heated cabin, travels for work

OLD FARM HOUSE WITH SOLAR



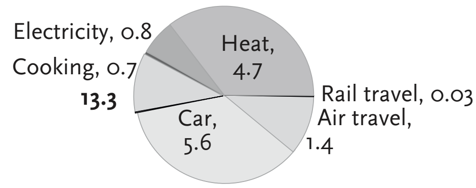
Single researcher, travels for work, with wood heat and grid-tied solar power.

OFF-THE-GRID FAMILY



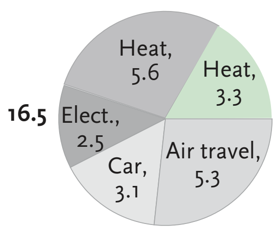
Single parent and child, small, efficient, house, wood heat, propane for ?.

OLD HOUSE IN TOWN



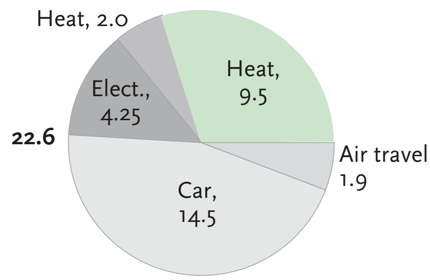
Professional couple in 1920s frame house, oil heat, travel for work

HISTORIC HOUSE IN VILLAGE



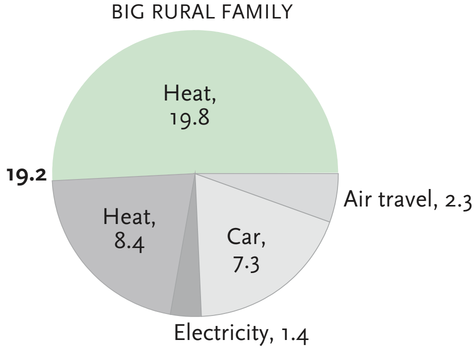
Professional couple and child in restored house in historic district.

EFFICIENT RURAL HOUSE



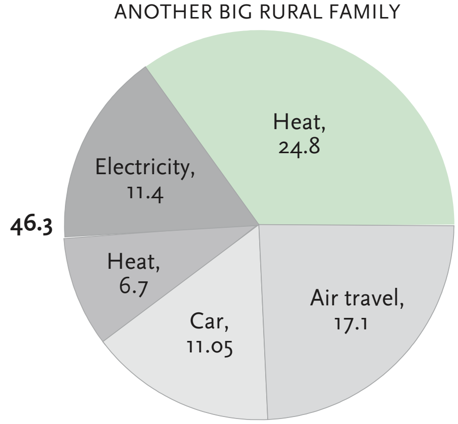
Professional couple in modern rural house with passive solar, both commute to work.

BIG RURAL FAMILY



Rural family of five in a medium-sized house, modest electricity and travel

ANOTHER BIG RURAL FAMILY



Rural family of five in a large house, much electricity and travel

Emissions from wood

Emissions from fossil fuels

8.2 Tons CO_2 per year **13.6** Tons of fossil fuel carbon per year

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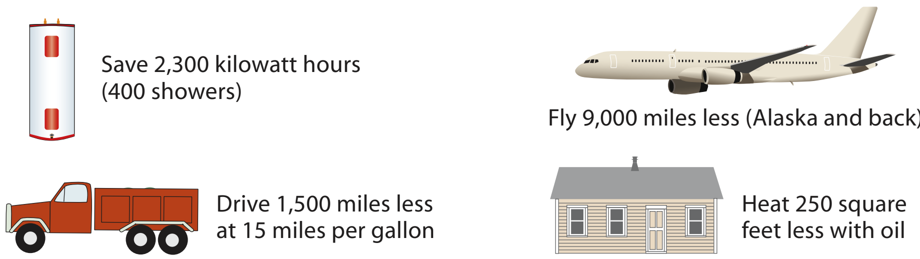
HOW TO SAVE 1 TON OF CARBON DIOXIDE BY REDUCING ENERGY CONSUMPTION

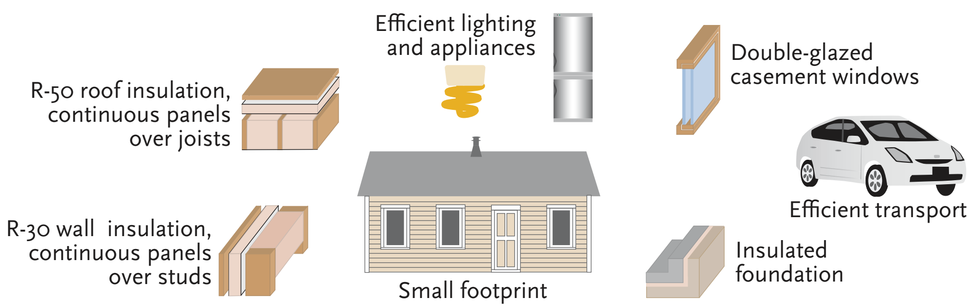


How can households reduce their energy consumption?

The first step in reducing carbon emissions is to reduce energy consumption. This is done by eliminating as much consumption as you can, and by making the remaining ones as efficient as possible.

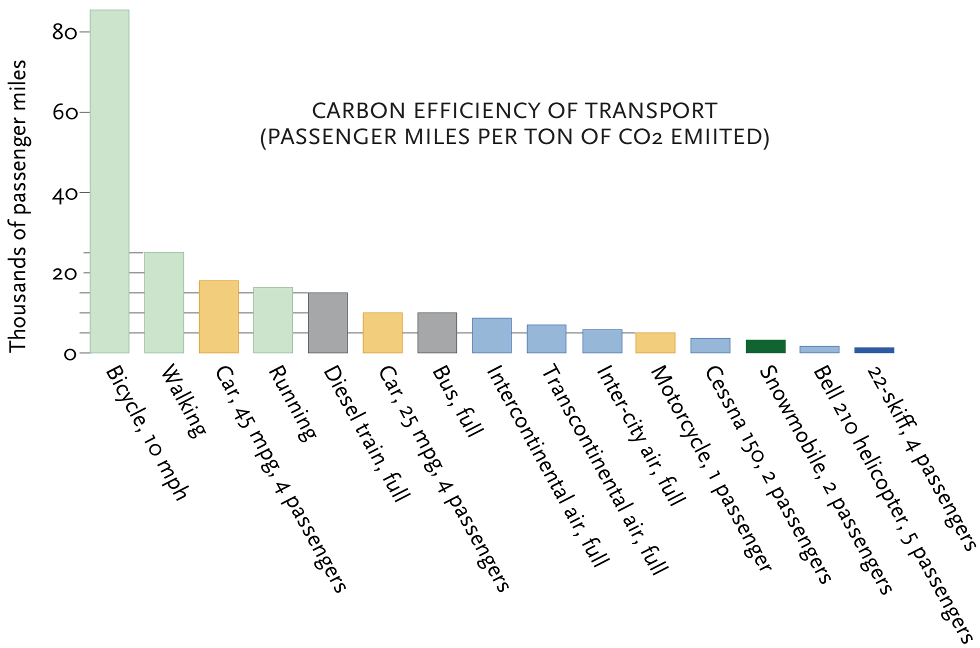
The cheapest way to reduce energy consumption is to not do things that use energy. It is cheaper to turn light bulbs off than replace them with fluorescents. It cheaper to not heat a wing of an old house than to insulate it, and cheaper to drive 20% fewer miles than buy a new car that is 20% more efficient. Modesty and simplicity have always been commendable. Now they may be essential.

