On the Road to Climate Stability: The Parable of the Secretary

A-Team Report on Prospects for Halting the Growth of CO_2 Emissions

James Hansen[1,2], Darnell Cain[3], Robert Schmunk[3]

After President Bush rejected United States participation in the Kyoto Protocol at the outset of his administration, he asked a cabinet-level group to advise him on alternative policies to deal with global warming (Andrew Revkin, New York Times, April 28, 2001). The Climate Change Working Group was chaired by Vice President Dick Cheney, other members being Secretary of State Colin Powell, Energy Secretary Spencer Abraham, Treasury Secretary Paul O'Neill, Interior Secretary Gale Norton, Agriculture Secretary Ann Veneman, Commerce Secretary Donald Evans, EPA Administrator Christine Todd Whitman, and National Security Advisor Condoleezza Rice. As reported in the Times, the initial two briefings to the group were on the science of climate change, the first by Dan Albritton, Jim Hansen and Ron Stouffer, the second by Jim Hansen and Dick Lindzen, while later sessions included business executives, economists, and others (examples of these reported by the Times being Bill Fay, Richard Schmalensee, and former EPA administrator Bill Reilly).

Albritton's science overview was discussed by Andrew Revkin (New York Times, June 12, 2001) and made available on a NOAA web site (www.oar.noaa.gov/education). Hansen was asked to address his papers on an "alternative scenario" for climate change [where he proposed that climate change could be slowed by (1) reducing non-CO_2 climate forcings, and (2) getting CO_2 emissions to level out in the near-term and decline significantly before mid-century].

Based on his perception of the energy-climate issues wrestled with by the cabinet-level group, Hansen defined a task for his education-outreach team. This team consisted of high school students, teachers, a professor and research colleagues working with Hansen in a summer program, the Institute on Planets and Climate. The task assignment to his student-educator-researcher team, the "A-Team", was couched by Hansen as a note from the Secretary of State requesting assistance in analyzing energy requirements projected by the Energy Department.

The A-Team, perceiving the relevance of the task to national needs and the future of the Earth, worked hard and enthusiastically, producing quantitative results for a path in which the United States achieves an energy and CO_2 emissions pathway consistent with the "alternative scenario". They showed that existing technologies could achieve a flattening of vehicle and power plant CO_2 emissions, developed a web-based tool to aide public understanding of policy options, and questioned the inevitability of rising CO_2 emissions.

A paper summarizing A-Team activities and conclusions was drafted in 2004, primarily by Jim Hansen, with the aim of communicating conclusions in a readable story format. The present article is an abbreviation of the 2004 draft. The discussions among the characters represent some of our thoughts during the two summers of the project. Jorge and Naomi are meant to be an amalgam of younger A-Team members, the "wizened professor" is Sam Borenstein/Jim Hansen/Lionel Pandolfo, and the "Secretary" is our perception of a combination Colin Powell/Paul O'Neill. Our knowledge of the latter two players is limited, so their opinions about energy and climate should be obtained from them. All A-Team members and current affiliations are given below. Darnell Cain was the principal architect of the vehicle emission scenarios and Robert Schmunk produced the final version of the Auto CO_2 tool.

[1,2,3]Affiliations given on page 2. Address correspondence to jhansen@giss.nasa.gov

Global warming, a result of human-made "greenhouse" gases, has gained recognition and currency in recent years. Yet the public, and indeed the "experts", are baffled by the problem. Are there disasters on the way? More important, what could be done to limit global warming and avoid disasters? Reports on the topic often leave the impression that it is impractical to halt the march toward dire consequences.

Not necessarily so, says a team of students, teachers, and scientists, at the NASA Goddard Institute for Space Studies (GISS). This group of budding and practicing scientists and educators, dubbed the A-Team (for their "alternative" or "A-Scenario") finds that the problem is more tractable than commonly assumed, and indeed that many benefits would accompany actions that diminish the problem.

The A-Team began by studying a scenario in which CO_2 emissions are stabilized early in 21st century and decline moderately by mid-century. In this A-scenario it is also assumed that it will be possible to get other greenhouse gases such as methane to stop increasing. The overall result is a global warming less than one degree Celsius, well below any scenario considered by the Intergovernmental Panel on Climate Change (IPCC).

Anticipating that experts would describe the A-scenario as "naïve", the A-Team concluded that they would need to demonstrate the technical feasibility of the most difficult aspect of the A-scenario: near-term stabilization of CO_2 emissions. A pretty tall order when one realizes that CO_2 is a bi-product of the world's energy system, and that it is widely agreed that global energy needs will continue to grow for the foreseeable future. The A-Team would need to show that stabilization of CO_2 emissions made practical sense, from an economic perspective.

The A-Team investigated a wide range of potential energy efficiency improvements, renewable energy sources, and new technology developments. They found that CO_2 emissions from vehicles and power plants present the most important obstacles to slowing human-made global warming, and they developed an interactive web-available tool that helps the public and decision-makers evaluate and compare options for fueling future transportation needs.

Surprisingly, the A-Team concludes that reasonable actions, relying primarily on available technology that pays for itself over time via decreased fuel needs and other benefits, can yield a downturn in CO_2 emissions consistent with the A-Scenario. But we are getting ahead of ourselves. Let us begin with the task assignment that was given to the A-Team, "The Secretary's Quandary", an imagined situation given to a real group of students and teachers.

A-Team Members: Darnell Cain, Emily Gibble, James Hansen, Carolyn Harris, Umit Kenis, Robert Kruckeberg, Lydie Louis, Katrina Smith-Mannschott, Tanya Martinez, Lionel Pandolfo, Colin Price, Anna Rouvinskaya, Crissaris Sarnelli, Robert Schmunk, Leila Woolley, Jane Zeng

Current Affiliations: Cain and Schmunk – SGT Inc. and NASA Goddard Institute for Space Studies (GISS), New York; Hansen – NASA GISS and Columbia University Earth Institute (CEI), New York; Gibble – McGill Univ., Montreal; Harris – CEI and John Heinz Center for Science, Economics and the Environment, Washington, DC; Kenis – High School for Environmental Studies, New York; Kruckeberg – A. Philip Randolph High School, New York; Louis – City College of New York, New York; Mannschott – Wesleyan College, Middletown, CT; Martinez and Sarnelli – Yale University, New Haven, CT; Pandolfo – Univ. British Columbia, Vancouver, Canada; Price – Tel Aviv University, Israel; Rouvinskaya – Brooklyn Technical High School, New York; Woolley – High School for Environmental Studies, New York; Zeng – Seward Park High School, New York.

THE SECRETARY'S QUANDARY.

The Secretary of State is caught between a rock and a hard place. As leader of the Department of State, he deals with countries around the world, and these countries are calling for the United States to reduce its emissions of CO_2, the principal gas that stands accused of bringing on dreaded Global Warming.

Different perspectives. Yet the Secretary realizes that the Department of Energy has a different perspective. Their job is to assure that the United States has a supply of affordable energy sufficient to drive a healthy growing economy. All parties, the President and his Cabinet, agree that a thriving economy is essential for achieving the technology development and the resources required to eventually stabilize atmospheric composition and solve the Global Warming problem.

It is also realized that the long-term solution of Global Warming will require many decades. Fossil fuels (coal, oil and gas) produce CO_2, these fuels power our economy, and the lifetime of energy systems (the "infrastructure") can be many decades. A strategy to deal with Global Warming will need to be devised in concert with continuing technological developments and continuing improvements in understanding of climate change science.

The principal issue concerns immediate actions, actions that could be taken now to influence the growth of CO_2. Recent research has shown that if the growth rate of CO_2 emissions is stabilized, i.e., if global use of fossil fuels leveled off and began to decline within a few decades, climate change should be moderate – some global warming would be expected, but the danger of disastrous climate change would be reduced greatly. Near-term leveling out of CO_2 emission rates would provide time to develop improved technologies and an economically sound strategy for eventual reduction in CO_2 emission rates and long-term stabilization of global climate.