A LOW ENERGY HOUSEHOLD



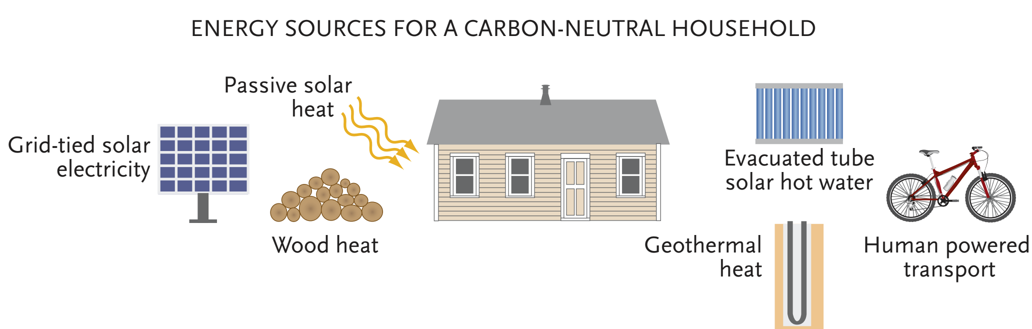
After you have reduced unnecessary consumption, the next step is to make the remaining energy uses more efficient. This involves sealing and insulating houses and choosing efficient appliances and transport. Unlike simply eliminating uses, this step is not cheap. A new, energy-efficient car is over $30,000. It cost the author about the same amount in materials, plus many months of his own labor, to rebuild and re-insulate his old house. But it has its rewards too. Learning to drive efficiently by watching the mile-per-gallon readout in a fuel-efficient car is fascinating. The author's old house, formerly one of the coldest pieces of 1840s' architecture still standing, is now cozy, and there is much less wood to cut and carry.

Finding efficient transport is difficult, because transport, at least over the kind of distances that we take for granted, is invariably energy intensive. If you have time and energy you can bicycle to Alaska and back at a few hundred watts of power and emit perhaps a hundred pounds of carbon dioxide. But if you want to get there



quickly and easily, this will require tens of thousands of watts of power, and emit a thousand pounds of carbon dioxide.

Since mechanical transport is carbon-intensive, it matters a great deal what kind we use, and even more how many passengers it is carrying. The graph shows some approximate figures for the carbon mileage (passenger miles per ton of CO_2) for different vehicles. Note the numbers of passengers matters more than the type of vehicle. An efficient car with four passengers is as good as a train, better than a loaded bus, and hence much better than a half-full bus. Also notice that light planes and other small, relatively high-powered machines (snowmobiles, motorcycles) are not very good, and that helicopters and small power boats are the worst of the worst. A five-pasenger helicopter of the sort commonly used for rescue work in the Adirondacks uses as much power in thirty minutes as the author's four kilowatt solar system generates in a year.

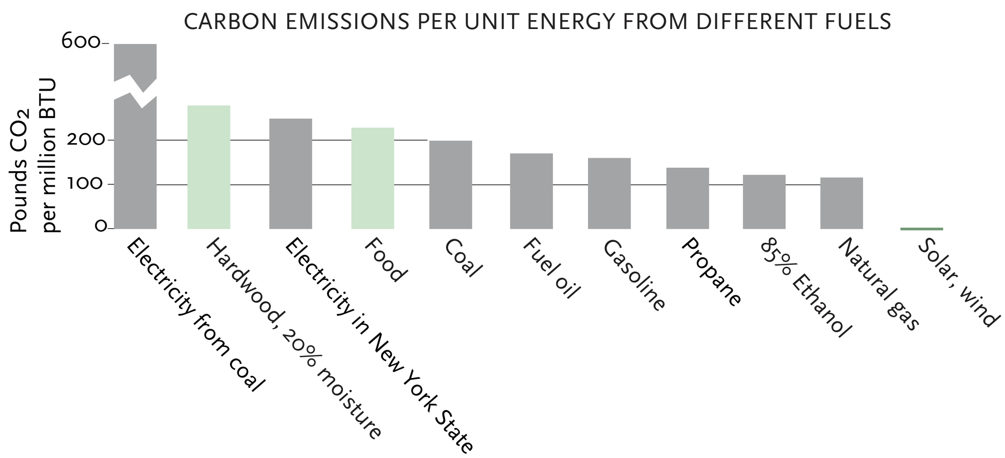


What fuels are most carbon efficient?

After a household reduces its energy consumption as much as possible, it can then further reduce its carbon emissions by choosing the fuels that emit as little carbon as possible for a unit of energy.

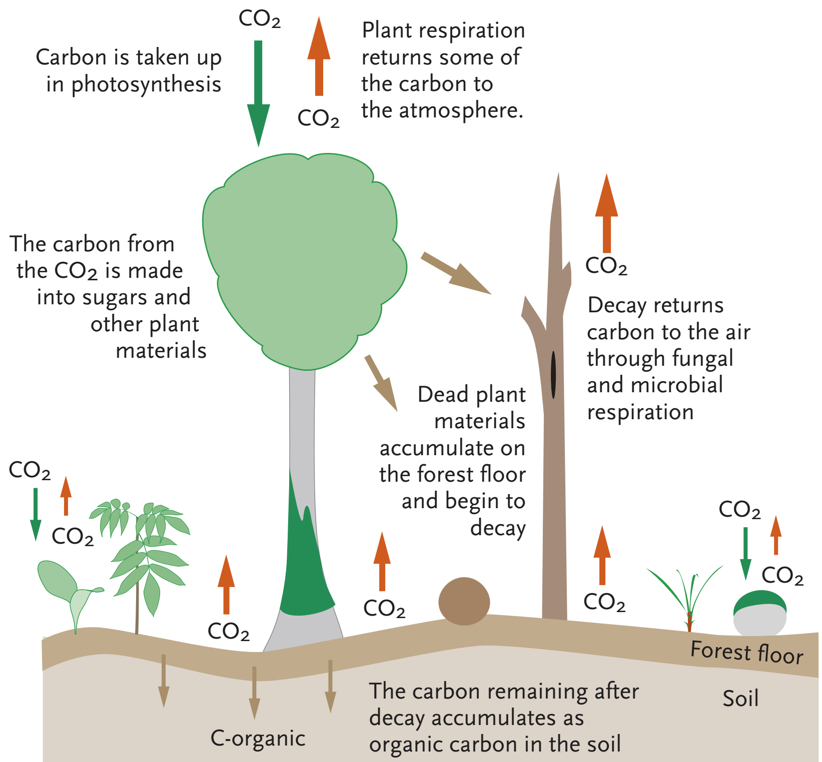
The most efficient fuels are those that emit no carbon or emit biological carbon that will be subsequently removed by growth. Solar electricity, solar hot water, and direct solar heating are carbon free. Geothermal heat requires electricity, but becomes carbon free when combined with solar electricity. Human-powered transport and wood heat emit carbon—lots of carbon in the case of wood heat—but are carbon neutral if the carbon is reabsorbed by crops and forests and doesn't stay in the air.

Switching to carbon-neutral and carbon-free fuels is expensive, but not prohibitively so. Wood heat for a 2000-square-foot house might cost $5,000, solar electricity $20,000 after state and federal rebates and tax incentives, and geothermal heat $20,000-$30,000. All these are comparable in cost to a new car, and many houses have new cars. Unlike new cars, green carbon and zero carbon technologies are good for the planet as well as their owners. And also unlike all new cars, the more you use them the more money you save.