The official bottom line. The Secretary of State is troubled because the Department of Energy has advised the President that the United States cannot stabilize its CO_2 emissions in the next decade. To be sure, dedicated professionals in the Department of Energy have made great strides in advancing the potential of energy efficiencies in the home, in commerce and in industry. Nevertheless the official bottom line is that, even with improved energy efficiencies, CO_2 emissions will need to increase about 15% in the next decade to provide healthy economic growth.

The Secretary realizes that as he travels about the world with this energy plan he will be severely beaten about the head and shoulders, at least in a figurative sense, in many countries that he visits. His disquiet arises, however, because he has come to realize that the climate change issue has at least some degree of validity, and with this energy plan the United States will be aggravating future climate problems for the young generation.

Furthermore, the Secretary has a nagging feeling that there is something inconsistent about the energy and CO_2 projections. He is aware that the growth rate of energy use and CO_2 emissions in the United States has been moderate in the past three decades, only about 1% per year, as opposed to a rate of 4% per year in the preceding century. He is also aware that the President is calling for aggressive new actions to improve energy efficiency and develop renewable energy sources. Yet the official projections have energy use and carbon dioxide emissions increasing with a growth rate at least as large as in recent decades. Something doesn't square up.

A team player's quandary. The Secretary's quandary arises because he realizes that the President must rely on his Department of Energy for projecting energy requirements, and the Secretary is a consummate team player. What can he do? His first thought is to doodle with the energy and CO_2 numbers himself, and try to figure out if there is something wrong with them. After all, like Benjamin Franklin, the Secretary is a bit of an amateur scientist (well, not quite like Benjamin Franklin). However, he soon realizes that this is impossible. He is dealing almost 24 hours a day with crises in the Middle East and around the world, including the war on terrorism.

THE A-TEAM ENTERS.

Suddenly, an idea hits the Secretary – he must call on the A-team. He and the President are committed to young people and to their education. And who better to investigate this problem than just the people who will inherit the consequences of whatever plan is carried out?

The scientific approach. The A-team enters. They look rag-tag – some bleary-eyed students, a couple of energetic teachers, a wizened professor – but the Secretary is not fooled by appearance. He understands their scientific approach – they give primacy to real data. Theories and models of what might happen in the future can stimulate and help organize one's thoughts, but they are only useful if they explain the real world. A convincing analysis must start with and place most weight on data and observations from the real world.

Their job, the Secretary explains, is to provide a hard-nosed analysis, one that can be taken to the President to help him. The President is continually besieged by environmental advocates, who see a problem behind every bush – they would shut down industry if they could. And he is besieged by energy advocates, who argue that we must give priority to having more and more energy – climate change may be an imaginary problem, they say, let future generations worry about it. The President's job is tough – he needs some objective scientific help.

One good graph. The Secretary can only provide the A-team with one graph. "One good graph is worth a million words", the Secretary says. This graph (Figure 1) defines the enigma. Perhaps, he says, it can also help the A-team define their analysis of the problem.

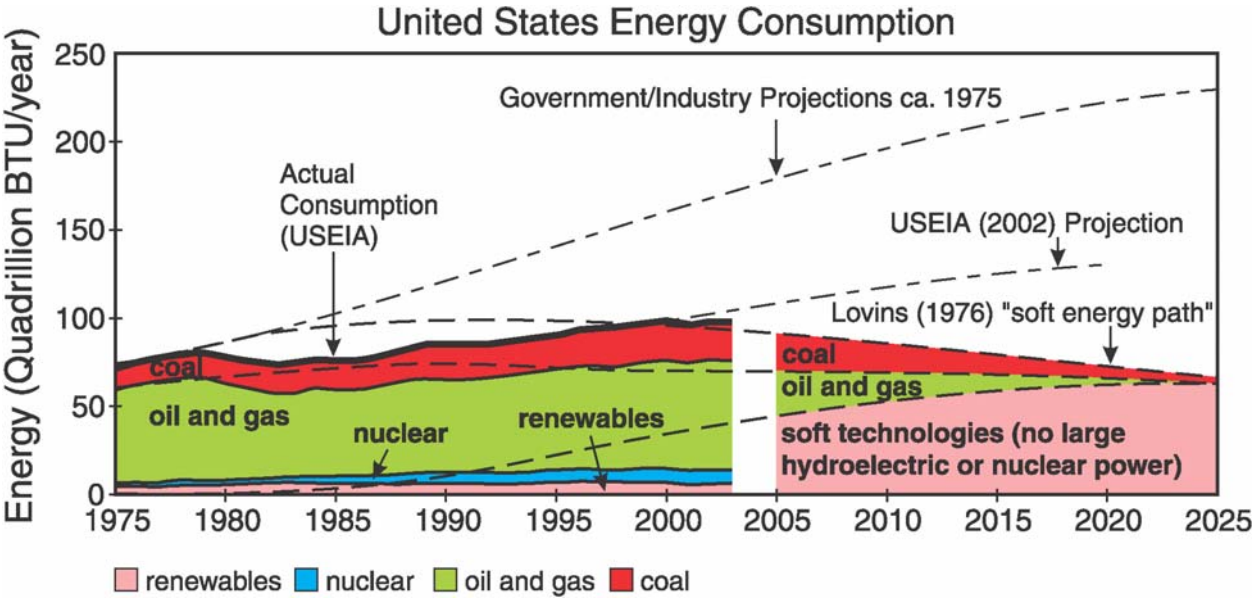

Figure 1. United States energy consumption. Data obtained from the U.S. Energy Information Administration (EIA).

The scenarios. The graph contrasts two energy paths for the United States that were proposed in the mid 1970s. The Department of Energy projected the need for strong energy growth rates. They said that the United States energy consumption of 70 quadrillion BTU/year in 1975 would need to increase to 200 quadrillion BTU/year forty years later, a growth rate of about 3% per year. If such an energy growth rate occurred, with the energy provided by fossil fuels, it would yield the famous and dramatic climate change, the abominable "business-as-usual" climate scenario – the scenario that the Intergovernmental Panel on Climate Change dwells upon to engender visions of impending climatic doom.

An extreme alternative to the Energy Department scenario was provided by Amory Lovins. Amory is an idealist and a renowned visionary, appropriately decorated as a boy-genius, a bit like Einstein (well, sort of). In his scenario, by means of continual improvements in energy efficiency, the energy use in the United States grows only slightly and then begins to decline. In addition, more and more of that energy is produced by what Lovins describes as "soft technologies", ones that do not include nuclear power or big hydroelectric plants, energy sources that are also banes of some environmentalists.

So, in Lovins' scenario CO_2 emissions (from coal, oil and gas) decline steadily and dramatically, almost disappearing by 2025. The students note that Lovins' scenario is more extreme than the "alternative scenario" that they have studied. In their "A-scenario" CO_2 emissions peak early in the 21st century, and

before mid-century begin to decline enough to prevent global warming from exceeding 1°C. The students are puzzled, as their A-scenario is already much more ambitious than any scenario considered by the Intergovernmental Panel on Climate Change. So they are eager to see how Lovins' even more optimistic scenario compares with the real world.

The real world. The real world data for energy use in the United States (heavy black curve in Figure 1) show that Lovins was at least half right. Energy use in the United States has grown only slowly, about 1% per year, since 1975. However, the data also show that the Lovins' scenario, if taken as a prediction, was half wrong, at least so far. Renewable energy sources, such as solar power and wind power are still so small in the United States that they barely show up in the graph. Before dismissing Lovins as a dreamer, remember that Edison and Smortelheimer were once laughed at too (Smortelheimer turned out to be a real nut – he died in Bellvue – so it is hard to say). Perhaps energy policies ignored opportunities, and Lovins was just ahead of time by a few decades.