Households using fossil fuels will not be carbon neutral but can still reduce their emissions by using lower emission fuels. Fuels differ in their carbon and energy contents, and hence in the amount of carbon they emit per unit of energy. Natural gas is the cleanest fossil fuel, releasing the lowest amount of carbon for a given amount of energy. Propane is about 20% worse than natural gas, and fuel oil 35% worse. Coal is very bad; a house heated with coal emits almost twice as much carbon dioxide as one of the same size heated with natural gas. Wood is also a high emitter, but if harvested sustainably the emissions are reabsorbed and do not accumulate in the air. Fossil fuel electricity is always bad, because electrical generation is an inefficient use of fuel. Heating a house with electricity derived from coal emits four times as much carbon as heating the same house with fuel oil, and six times as much as heating with natural gas.

Thus, fuel choices are important. The lowest carbon households are going to be small, simple, well-insulated ones which use carbon-neutral fuels. Among the others, the ones that use electricity sparingly and heat with propane and natural gas are going to be significantly more efficient than those that use more electricity and heat with coal or oil.



8 FORESTS CAN REMOVE CARBON AND REPLACE FOSSIL FUELS

Forests, like other living communities, store carbon and produce biomass. This gives them a double role in the climate change story. They can be used to produce carbon-neutral fuels that can replace fossil fuels, and they can be used to remove carbon from the atmosphere. In the first role, they are like other alternative forms of energy. In the second role they are unique. We have other ways, like solar and geothermal, of getting carbon-neutral energy. But we have, as yet, no artificial way of getting carbon out of the atmosphere once it has been released.

The capacity of forests to remove carbon and produce biomass is significant but not enormous. An acre of young Adirondack forest growing vigorously, stores energy at an average rate of about 400 watts. The average rate of energy use of the households whose carbon budgets are shown on page 43 is 5,000 to 10,000 watts. If these households were to try to get all their energy from the forests, and if they could capture half of the forest's energy on a sustainable basis, each household would need 25 to 50 acres of forest to provide its energy. This might work in a rural area like the Adirondacks where the population density was 10 to 20 persons per square miles, but it would not work in developed areas where the population density is higher.

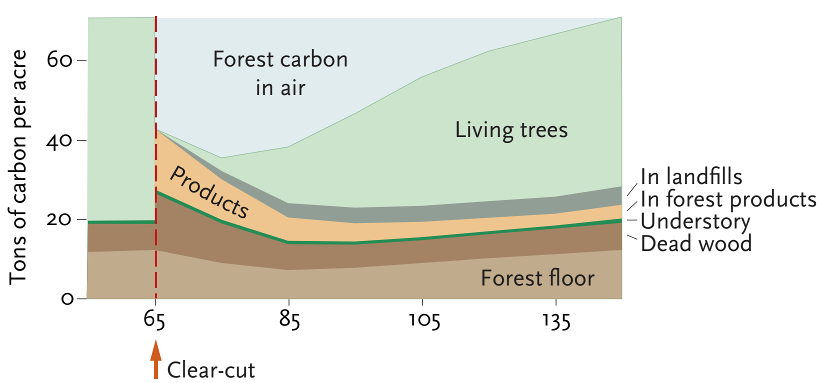
Another estimate of the significance of Adirondack carbon storage comes from looking at the Adirondack Park as a whole. We estimate that Adirondack forests, if unharvested, would store somewhere around 7 million tons of CO_2 every year. This is probably comparable to or larger than what the Adirondacks emit every year. But it is only 3% of the 200 million tons that New York State emits every year.

Thus the Adirondack forests can make an important contribution to the energy and carbon budgets of the Adirondack region but can only contribute a few per cent to the carbon economy of New York as a whole. This does not mean they are negligible, but only that they can be at most a small part of the solution of a large problem.

How does forest management affect forest carbon budgets?

Small or not, forests can have beneficial greenhouse effects, and it the coming century it will be important to manage them to maximize these benefits. To do this we need to know how forest management affects the carbon stored in the forest.

THE REDISTRIBUTION OF CARBON AFTER A CLEAR-CUT



The principles involved are summarized in the graph above and shown in more detail in the diagrams on the right-hand page. In their simplest form they are that:

Left to themselves, forests will store carbon for many years. The rate declines as the forest gets older but doesn't go to zero. Many forests 150 years old or more are still storing carbon at appreciable rates.

When a forest is cut, stored carbon is released into the air. The carbon will eventually be recaptured by growth, but while it is in the air, it causes climate change.

The wood removed from a forest is variously used for energy, made into products, or discarded as waste. The carbon in wastes, short-lived products, and biomass used for energy is released into the air quickly. The carbon in long-lived products is also released into the air, but more slowly.

The transport of logs and the manufacture and transport of forest products usually requires fossil fuels and releases additional carbon in the air.

The forester or forest owner who wants to manage land for carbon benefits is thus faced with a dilemma. Every forest operation releases carbon into the atmosphere and thus has an adverse short-term greenhouse effect. The carbon forester's problem is to secure enough long-term long term benefits to offset the short term damage done by the releases duiring harvest.

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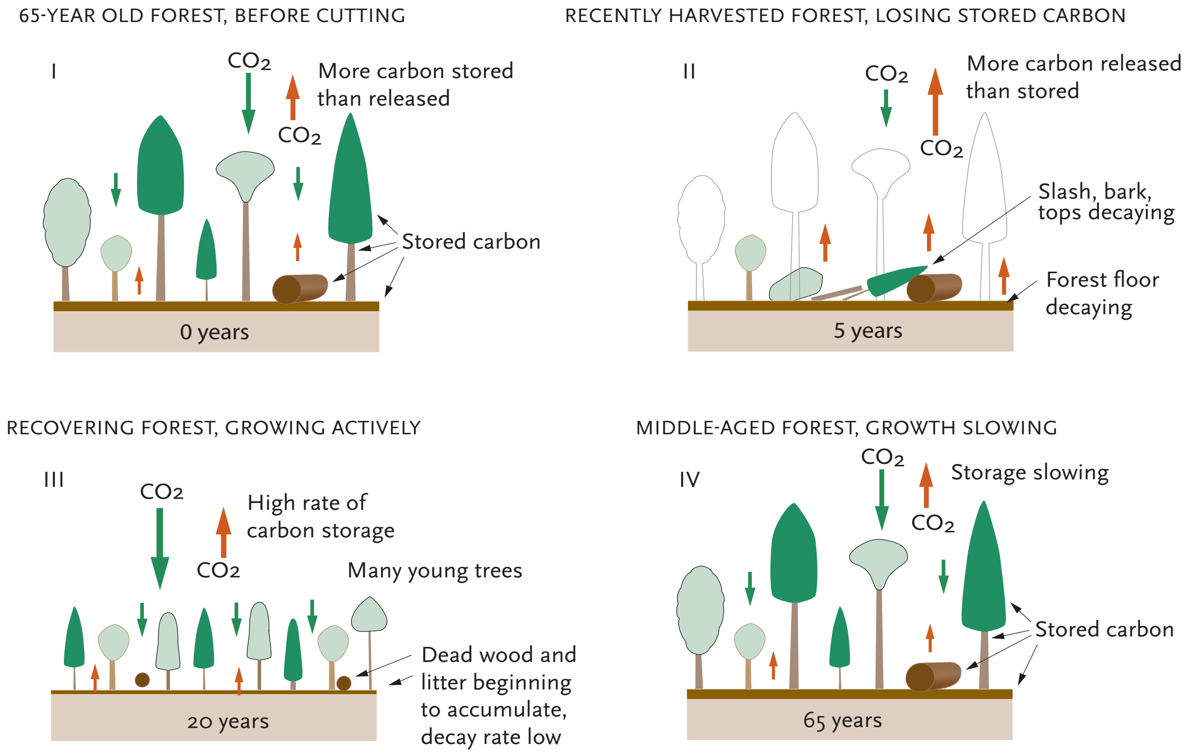
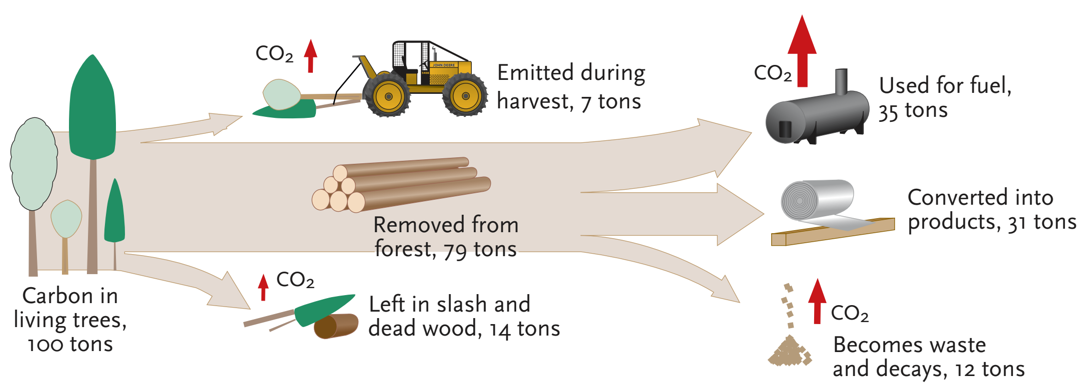
CHANGES IN FOREST CARBON THROUGH A CUTTING CYCLE



CARBON FLOWS FROM A CLEARCUT HARVEST



How can forests be managed to maximize greenhouse benefits?

There are really only three ways that this might be done:

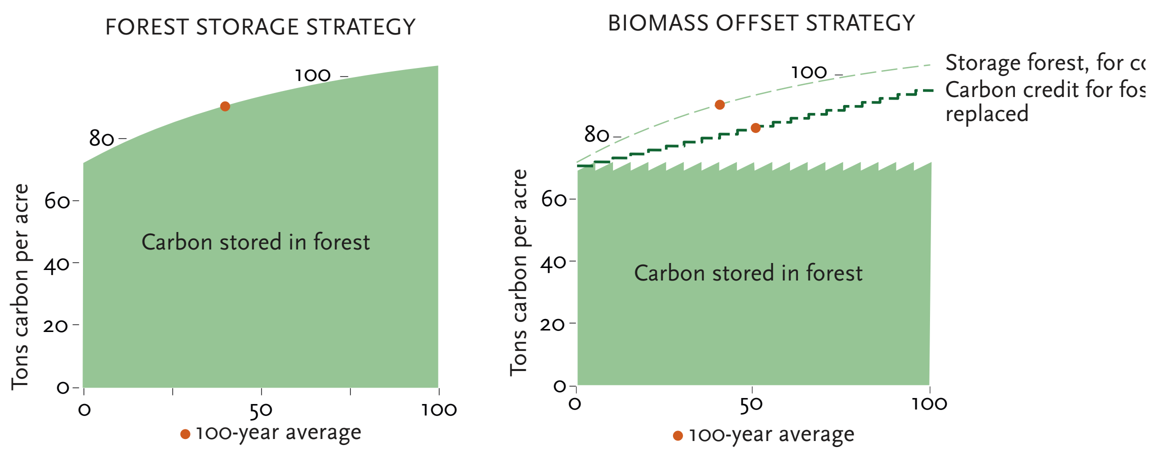
Simply let the forest grow and store carbon naturally, thus avoiding the carbon releases associated with harvests altogether (*Storage strategy*).

Convert some or all of the harvested wood into fuel, and use this fuel to replace fossil fuels (*Biomass strategy*).

Convert some of the harvested wood into long lived products, and hope that the carbon stored in these products offsets the carbon released into the atmosphere (*Products strategy*).

To determine which of these strategies is best, we have to compute the flows of carbon in and out of the forest over some period of time, say a hundred years. The quantity that best captures the greenhouse benefits is the average amount of carbon in the forest over this time.

Here are diagrams of the first two strategies, applied to a 65-year old forest. The red dots show the average storage. In the forest storage strategy the forest is simply let grow. In the biomass offset strategy the forest is maintained at a constant carbon level by harvesting sustainably at the growth rate (this way the carbon from harvesting is removed the same year it is released). The energy from the harvested products is used to replace fossil fuels, resulting in a carbon credit that accumulates over time.