"It is pretty clear", says the wizened professor, "that the real world will fall somewhere between the Energy Department and Lovins extremes, but where it falls in that range will be critical. If it is possible to flatten out U.S. CO_2 emissions, that is achieve zero growth rate, and if later advanced technology can help drive down emissions, the problem seems tractable. It would be consistent with the A-Scenario."

The high-efficiency low-emissions path. "What good will it do" pipes in Jorge, "to slow U.S. emissions? Everyone says that emissions from China, India and other developing countries will increase so fast that they will overwhelm whatever happens in the rest of the world."

"I'm not saying that the global problem will be easy, but it will be feasible if the U.S. can get on the A-scenario path," the professor responds. "For one thing, the U.S. emits more CO_2 than any country by far, more than all the countries in the European Union put together. So U.S. emissions themselves are important. But the U.S. is also a technology leader. If the U.S. finds a path to declining CO_2 emissions, involving energy efficiencies and new low emission energy sources, it is unlikely that developing countries will follow the old low-efficiency high pollution track."

"He has a good point," the Secretary interjects, "there are high costs associated with the old approach, including the need to find and protect the energy sources, and there is a high cost in local pollution as larger and larger fuel loads are burned. Other countries would prefer not to follow that path, even if they could, if an alternative is available."

"Developing country CO_2 emissions will surely increase," says the professor, "but whether they follow a path like that of the U.S. early last century, with emissions sky-rocketing at the same rate as economic growth, or a path with emissions under better control, will make a world of difference."

"Remember," chimes in Naomi, "the 'climate impacts' team found that developing countries stand to suffer the most from global warming. Their interests will be served by a high-efficiency low-emissions path. If the U.S. shows that it can prosper on such a path, it should be possible to convince the rest of the world."

The sine qua non. "You may be right," chides the Secretary, "but I believe we agreed that the international problem was my concern. I am asking your help on the technical question: is there a practical path for the U.S. that leads to reduced CO_2 emissions? That seems to be the sine qua non."

"Huh? Sorry, I guess we were getting carried away." After a pause, her voice strengthened, "but it seems to me that we have to be concerned with emissions now and in the next decade or two. If emissions follow the 'business-as-usual' path of IPCC for even that long, it will be impossible to get onto the A-Scenario path, and dramatic climate changes before the end-of-century will be assured. I may not be alive at the end-of-century, but my children, if I have them, will be. We are not talking about the 'seventh generation', we are talking about our families."

Her mini-lecture caused another pause, but then Jorge spoke up, "Here's the way I look at it. We can't foresee exactly how climate change will develop, but we can see the need to slow emissions. It's like what Joe Torre, the Yankee manager, tells his pitchers, 'hold those guys down to a reasonable level, to give us a chance. If you do that we usually find a way to win.'"

"Good point," says the professor, "so let's get to work on the sine qua non."

THE A-TEAM STRUGGLES.

The A-team knows that their job is not to suggest policy, but rather to quantify the impact of potential actions. They must start with a realistic assessment of the current growth rates of energy use and CO_2 emissions. Then they can consider a variety of potential actions, along the lines proposed by the President, to see how much each of these could reduce the growth rates of energy use and CO_2 emissions. The Secretary of State can then take this list of potential actions to the President for his consideration. If the A-Team does their job well, if they identify realistic actions that yield near-term flattening of emissions and eventual decline of emissions, they may save the planet. No mean accomplishment for a bunch of high schoolers.

Dividing up the problem. How can the A-team attack this problem quantitatively? They will need to have data on current energy use in the United States, the division of energy uses into electrical and non-electrical, and the proportions that are provided by coal, oil and gas. They can divide the energy use into appropriate sectors, e.g., energy use can be divided into residential, commercial, and industrial, and these can be divided into lighting, heating, and other uses. Transportation can be divided into automobiles, trucks, aircraft, ships, and so forth.

It will be essential to quantify well those sectors where there are potential energy savings over and above business-as-usual, specifically savings that seem feasible within the President's call for aggressive actions. For example, they can look at the potential of available technologies to increase the miles-per-gallon for automobiles, but they must estimate a realistic rate for improved capabilities to penetrate the market, remember that it only affects the new cars, and note that the number of miles driven per car may increase.

On the one hand, the A-Team suspects that potential energy savings can reduce energy growth rates, but they anticipate that it may be difficult to find enough savings to flatten energy use, given increasing population and a growing economy. On the other hand, there are two additional factors to consider beyond energy efficiency. First, there are a number of renewable energy sources that produce little or no CO_2. Perhaps these sources can expand enough to handle much of the growth in demand for energy. Second, there are technologies, existing or on the horizon, that could alter the equation. These include capture and sequestration of CO_2 at power plants, perhaps a new generation of nuclear power plants that solves many of the problems with existing nuclear power, or simply fuel switching among fossil fuels, or the introduction of new more efficient fossil power plants. What are realistic potentials of such options, their merits and demerits, and on what time scales?

Task assignments. The wizened professor divides the A-Team into five two-person teams, each with a high-school student and an older teacher or researcher. Each team is expected to evaluate one energy efficiency option, one renewable energy source, and one advanced technology.[1] And for each of these topics the team is expected to define 3 scenarios: (1) current trends, (2) moderate new actions, (3) strong new actions.

"Current trends" is defined to include energy efficiency improvements that industry and consumers would pursue without special encouragement. We use terminology "current trends", rather than "business-as-usual", because the latter terminology has been corrupted via its use for unrealistic 3-4%/year growth of CO_2 emissions.

"Moderate action" includes new policies that make practical sense and cost little or nothing, when the benefits of reduced fuel use and reduced air pollution are factored in. These actions may include removal of barriers to efficiency, and adjustment of policies to encourage and reward efficiency and innovation. These actions are things that would not happen under current trends. They require a change of policy or government action.

"Strong action" includes special government efforts to develop, or to encourage development of, new technologies and/or mandated energy reforms. These require substantial economic investments. It would be unrealistic for policy makers to pursue strong actions in all 15 task areas, but if some of these 15

[1] The 15 tasks were: renewable energies (solar, wind, geothermal, biomass, hydroelectric), energy efficiencies (transportation, coal power plants, and three end-use efficiencies for electricity use – residential, commercial, industrial), and advanced technologies (CO_2 sequestration, nuclear power, hydrogen from renewable energy sources, transportation reform, fuel switching).

areas are identified to provide very high payoff in reduced CO_2 emissions, decision makers may wish to increase support for one or more of these areas so that they can reach fruition.

Time horizons. In each case, two time horizons are to be emphasized: 2015 and 2030. Changes within the first time horizon are probably dependent on existing technologies, while the longer horizon may allow the impact of more fundamental changes to be felt.

As an example of what these three scenarios might correspond to, consider the controversial case of nuclear power. Current trends might be: no new plant construction, a few plant closings, and upgrades of power rating in a number of the operating plants. Moderate new actions might include solution of waste disposal problem (this has a cost, but we are stuck with finding a solution in any case) and more efficient licensing leading to new construction at a modest number of existing sites where nuclear plants are acceptable. Strong action might include construction of clusters of next generation plants in remote regions, where they would be used mainly to produce hydrogen for pollution-free vehicles.

The exciting part. The bottom line will be a summary of the impact on future CO_2 emissions of various policy options. For example, what will be the curve for future CO_2 emissions if the most effective "moderate actions" are pursued? Will CO_2 emissions flatten out and then decline before 2030? Which of the possible "strong actions" would be most effective in further reducing emissions?

"You will need to present a rationale for your choice of scenarios", the wizened professor notes, "and quantify the implications of each scenario for energy production and CO_2 emissions on the 2015 and 2030 time horizons. You will present your analysis to the whole team, explaining how you reached the conclusions and defending them against criticisms. So you will need to research the topic, provide references for different perspectives, a rationale for your choices, and caveats noting why you may be wrong. If you do well enough, we will try to prepare a scientific paper."

"The exciting part will occur at the end, when we add up the results of the mini-teams and see if there is a plausible scenario with declining CO_2 emissions. If we fail, next summer's assignment will be to work on the problem of terraforming Mars. Perhaps by adding some trace gases to the Mars atmosphere we can warm it up enough for habitability, and we can all escape to that planet."

A-Team's progress. The A-Team toiled assiduously for two summers, never losing their enthusiasm or the sense that they were doing something important. By the end of the second summer, when support for the education program expired, they had draft quantitative assessments for the five energy efficiencies and five renewable energies, and it was decided to prepare a report for the Secretary.

They had concluded that plausible increases in renewable energy sources during the next two decades, even with strong government support, could not halt the growth in CO_2 emissions. A greater potential was found for energy efficiencies. Indeed, infusion of available technologies was found to be capable of halting growth of emissions for decades. With the help of increasing renewable energy use, the flattened and even declining CO_2 emissions of the A-scenario were judged as being possible and leading to a large reduction in requirements for oil imports.

The A-Team concluded that the single greatest challenge the world faced, if it wished to slow CO_2 emissions and avoid dangerous human-made interference with climate, was posed by growing emissions from personal vehicles. This was true not only in the United States, where the popularity of SUVs (sports utility vehicles) and other "light trucks" has stalled improvement of vehicle efficiency, but also in the developing world, where the number of vehicles is increasing rapidly.

The A-Team reached a point where they believed that they had produced a tool that would help decision-makers address the CO_2 emissions problem. Thus they prepared an interim report for the Secretary, which follows herewith.

A-TEAM REPORT: HALTING THE GROWTH OF CO_2 EMISSIONS.

Global energy picture. World energy consumption is summarized in Figure 2a. The United States, the European Union, China, Russia, Japan and India together use two-thirds of the world's energy. The United States energy consumption is about one-quarter of the world total, and is one-third larger than the energy use of the European Union. As Europe has more than a third again as many people as the United States, this means that energy use per person is nearly twice as much in the United States as in Europe,

despite comparable standards of living. This gap in energy use has been widening, as the annual growth rate of energy use by the United States has been 1%/year since 1980, but only 0.5% per year in Europe (line graph in Figure 2a).

The highest energy growth rates have been in China (4%/year) and India (6%/year). Growth rates for energy use generally have been well below economic growth rates. The long-term trend to use energy more efficiently seems to be the norm for open growing economies, and thus it should be incorporated in defining "business as usual" or "current trend" scenarios. The unusual case in Figure 2a is Russia, where energy use prior to 1990 grew rapidly in an inefficient state-controlled economy, but energy use declined in the 1990s with the economic collapse from which Russia is presently emerging.

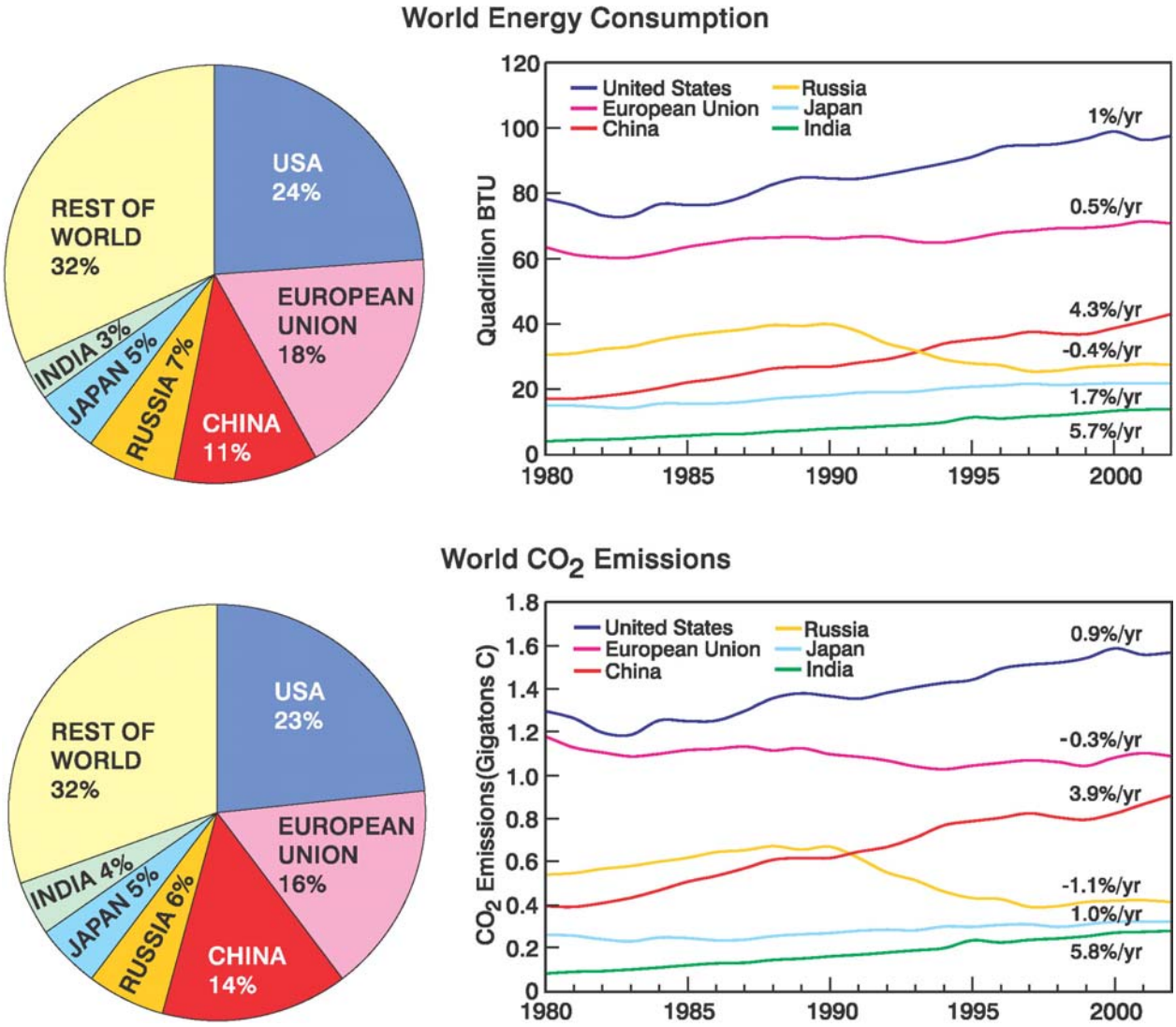

Figure 2. World energy consumption (top) and world CO_2 emissions (bottom) based on data from EIA (2003). Pie charts are the division of energy use and CO_2 emissions among countries in 2002. Line graphs show the histories since 1980 including the annual growth rates.

Global CO_2 emissions. The world CO_2 emissions (Figure 2b) mimic rather closely the division of energy use among different countries. China and India have somewhat larger portions in the CO_2 emissions pie chart than in the energy chart, because those countries use coal for their energy needs to a greater extent than the average country. CO_2 emissions per unit energy are largest for coal, among the fossil fuels, intermediate for oil, and least for natural gas. The declining CO_2 emissions in the European Union since

1980 reflect in part a shift away from coal to natural gas, especially in the United Kingdom, where oil and gas available from the North Sea permitted the closing of most coal mines.