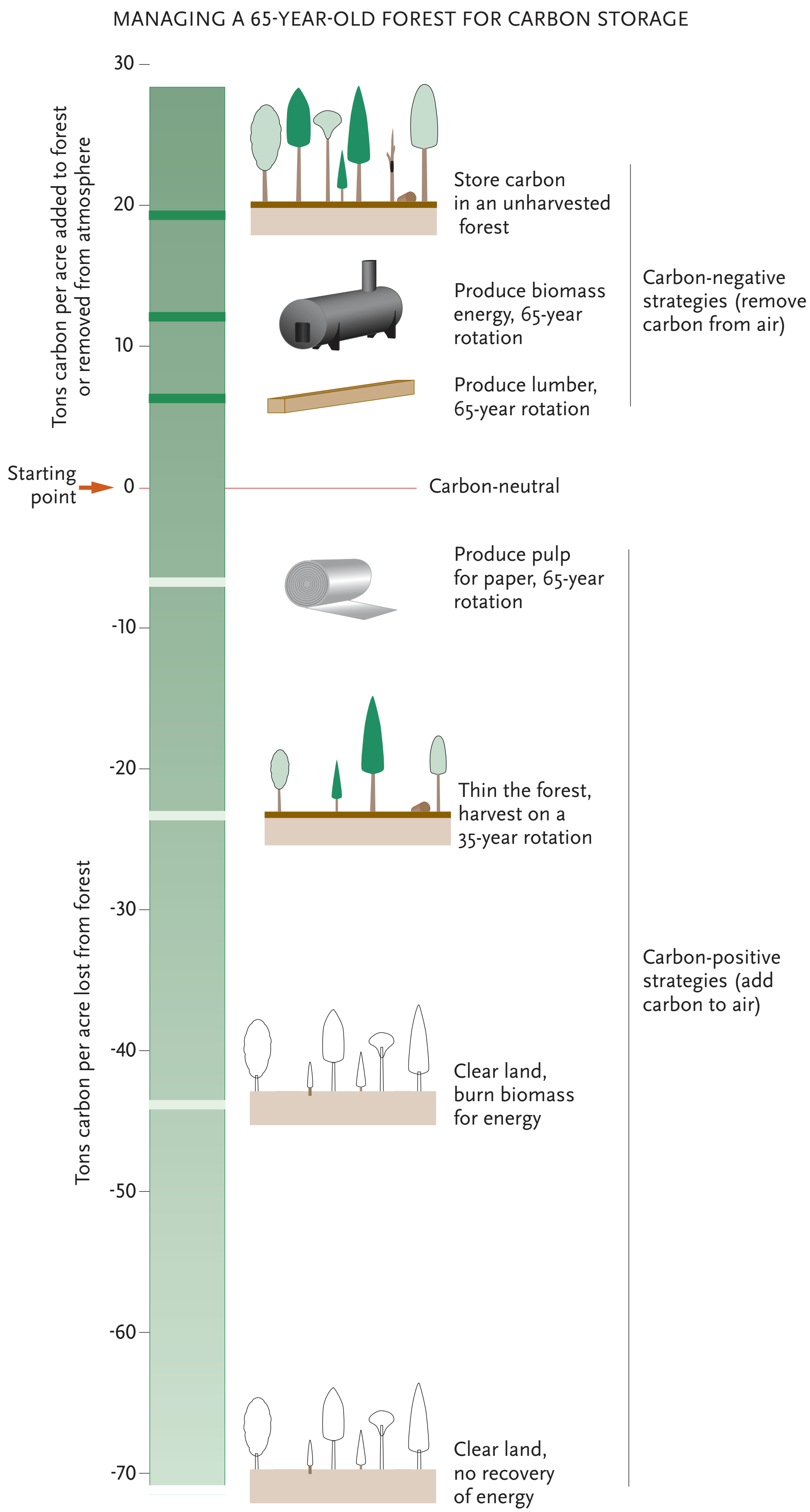


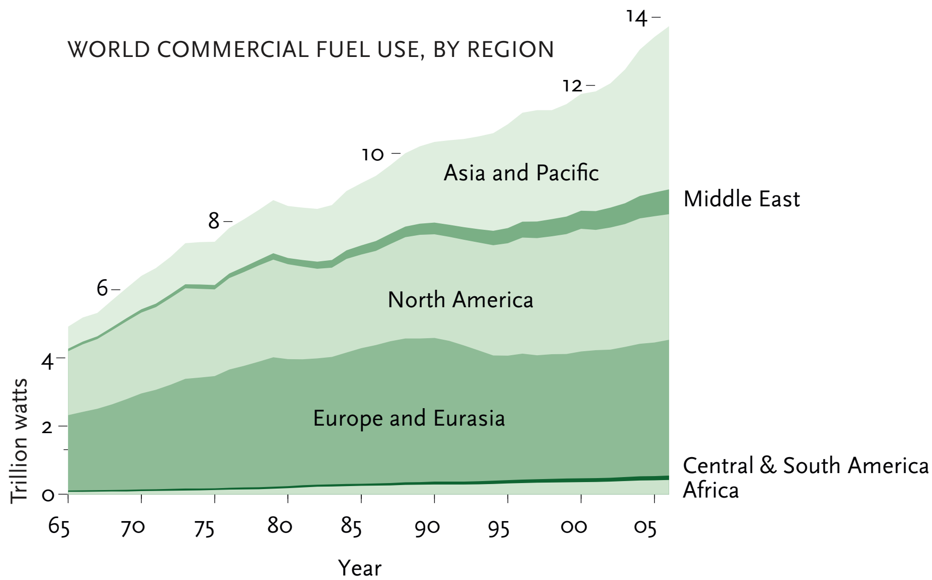
Both strategies are carbon-negative and so have climate benefits. One removes carbon from the atmosphere, the others prevents more carbon from being emitted. Because you neither can nor should convert 100% of the growth into fuel, the storage strategy has better short-term, carbon benefits. But it produces no income, and income drives forestry. The biomass strategy both has carbon benefits and produces income, which is an excellent combination.

Compared to these two strategies, the other strategies are either harmful (climate positive, releasing carbon) or at most slightly negative. Long-lived products turn out to be a poor way of storing carbon because very little carbon actually winds up in the products, and because fossil fuel energy (not accounted for in our analysis) is required to manufacture and transport them. They probably turn out to be at best carbon neutral.

Other strategies are clearly carbon positive. Making paper or other short-lived, energy-intensive products is carbon-positive because fossil fuel energy is used in the manufacture and there is no long-term carbon storage. Thinning forests and shortening cutting cycles to accelerate growth is carbon positive because it releases carbon and then doesn't allow the forest to grow old enough to reabsorb it.

Finally, clearing forest land for development is the worst carbon strategy of all, because all the carbon from the forest goes into the air, and there is no forest left to reabsorb it. A new house with an acre of cleared ground comes with a forty-ton to seventy-ton carbon debt and, because grass isn't as good at storing carbon as trees, no way of paying it.


MANAGING A 65-YEAR-OLD FOREST FOR CARBON STORAGE
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
Tons carbon per acre added to forest or removed from atmosphere
Tons carbon per acre lost from forest
Starting point
Store carbon in an unharvested forest
Produce biomass energy, 65-year rotation
Produce lumber, 65-year rotation
Carbon-negative strategies (remove carbon from air)
Carbon-neutral
Produce pulp for paper, 65-year rotation
Thin the forest, harvest on a 35-year rotation
Carbon-positive strategies (add carbon to air)
Clear land, burn biomass for energy
Clear land, no recovery of energy



9 WE MUST ACT SOON

We end this paper where we started, with world energy consumption and the prospects for world climate change.

The world and the Adirondacks are closely tied. How much the Adirondacks warm will be determined by how much the world warms. And conversely, how fast the world warms will be determined by how much energy we and other people like us, consume.

Currently the world picture is not good. World energy use and world carbon emissions are rising at the fastest rate that they have in forty years. Between 1970 and 2000, atmospheric carbon dioxide rose at a steady rate of 1.5 parts per million per year. Since 2000 the rate has accelerated, averaging 2.1 parts per million per year.

The increasing rate of consumption is alarming. At a minimum, it suggests that we are currently above the highest emission scenario in the graph on p. 18, and will have to work all that much harder to achieve meaningful emissions reductions in the next century.

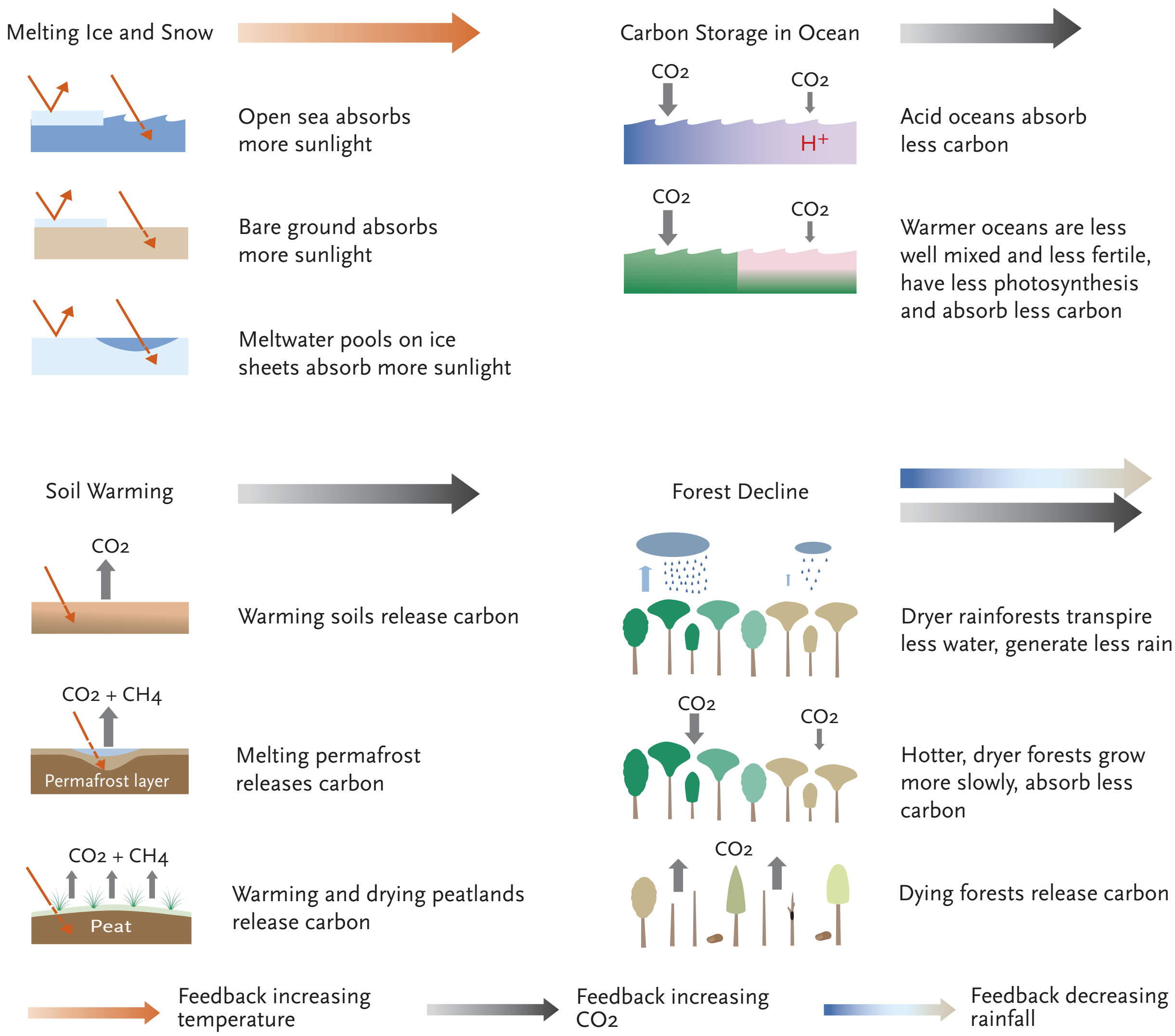
At a maximum, it suggests that we may be capable, within the next century, of pushing the planet to a temperature where natural processes start releasing large amounts of carbon from forests and soils. If this happens, climate change may become uncontrollable. We will, in effect, have lit a planetary fire that will be beyond our ability to put out.

In this section, we look briefly at the risk of runaway climate change. More information can be found in the references cited in the notes and in Mark Lynas's important book *Six Degrees.*

Feedbacks in the Climate Cycle

A positive feedback is a way that a process makes itself run faster. Fires grow and avalanches accelerate because of positive feedback. The risk of runaway climate

POSITIVE FEEDBACKS IN THE WARMING PROCESS



change arises because there are strong positive feedbacks in the climate cycle. In the simplest terms, the fossil-fuel carbon we release today could trigger enough warming to cause large natural releases of carbon tomorrow. These could cause additional warming and lead to even more carbon releases.

The diagram shows a number of ways that this could happen. Some, like the melting of ice and snow, affect temperature directly. As the planet warms it loses ice and snow. This makes it able to absorb more sunlight, and it warms still more.

Other feedbacks work through the carbon cycle. Currently about a third of the fossil fuel carbon released every year is absorbed by the oceans. This process, called the ocean pump, slows the build up of carbon in the air. But as the oceans absorb more carbon dioxide they also become more acid and less able to absorb. Eventually the ocean pump will start to fail, and when it does the carbon dioxide will remain in the air, and increase the rate of warming.

Another feedback, of special concern in the Adirondacks, involves the carbon stored in forests. Currently most forests, including those in the Adirondacks, are carbon sinks, removing carbon from the air and storing it in wood and the soil. Like the ocean pump, this forest pump is of great importance in slowing down global warming, removing about 2 billion tons of carbon from the atmosphere every year.

Also like the ocean pump, at some point the forest pump will start to fail. Warming temperatures will increase the release of carbon from the soil. Dryer summers will reduce photosynthesis. Dominant trees will be pushed beyond their climatic limits. Forests will start to decline, and become carbon sources instead of sinks. Then the temperature will rise more and the cycle will become self accelerating.

The Prospects For World Temperature

The graph, like the one on p. 19, shows the relation between the stabilized CO_2 level when we stop using fossil fuels and the final world temperature rise that results. It is adapted from a similar graph in the 2007 IPCC *Impacts Adaptation, and Mitigation* report. The bold Roman numbers (**I**, **II**, **III**) indicate the final CO_2 levels and possible range of warming for the low-, medium-, and high-emission scenarios shown on p. 18.

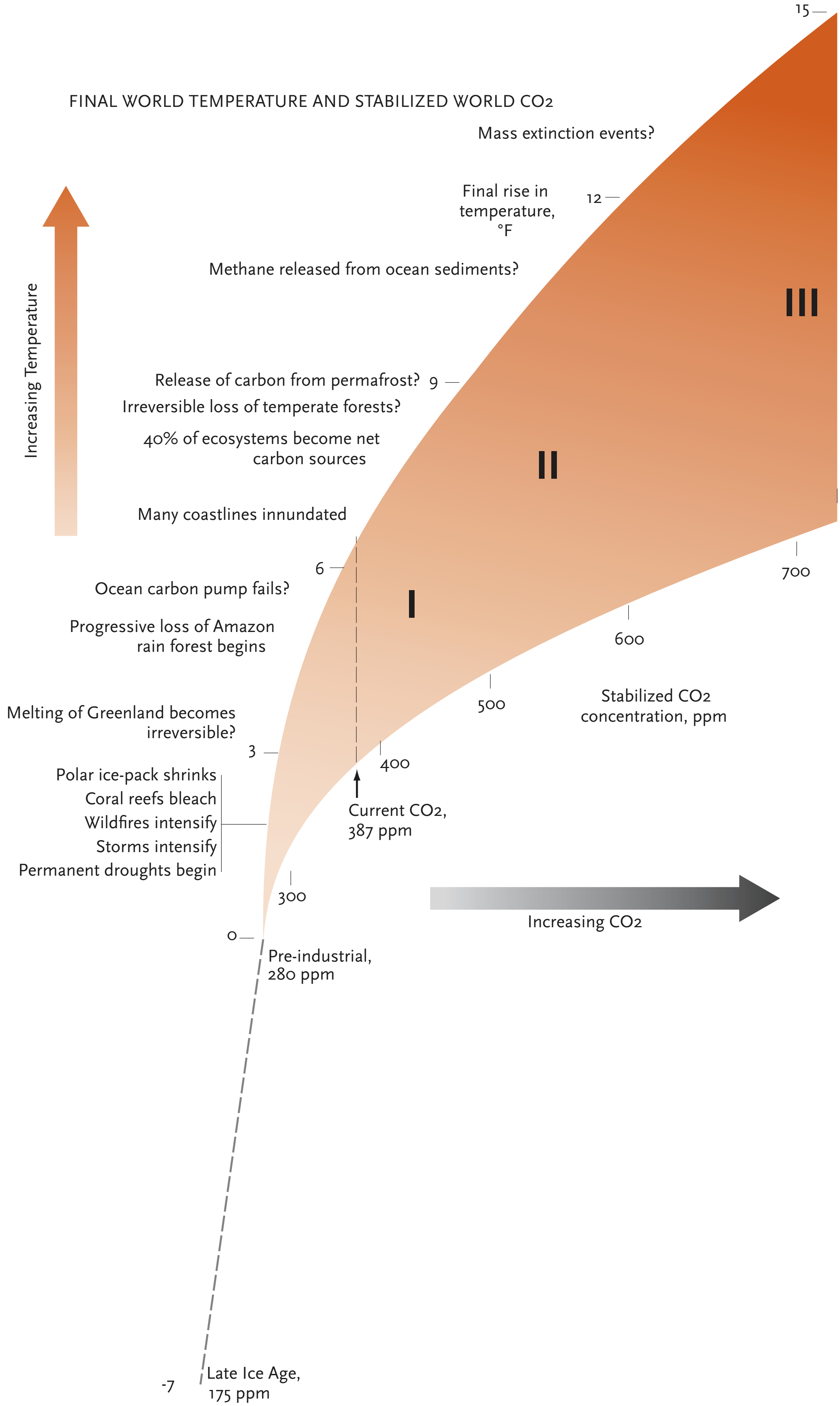
The labels to the left of the graph indicate possible feedbacks and consequences. They have been taken from the literature and from other sections of the *Impacts Adaptation, and Mitigation* report. Many have question marks under them, indicating that the temperature at which they will occur is uncertain. All are believed to be possible within the temperature range shown on the graph, but there is considerable uncertainty about when they will start and at what temperature they will become irreversible.