Energy consumption by the entire world increased over the period 1980-2002 at an average annual growth rate of 1.7% per year. CO_2 emissions from the entire world, on the other hand, increased at 1.3% per year. The lesser growth rate for CO_2 emissions than for energy use during this period reflects mainly fuel switching from coal to gas. Renewable energies that produce little or no CO_2 have the potential to further divorce CO_2 growth from energy growth. However, renewable sources such as wind and solar power as yet provide only a tiny fraction of world energy use, as discussed for the United States in connection with Figure 1.

The growth of global CO_2 emissions at 1.3%/year seems moderate, and indeed it is much less than the 4.5%/year growth that occurred from the end of World War II until the early 1970s, when the increased cost of oil put a higher premium on energy efficiency. However, this remaining growth of emissions is the cause for concern about the Earth's climate. If that growth continues for 50 years, it yields almost a doubling of annual CO_2 emissions. Undoubtedly that would cause the Earth's temperature to reach levels not experienced in hundreds of thousands of years, probably in millions of years, with likely consequences that include a large rise of sea level.

The level of "Dangerous Anthropogenic Interference". All nations, including the United States, agreed to the goal of avoiding dangerous anthropogenic interference with climate in the United Nations Framework Convention on Climate Change, signed in Rio de Janeiro in 1991. The A-Team, by studying the Earth's history, concluded that global warming of more than about 1°C above the level in 2000 was likely to constitute "dangerous anthropogenic interference". Their rationale, as discussed in references below, was that warming in the 20th century had pushed global temperature back to the peak of the current interglacial period, and further warming of more than 1°C would approach the warmth of periods that included large sea level changes and regional climate shifts.

The limitations on greenhouse gas emissions required to keep additional warming tolerable will need to be worked out as a product of progressive understanding of the climate problem. Allowable emissions depend upon the continuing rate at which the Earth can absorb CO_2 emissions, changes that occur in other human-made climate forcing agents (especially other greenhouse gases and aerosols), and the sensitivity of the climate to these forcings. Limitations on emissions will also depend upon the ability and willingness of humans to tolerate and adapt to climate changes and their consequences, thus upon a more precise evaluation of the level of "dangerous anthropogenic interference".

What this all boils down to is a conclusion that the growth rate of CO_2 emissions is a critical factor affecting future climate. On the one hand, if unconstrained growth of uncaptured CO_2 emissions continues, large climate changes appear to be inevitable, or at least so likely that it would be fool-hardy to proceed down that path. On the other hand, a very different picture emerges if uncaptured CO_2 emissions peak in the near-term and if a significant decline of emissions were to begin before mid-century. Climate simulations carried out by members of the A-Team indicate that such a scenario could keep further global warming under 1°C, a degree of climate change that would probably obviate large climate disasters such as ice sheet collapse and large sea level rise.

Of course it is technically possible to flatten out CO_2 emissions. That is not the issue. The question is whether it can be done in ways that do not harm economic development or which even improve economic conditions. Economic practicality of innovations must be central to the analysis.

United States in the global picture. How does the United States fit into the global picture? It is informative to examine more closely the proportion of CO_2 emissions from the United States, and especially how the United States' portion has changed with time. That is the quantity shown in Figure 3.

The United States portion of global fossil fuel CO_2 emissions grew remarkably from about 10% in 1850 to half of the world emissions in 1920. Subsequently the United States portion of global emissions has declined, except for a temporary spike back to 50% during World War II as U.S. industry supplied the war effort. In the 1990s, however, despite rapid economic growth in the developing world, the U.S. portion of CO_2 emissions stopped declining, even rebounding slightly.

As the United States is a global leader in technology development, it is unlikely that global CO_2 emissions will level off and decline, unless the United States can move its CO_2 emissions in that direction. Thus we examine the sources of the United States emissions and where the growth is coming from.

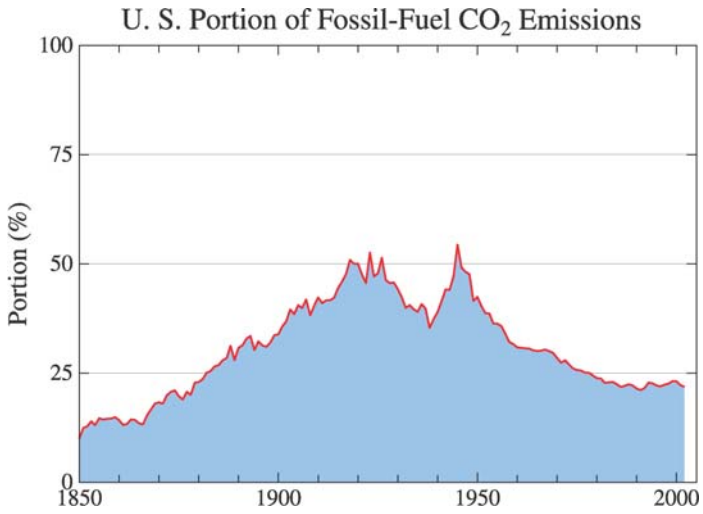

Figure 3. United States portion of global fossil fuel CO_2 emissions [update of Fig. 6 of Hansen and Sato (2001), based on data of Marland and Boden (1998)].

Energy use by sector. Figure 4 shows the United States CO_2 emissions, divided according to energy use sector. Industry and transportation together produce more than 60 percent of CO_2 emissions. Although industry is the greatest energy user, transportation emits more CO_2. Moreover, the transportation emissions have been growing rapidly, unlike emissions from industry.

While the United States economy experienced strong growth over the past three decades, industry reduced its CO_2 emissions by several percent. Transportation, on the other hand, experienced the largest absolute growth of CO_2 emissions of any sector, and is now the largest source of CO_2 in the United States. Indeed, transportation emissions of CO_2 are growing rapidly worldwide. Unless the growth of CO_2 emissions from transportation can be slowed, there seems to be little hope of flattening out total CO_2 emissions. And unless the United States, as a technology leader, can flatten its growth of CO_2 emissions from transportation, how can the world as a whole do so? So let us examine the source of the transportation CO_2 emissions in the United States.

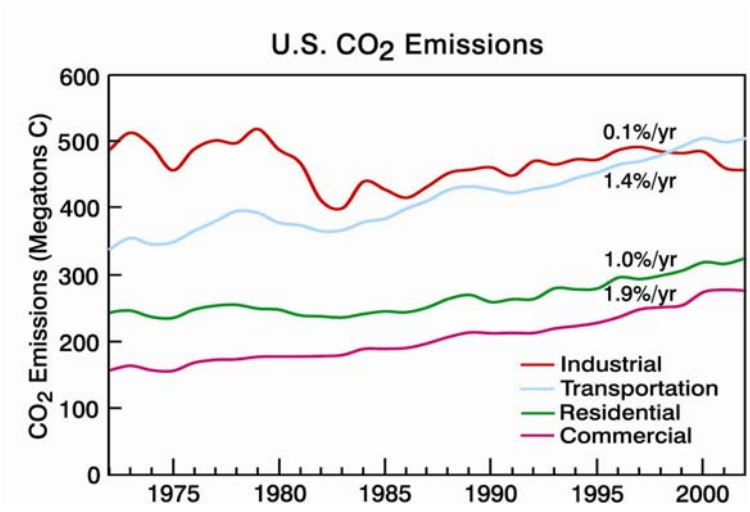

Figure 4. United States CO_2 emissions based on data from EIA (2003).

Transportation CO_2 emissions. Automobiles are the largest contributor to transportation CO_2 emissions at 34%. Together with light trucks, which include sports utility vehicles (SUVs), vans and pickups, the passenger vehicles emit about 60% of the CO_2 from transportation. The next largest contributor

is heavy trucks. Heavy trucks, mostly with diesel engines, are already highly efficient, as their design and use are driven by commercial applications with economic objectives that encourage minimization of fuel use.