The graph is shocking. Were it not drawn from the consensus report of the world's preeminent climate science organization, it would doubtless be dismissed as alarmist and sensational.

The graph says, for example, that the CO_2 we have already added to the atmosphere commits us to a world warming of 3 to 6 degrees. As a result, we may not be able to avoid at least partial losses of the losses of the Amazon rain forests, the Greenland ice sheet, and the ocean carbon pump. Each of these will cause more warming, and then, perhaps, further losses.

The graph also says even with moderate emission reductions under Scenario **II**, we may find ourself in a temperature regime that is farther from the temperature of 1900 than 1900 was from the late ice ages. At those temperatures it is possible that we will see great changes in the habitability of the earth. Much tropical and dryland agriculture may fail; coastlines will be inundated; mid-latitude deserts will expand; temperate forests will decline and become carbon sources; and the great peat deposits of the boreal zone will be releasing carbon dioxide and methane.

Amidst such a sea of world change, it goes without saying, there will be very little prospect for the survival of the Adirondacks in anything like their present form.


FINAL WORLD TEMPERATURE AND STABILIZED WORLD CO_2
Mass extinction events?
Final rise in temperature, °F
Methane released from ocean sediments?
Release of carbon from permafrost?
Irreversible loss of temperate forests?
40% of ecosystems become net carbon sources
Many coastlines innundated
Ocean carbon pump fails?
Progressive loss of Amazon rain forest begins
Melting of Greenland becomes irreversible?
Polar ice-pack shrinks
Coral reefs bleach
Wildfires intensify
Storms intensify
Permanent droughts begin
Increasing Temperature
15
12
9
6
3
0
-7
I
II
III
300
400
500
600
700
Current CO_2, 387 ppm
Stabilized CO_2 concentration, ppm
Increasing CO_2
Pre-industrial, 280 ppm
Late Ice Age, 175 ppm

Eagle and raven tracks, Meacham Lake, March 2008

EPILOGUE

Readers who have followed this far, and who take the threats we have just described seriously, will react to the threats in their own way and have their own thoughts about what to do. For what it is worth, here are the author's.

I have been studying natural history for fifty years and climate change for twenty. In the last few years I have been seeing changes, particularly the rapid melting of the polar ice pack and the Greenland and Antarctic ice sheets, that scientists had believed would not come for many years.

As a result, I have come to take the threat of runaway climate change seriously. It appears to me that humans have, within my lifetime, gone from the ability to damage parts of the planet to the ability to damage the planet as a whole. I am not sure this is true but think that it may be.

I also see changes closer to home. We have new birds, less snow and ice, different seasons and colors, new diseases. Thus far, these are not threatening. But they represent, if the climate models are right, the warning signs—the high clouds the day before the storm—of larger changes that could be very threatening.

The large changes will probably not come in this generation and, with luck, not in this century. But the models say not to wait to act. Even though climate change has barely begun, we may already be near a critical point in the earth's carbon balance, and what we do in the next few decades may influence the future of the planet for centuries to come.

If this is true, our generation has a great responsibility to do the right thing. I hope we will, some day, be judged to have been worthy of it.

As I think about this responsibility, I keep coming back to the idea that a surprising amount of it is individual. Nations and institutions of course have major roles in the climate story, and we will be able to accomplish nothing without national and international leadership. But individual consumption drives much energy use, and it is we as individuals who do the consuming and who, in the last analysis, must change what we do.

The thought that we have individual responsibility for stopping climate change is discouraging, because the amount an individual can do is small and there is so much to be done. But it is also encouraging, because we can act immediately, without waiting for governments and treaties, and because many individuals acting together can do a lot.

And it is encouraging because, unlike nations, we already know what we need to do. We need to assess our own fossil fuel consumption and then reduce it. When we have run out of effective ways of reducing our own consumption, we need to offset this consumption by working with other people to reduce theirs.

Good tools for doing this already exist. Using them, of course, takes money and energy. Some of you reading this will not have resources to change your fossil fuel consumption. Here I see a role for government, and hope soon there will be a government climate action program to help you.

Many of you, on the other hand, have the resources to change your own consumption and possibly to help your neighbors change theirs as well. To you I say, "What are you waiting for?" Our parents and grandparents were asked to save the free world and they did. You are being asked, with apologies for a dramatic phrase, to save the planet. It is the great challenge, the great battle if you like, of our generation and perhaps one of the greatest to face any generation.

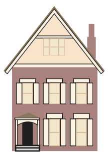
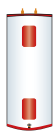
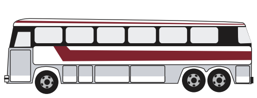
And it will be exciting to be part of. For the last five years, I have both been trying to research and write about climate issues and change my own climate footprint by rebuilding my house and installing solar power. The process has taught me that thought, by itself, can become fearful and draining, and needs to be balanced by action. Yeats said of that balance:

> When at last all words are said,
> And a man is fighting mad,
> Something drops from eyes long blind,
> He completes his partial mind,
> For a moment stands at ease,
> Laughs out loud, his heart at peace.

To those of you who may also be feeling darkness or confusion, I recommend the energy and solace of action.

Where then, readers, do you stand? Are things as serious as I take them to be? If so, how should we act? What should we do first? Will you start? Will you lead us?

HOUSEHOLD WATTAGE CALCULATOR (THIS GIVES THE AVERAGE ENERGY CONSUMPTION PER YEAR IN WATTS)

		Watts used
HEATING FUEL		
	______ Gallons of fuel oil or kerosene x 4.6 =	____________
	______ Gallons of propane x 3 =	____________
	______ Cords of wood x 730 =	____________
	______ Tons of coal x 830 =	____________
ELECTRICITY		
	______ Thousand kilowatt hours x 110 =	____________
ALTERNATE CALCULATION OF HEAT PLUS ELECTRICITY		
	______ Thousand square feet in house x 1500 =	____________
TRANSPORT		
	______ Thousand car miles x 4000 / miles per gallon =	____________
	______ Thousand train miles x 27 =	____________
	______ Thousand bus miles x 41 =	____________
	______ Thousand long-haul air miles x 50 =	____________
	______ Thousand short-haul air miles x 73 =	____________
LIGHT MACHINERY, RECREATION		
	______ Gallons of gasoline x 4.0 =	____________

To get average power consumption in watts, multiply the yearly usage by the conversion factors given above. To get the energy used in millions of Btus per year, multiply the wattage by 0.03.

HOUSEHOLD CARBON CALCULATOR

Tons of CO_2 emitted

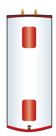
HEATING FUEL

_______ Gallons of fuel oil or kerosene x 0.011 = ______________

_______ Gallons of propane x 0.0063 = ______________

_______ Cords of wood x 3.3 = ______________

_______ Tons of coal x 2.7 = ______________



ELECTRICITY

_______ Thousand kilowatt hours x 0.43 = ______________

ALTERNATE CALCULATION OF HEAT PLUS ELECTRICITY

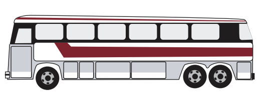
_______ Oil heat: thousand square feet in house x 4 = ______________

_______ Electric heat: thousand square feet in house x 5.5 = ______________

TRANSPORT

_______ Thousand car miles x 10 / miles per gallon = ______________

_______ Thousand train miles x 0.067 = ______________



_______ Thousand bus miles x 0.1 = ______________

____

_______ Thousand long-haul air miles x 0.11 = ______________

_______ Thousand short-haul air miles x 0.16 = ______________

LIGHT MACHINERY, RECREATION

_______ Gallons of gasoline x 0.01 = ______________

SOURCES AND NOTES

For authority and consistency, we have tried to use a relatively few, widely accepted sources in preparing this report. The major ones are

Weather data: United States Historical Climatology Network (USHCN), cdiac.ornl.gov/epubs/ndp/ushcn/newushcn.html; National Snow and Ice Data Center (NSIDC), nsidc.org

Energy consumption and emissions: United States Depart of Energy, Energy Information Agency (EIA), eia.doe.gov; *BP Statistical Review of World Energy, June, 2007*, British Petroleum Company (BP).

World climate change, impacts, scenarios: Intergovernmental Panel on Climate Change, 2007. *Climate Change 2007. Volume I, The Physical Science Basis. Volume II, Impacts, Adaptation, and Vulnerability. Volume III, Mitigation of Climate Change.* Cambridge University Press. Abbreviated IPCC I, II, III.

Regional climate change: Northeastern Climate Impacts Assessment (NECIA), northeastclimateimpacts.org, and various reports and technical papers on their website.

p. 4 Temperature data from the USHCN. the points are the averages of 19 stations, smoothed by a LOESS smooth. Carbon cycle from IPCC I.

p. 5 Carbon emissions and atmospheric carbon dioxide from IPCC I. Lower figure is original. The observed temperatures are computed from USHCN data. The high- low-emission predictions are from the NECIA.

pp. 7-11 All climate data from the USHCN. Lake ice data from the NSIDC. The analysis and the graphics are original.

p. 13 The figure is original, from published rates of fuel consumption. Notes that the powers given are the input power—the rate at which the machine consumes energy—and not the mechanical power the machine produces.

p. 14 Original figure, based on the survey of Adirondack households described on p. 43. Emission factors taken from EIA.

p. 15 Upper figure from EIA data. Lower figure original. The windmills are assumed to be 1 MW and have a capacity factor of near 100%; the solar cells are assumed to produce 10 KW hours per square foot, typical for the northern parts of the country. The nuclear plants are assumed to be 1 GW and have a capacity factor near 100%. The forest is assumed to capture energy at 400 W per acre, and to provide 200 W per acre of biomass or biofuel.

p. 16 Data from EIA.

p. 17 Data from IPCC III. Estimate of fossil-fuel reserves from different sources differ widely, and are probably only meaningful in a general way.

p. 18 Scenarios from IPCC III.

p. 19 The figure is original, though derived from a figure relating final world CO_2 levels and temperatures in IPCC III. It uses energy consumption data from EIA and assumes, based on the NECIA models, that New York temperatures will rise 1.7 times faster than world temperatures. The estimates of what this will mean for the Adirondacks are original.

p. 20 The figure is original.

p. 21 Upper figure original, lower one based on Iverson, L. Prasad, A., and Matthews, S., "Potential changes in suitable habitat for 134 trees species in the Northeastern United States." Preprint posted on the NECIA web site.

p. 22 Adapted from a simulation by the NECIA.

p. 23 With the exception of the historical photos, the images and figures in this chapter are all original.

p. 24 From National Wetlands Inventory maps prepared by the Adirondack Park Agency.

p. 27 From data gathered by the author, 1982 to 2007.

p. 28 Boreal bird records from research done by Michale Glennon of the Wildlife Conservation Society and her colleagues.

p. 30 The historical images are grayed out because permission has not been secured.p. 31 Chronology from material gathered by Elizabeth McKenna.

p. 33 Snow cover from the NECIA. Ski areas from published maps and several ski area associations. Small ski areas open and close frequently, and the existing maps tend to be out of date and do not always agree with each other.

p. 35 Frog dates from ...

p. 36 Figure is original; data from John Bull, *Birds of New York,* and the 1980-1985 and 2000-2005 Breeding Bird Atlas projects. Curt Stager: Stager, J.C. et al, "Historical patterns and effects of changes in Adirondack climates since the early 20th century." Adirondack Journal of Environmental Studies, in press.

p. 37 Original figure, from Breeding Bird Atlas data supplied by the New York State DEC.

p. 38 Data supplied by the Town of Webb.

p. 39-40 Data from EIA.

pp. 41-43 Data gathered by the Wildlife Conservation Society Adirondack Program. The multipliers used to convert usage into watts and emissions are given in the worksheets on pp. 58-59. They were taken from the EIA and other sources, and are approximate, and not always consistent from one source to the next.

p. 44 The figures are original.

p. 45 The graph is original and uses the same emissions factors as the worksheet on p. 59. The carbon emissions from human activities are estimated using an emission factor for carbohydrates of 0.0001 grams CO_2 per joule. The figure is original.

p. 46 The figure is original. The emission factors for fossil fuels are from EIA. The factor for hardwood assumes a 50% carbon content and a heat content of 6400 BTU per pound, lower than many sources quote but typical of actual firewood in actual stoves. The emission factor for food is 0.0001 grams CO_2 per joule.

p. 47-51 The figures and models in the chapter are original and derive from a report on *Biofuels and the Northern Forest* being prepared by the author and Charley Canham. The models are based on the United States Forest Service tables of forest carbon in Smith. J.E. et al, 2006, *Methods For Calculating Forest Ecosystem and Harvested Carbon With Standard Estimates for the Forest Types of the United States*. United States Department of Agriculture, Forest Service, General Technical Report NE-343.

p. 52 Figure from BP. Citation is Mark Lynas, *Six Degrees: Our Future on a Hotter Planet*. National Geographic Press, 2008.

p. 53 Figure is original.

p. 55 Figure adapted from IPCC III, converting Celsius to Fahrenheit and using the CO_2 values instead of CO_2(e). The annotations indicating the effects of different amounts of warming are not in the original. They are taken from IPCC II and Lenton, T.M. et al, 2008, "Tipping Elements in the Earth's Climate System," *Proceedings of the National Academy of Sciences*, 105(6): 1786-1793.

DRAFT

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