Although heavy trucks should not be neglected, primary attention must be paid to passenger vehicles, if the growth of CO_2 emissions from transportation is to be slowed. CO_2 emissions from light trucks have been the primary source of growth of CO_2 emissions by transportation in the past two decades. The growing popularity of SUVs and pickups for personal use, and the fact that these vehicles are classified as trucks that need not meet the EPA fuel efficiency standards for automobiles, has been at the root of this growth.

The A-Team's problem. The A-Team was charged not with recommending policies to halt further increase in the rate of CO_2 emissions, but only with providing information that would help policy makers consider and evaluate alternative actions. There are many possibilities for reducing emissions, but which ones are most practical and how much could each contribute toward the goal of a flattened emission rate by 2015 and declining emissions by 2030?

The A-Team realized that the problem is a contentious one. On the one hand, auto manufacturers have used light truck popularity as a route to restored profitability, thus contributing to economic growth, job creation in the United States, and profits for investors. Environmentalists, on the other hand, are livid that politicians connived at the classification of personal transportation vehicles as trucks, allowing manufacturers to escape EPA efficiency rules, and ignored the economic and security implications that attend the ensuing need for increased foreign sources of oil. Manufacturers contend they are responding to consumer preferences, while environmentalists contend that the auto-makers advertise lavishly to help create those preferences.

Avoiding the cross-fire. "It will not be easy to avoid getting hit by this cross-fire", says the professor, "even though we will stick to technical issues, because the technical issues themselves are hotly debated and depend upon many assumptions and choices. We had better try to create a tool that allows the assumptions and choices to be changed readily, so anyone will be free to examine the effect of alternative choices."

So the A-Team decided to make a computer program that could be used to test the impact of alternative choices for the future fleet of vehicles. They would put this on the web, and allow the user to make their own choices for the degree of technology infusion and to see what impact that would have on future CO_2 emissions. Also it should have some variable input parameters for the current trends, i.e., for the baseline case of future CO_2 emissions in the absence of concerted actions aimed at reducing emissions.

Input data. The A-Team assembled data that could be used for computations and to define current trends. They obtained data for the history of automobiles and light trucks in the United States for the past 30 years, including estimated miles driven and fuel efficiency from the Federal Highway Administration. The difficulty in obtaining absolute accuracy is not a major problem for our purposes, because what we wish to know is the relative differences among alternative courses of action.

Births and deaths. The A-Team also needed to estimate the number of new vehicles that will be sold each year and the rate at which older vehicles are retired from use. Sales of autos and light trucks have increased at a rate of about 140,000 per year since 1970. As a nominal value for near-term trends the A-Team chose a continued annual increase in sales of 140,000 per year.

They also obtained data for automobile survival rate from the Federal Reserve. Thus, for example, in 1980 only 61% of the 1970 autos were still on the road, but in 2000 84% of the 1990 autos were still on the road. "The shorter lifetime of cars produced a few decades ago had more to do with Detroit's 'planned obsolescence' than with inferior technology", groused the wizened professor, "so it's a little difficult to accept their contention that they don't influence consumer preference." "Don't opinionate", chided Naomi, "just give us the numbers." The survival rate of light trucks has changed little with time, and it is even somewhat longer for 1970 trucks than for recent ones.

The hard part. There are many technological possibilities for improving fuel efficiency, indeed, there are many improvements that would pay for themselves via reduced fuel costs. That does not mean they will happen automatically, as the technology changes may have other effects. To quote the 2002 report of the National Research Council [*Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards*]: "To understand how the fuel economy of passenger vehicles can be increased, one must consider

the vehicle as a system. High fuel economy is only one of many vehicle attributes that may be desirable to consumers. Vehicle performance, handling, safety, comfort, reliability, passenger- and load-carrying capacity, size, styling, quietness, and costs are also important features. Governmental regulations require vehicles to meet increasingly stringent requirements, such as reduced exhaust emissions and enhanced safety features. Ultimately these requirements influence final vehicle design, technology content, and fuel economy. Manufacturers must assess trade-offs among these sometimes-conflicting characteristics to produce vehicles that consumers find appealing and affordable."

The possibilities. In general, there are three ways to reduce the amount of fuel required to move a vehicle a given distance. First, one can increase the efficiency of the powertrain, i.e., the engine, transmission, and final drive, to increase the work from a given fuel amount. Second, one can reduce the required work by reducing the vehicle weight, rolling resistance, or accessory load, or improving the vehicle's aerodynamics. Third, one can salvage energy via regenerative braking or shutting the engine off during idling.

A good range of discussions of the potentials and problems of candidate technologies is provided by (1) the NRC [2002] report mentioned above, which includes a discussion of industry criticisms of the preliminary version of that report, (2) Department of Transportation National Highway Traffic Safety Administration economic assessment of CAFE standards [DOT, 2002, 2003], (3) California Air Resources Board [CARB, 2004] proposal for maximum feasible and cost-effective reductions of greenhouse gas emissions from motor vehicles. In perusing these reports it will be noted that the NRC and CARB cost/benefit estimates are broadly similar (see NRC Figures 3-4 to 3-7 and CARB Figures 5-6 to 5-10). However, engineers in the automobile industry have challenged the NRC numbers on technical grounds. A good approach may be to use the NRC report to help identify and compare potential efficiency gains, but to be conservative in assumptions about potential efficiency gains and the time needed to achieve them. Greater gains may be possible if industry accepts efficiency as its primary technical objective.

NRC report. The NRC report describes a large number of possible efficiency improvements, which it classifies as (1) "production-intent" (they mean "ready", in plain English) technologies, which are already available and could be incorporated in vehicles once a decision is reached to use them, or (2) "emerging" technologies, which is short-hand for technologies that are still under development but are sufficiently well understood that they should be available within 10-15 years. Let us give a few examples to clarify the discussion, first for engine technologies.

Multivalve, overhead camshaft valve trains. Never mind what in the world that means. It is "ready" technology that could reduce fuel consumption 2-5% at constant performance. However, in the past, improvements such as this have been used instead mainly to improve automobile performance (more horsepower or bigger vehicle), not to reduce fuel needs.

Direct-injection diesel engines. This is an example of an "emerging" technology. In fact it is already used in passenger cars and light trucks in Europe, where lean-burn combustion systems and nearly smokeless and odorless emissions have improved consumer acceptance. Huge improvements in efficiency, as much as 30% or so over gasoline engines, are possible. Two problems face the diesel engines: (1) it has not been shown that they can meet stricter emission standards in the United States, and (2) they increase the purchase price of the vehicle by $2000-3000. Also it should be borne in mind that the efficiency advantage of diesel over gasoline will decline somewhat as requirements for after-treatment of engine exhaust products are made stricter and as the efficiency of gasoline vehicles increases [Sullivan et al., 2004].

Next consider transmission technologies. Five-speed automatic transmissions allow the engine to operate in its most efficient range more of the time and offer a 2-3% fuel savings over a four-speed transmission. There is also a "ready" continuously variable transmission (it uses belts or chains to vary speed ratios across two variable diameter pulleys) that improves fuel consumption 4-8%, but there are questions about its production costs and operational characteristics that might affect customer acceptance.

Now consider vehicle technologies. Aerodynamic drag can be reduced at potential fuel savings of 1-2%, e.g., by replacing side mirrors with video mini-cameras, but that would require a change in safety regulations. Vehicle weight can be reduced, but there is a tradeoff with safety, even if compensating changes via more crashworthy design and strong light-weight materials are used.

"Emerging" vehicle technologies include hybrid-electric vehicles, which are really a range of vehicle types. Without details, we mention "mild" hybrids, with about 15% fuel use improvements, and "full" hybrids, with about 30% improvements. A primary consideration is that hybrids come with a cost premium of about $3000-5000 for a mild hybrid, after production volume reaches 100,000 per year, and $7,500 or more for a full hybrid. On the other hand, hybrids also offer the possibility of improvements in air quality, which has substantial value for society. Still unproven and further away, at least 10-15 years from commercial application, is the possibility of fuel-cell hybrid-electric vehicles, which, potentially, could use fuels other than hydrogen and still produce very low local exhaust emissions.

It is difficult to predict what candidate technologies will win acceptance and be widely used. The net fuel efficiency improvement will depend upon the importance that policy makers place on dealing with climate change and reducing dependence on foreign energy sources. If incentives and requirements are not imposed, efficiency improvements may be given low priority or the gains may be used for vehicle performance enhancements as opposed to fuel savings. However, policy choices, in turn, depend upon what the perceived gains are. Are the potential gains, for example, sufficient to turn the corner on the global warming problem?

Moderate and strong action scenarios. "O.K." says the professor, "now we must attack the REALLY hard part of the problem." "What do we mean when we say there are 'moderate actions' and 'strong actions' that policy makers could take? These are subjective terms. How can we quantify them?"

The team decided that, at least in some approximate way, 'moderate action' should encompass those actions that would largely pay for themselves over the vehicle lifetime via reduced fuel costs. 'Strong action' would include more costly technologies that would increase the cost of the vehicles to consumers even considering the reduced fuel needs. 'Strong action' may have other benefits, e.g., reduced air pollution and increased energy independence for the nation, so in a broad and long-term sense 'strong actions' might also pay for themselves. However, these national benefits are more difficult to quantify, so it becomes a matter of policy judgments. The A-Team decided that for potential 'strong actions' they would include technologies widely considered to be feasible, and to the extent practical they would estimate the costs associated with this more aggressive reduction in fuel use.

There are many alternatives for improving auto efficiency, some easy, some harder and more costly. The A-Team decided it would try two approaches to get a feeling for what is practical and what the fuel savings might be. First, one of the students, Jorge, who had some understanding of how cars work, would study various efficiency improvements that have been proposed, and second they would use the NRC report but with conservative assumptions about technological capabilities. Jorge likes vehicles that are available now. He is eager to get one of his own and he doesn't want the time at which he can afford it to be pushed off into the future.

Jorge's choice. Jorge's aim is to get an SUV. He wants it to be more environmentally-friendly than the current crop, but he doesn't want to pay much more. In particular, he would like the added cost to be recouped from fuel savings in the first few years of ownership. After studying many possible efficiency improvements with available technologies, he chooses several that are compatible. A big gain, 4%, is provided by variable valve lift and timing, and the smallest, 1%, from improved low-friction lubrication. The total impact of the chosen technology changes on the vehicle price is estimated by the NRC report to be $1110, including a factor of 1.4 to account for supplier and dealer profit margins.

The simple sum of Jorge's fuel savings is ~24%, but the net impact when they are combined is between 21% and 22%. The percent improvement in MPG is [100%/(100% – ΔFC) – 100%] ~ 27%, where ΔFC (0.21 in this case) is the fractional reduction in fuel consumption [a 0.5 (50%) decrease in fuel consumption would yield a doubling, i.e., 100 % increase in MPG]. That improvement would increase the performance of Jorge's SUV to 22.7 MPG, compared with the 17.9 MPG of the SUV in the showroom today. At $2/gallon and 12,000 miles driven per year, Jorge will save almost 150 gallons of gas or $300 per year, so payback would take just under four years. Jorge has studied the arguments between the NRC experts, who say that their estimates are conservative, and manufacturers, who think they are too optimistic. He is satisfied that he can expect payback in a reasonable period.

The fun begins. "Your analysis looks good," comments the professor, "the manufacturers may quarrel with some of the NRC numbers, and by 2015 they may be able to find better technology changes, but

a 4.8 MPG improvement by 2015 for light trucks seems reasonable." "Now the fun begins. Let's plug this number into the Auto CO_2 Tool and see what comes out. We also need a number for the MPG improvement in automobiles, which won't be as large as that for SUVs. Let's take 2.8 MPG as a plausible conservative improvement for automobiles by 2015."

The results are shown in Figure 5a. CO_2 emissions flatten out after 2015 and decline slightly as the more efficient autos populate the fleet, but after 2030 the emissions resume their climb as the U.S. population and the total number of vehicles on the road increases. "Wow," says Jorge, "my changes had a big impact. By 2030 it saves us 3,340,000 barrels of oil per day. And by 2050 the integrated saving is equivalent to more than 4 times the oil in the Arctic National Wildlife Refuge (ANWR)."

"That's not a legitimate unit," says Naomi, "we don't know for sure how much oil there is in ANWR, and that unit is used with predilections in mind."

"Very good, Naomi! Nevertheless, I think that it is a useful unit," the professor interjects, "because people don't have a feeling for how significant a million barrels of oil or a quad of energy is. The U.S. Geological Survey [2001] lists 10.4 billion barrels (range 5.7 to 16) of recoverable oil for ANWR. Let's use that estimate. If anyone believes there is twice as much or half as much oil in the Refuge, they can scale our result accordingly."

Jorge's efficiency improvements have a big effect, but they don't solve the climate problem. His projected CO_2 emissions are still well above those of today. However, Jorge's change is a one-time improvement, with no further change of efficiency after 2015. Let's consider some potential national strategic approaches with larger efficiency improvements, as suggested by NRC, and also the possibility that a significant fraction of the fleet might become advanced hybrid-electric or hydrogen vehicles.

A national strategic perspective. The National Research Council "CAFE" (Corporate Average Fuel Economy) study, discussed above, provides estimates of potential improvements in fuel economy. The A-Team decided to make use of the NRC study, but to make reasonably conservative assumptions about the fuel economies that would be incorporated in future vehicles in any national strategic plan. Following the NRC, they assumed that there would be a 5% growth in vehicle weight for improving vehicle safety, which translates into a 3.5% fuel penalty.

The NRC CAFE study quantified three degrees of technology infusion for autos and light trucks, dubbed Path 1, Path 2 and Path 3, which are successively more costly. Path 3 assumes that some "emerging technologies", such as low-emission diesel engines, will be feasible, so Path 3 is only relevant to the longer term.

"Let's try a moderately aggressive course," suggests the professor, "not the most extreme that NRC thought possible, but something substantial. If the climate and energy problems are taken seriously, it should be possible to achieve 'Path 1.5' by 2015 and 'Path 2.5' by 2030. By Path 2.5 I mean something midway between Path 2 and Path 3. Path 2.5 requires use of some emerging technologies, but we will be allowing 25 years to complete their development, longer than NRC estimated as being necessary."

So, in the A-Team's "moderate action" scenario new vehicles in the United States in 2015 are assumed to achieve the midpoint of NRC's Path 1 and Path 2, and new vehicles in 2030 achieve the midpoint of Path 2 and Path 3. Improved fuel efficiencies vary considerably depending on vehicle size and type. For example, Path 2 results in fuel use reductions of 18% for subcompact autos, 21% for midsize autos, and 30% for large autos, while for light trucks the savings range from 26% for small SUVs to 37% for large pickups.

The resulting "moderate action" fleet average improvement of fuel consumption efficiency is 16% for autos in 2015 (Path 1.5) at an estimated cost of $800 per vehicle. In 2030 (Path 2.5) the new car improvement in fuel efficiency is 32% at an estimated cost that varies with vehicle size from $1500 for compacts, $2500 for midsize and $3000 for large autos. For light trucks the improvement in fuel consumption efficiency of new vehicles in 2015 is 21% at a cost of $1500 per vehicle, while in 2030 it is 37% at a cost of $2500 per vehicle.

Getting somewhere. Jorge punched these four numbers into the Auto CO_2 Tool and watched the graph pop up (Fig. 5b). "Now we are getting somewhere. Look, after the bump-up of the next decade, the emissions come down to about today's level."

"Look, we save the oil of more than 7 ANWRs by 2050," Naomi pipes in.

"That's progress," says the professor, "but we haven't reached the A-Scenario. It requires CO_2 emissions to be trending downward by 2050, so that it is practical to stabilize climate later in the century. Apparently we need 'strong action' to achieve the A-Scenario."

Strong action. The A-Team decided that "strong action" scenarios would have some fraction of the vehicle fleet replaced by a technology with substantially higher fuel efficiency, while the remaining conventional fleet has the moderate action improvements of fuel efficiency. They include two possibilities for high efficiency vehicles: advanced hybrid-electric vehicles and hydrogen powered vehicles.

Hybrid vehicles are beginning to come on the market now, and DOE [Greene et al., 2004] estimates that they may gain 10-15% of the market by 2012. However, today's hybrids do not approach their EPA sticker MPG in actual driving conditions. Therefore, to be conservative, for the period prior to 2015 we have not included a specific contribution from hybrids towards reducing fuel consumption, but rather have included hybrids in the conventional automobile and light truck fleet, assuming that their contributions may be needed to achieve the fleet average improvements in fuel efficiency in the Jorge and moderate action scenarios.

Advanced hybrid vehicles are assumed to achieve 45 MPG in typical driving conditions. This is a realistic, even conservative, expectation for small to moderate sized hybrid-electric vehicles in future decades that take advantage of a range of technologic improvements to assure high efficiency in different driving conditions.

Hydrogen is assumed to be obtained from a source that produces little or no CO_2 (renewable energy, nuclear power or a fossil fuel power plant with CO_2 sequestration). However, a penalty is added to each hydrogen vehicle equal to 20% of the CO_2 emissions from a conventional vehicle. The penalty is meant to account for the fact that some CO_2 emissions or other greenhouse gas emissions are likely to occur in the production of the hydrogen or in vehicle use. The magnitude of this penalty is very uncertain, so it is included as a variable parameter in Auto CO_2 Tool.

A "strong action" scenario is shown in Figure 5c. In the specific case illustrated, advanced hybrid vehicles begin to penetrate the market in 2015, achieving 20% of the market by 2030 and 40% by 2050. Hydrogen vehicles begin to penetrate the market in 2030, achieving 30% of the market by 2050. The remaining 30% of vehicle sales in 2050 are conventional vehicles having the efficiencies achieved in 2030 under the "moderate action" scenario.

Voila. Jorge punches these numbers into the Auto CO_2 Tool. "Voila!," he declares, "this looks pretty much like the A-Scenario. Hydrogen doesn't reduce integrated emissions for the first half of the century much. But by 2050 CO_2 emissions are headed downward, even though sales of light trucks plus automobiles have reached 23 million per year and more than 370 million vehicles are on the road."

"Hmm," muses Naomi, "this all seems logical, but is it really practical to get onto that path?"

"Well," says the professor, "the scenario allows for a range of vehicle types. The hybrid-electric should be good for the smaller more economical vehicles. Remember, we tried to be conservative, so that the results cannot be dismissed. We included 20% of conventional emissions for cars using hydrogen produced by renewable or nuclear sources, and the maximum advanced hybrid has only 45 MPG, even in 2050. Once manufacturers take up the challenge, they can probably do even better."

"But," says Jorge, "I think that there is also going to be consumer demand for higher performance vehicles. Perhaps the hydrogen-powered vehicles could provide that, but aren't they going to be much more expensive?"

"Sure," chimes in Naomi, "but I guess if you can afford a Hummer, you can afford a hydrogen vehicle."

Dollars and sense. "Hey," says the professor, "just for fun, let's convert these oil savings into dollars."

"Wait a minute. You have been told before that you are not an economist. Don't muck around where you shouldn't be."

"All that I'm going to do is multiply the number of barrels of oil saved times the price of a barrel. Let's say $50 a barrel. The moderate action scenario saves 5,470,000 barrels of oil per day in 2030. At $50 per barrel that comes to $100 billion per year." See Figure 6.

"$100 billion here, $100 billion there, pretty soon you are talking about real money!"

"Let's see, after 10 years – what could you finance with that?"

"We better stop it – that's economics."

This won't just happen. "The moderate action scenario is certainly possible, but what is the chance it will actually happen?," mutters the professor. "You see the continued growth in emissions during the next 10 years (Figure 5). The reason emissions decline after that is our assumption that a plan will be put in place to require major improvements by 2015. It takes time to tool up the manufacturing. These changes are not things that will simply happen because gas prices increase to $2 or $3 or even $4 per gallon."

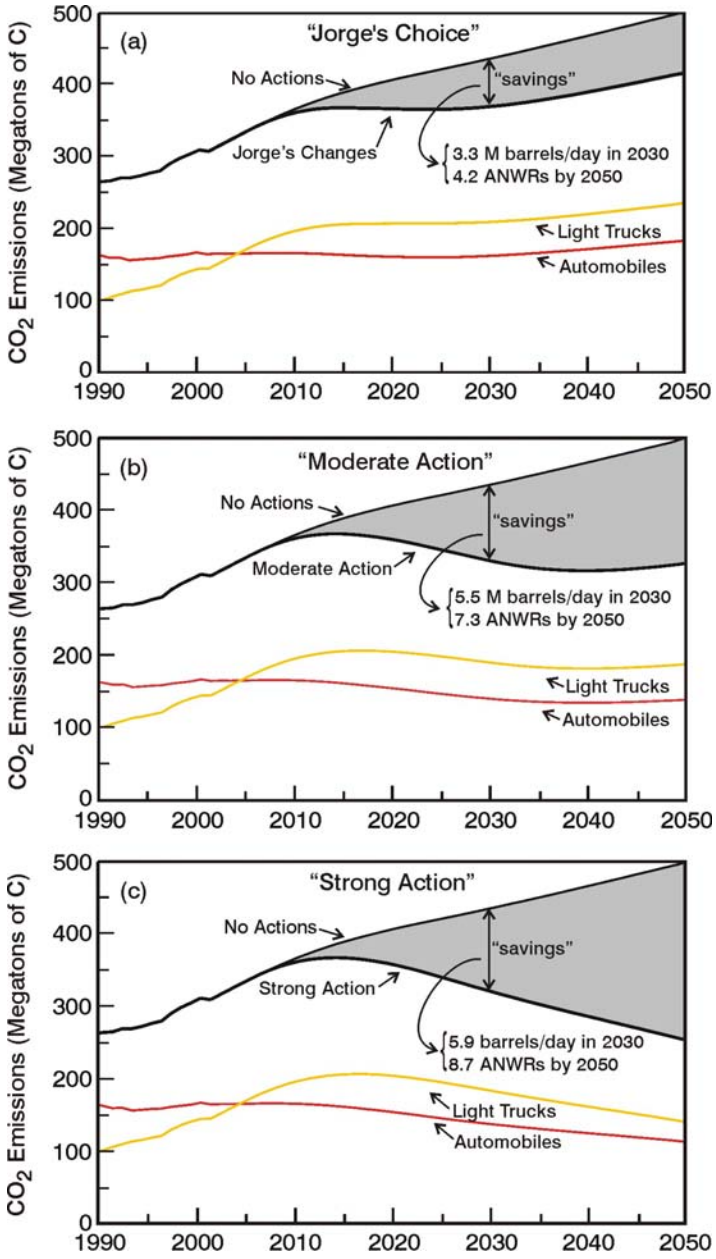

Figure 5. CO_2 emissions in the United States from automobiles and light trucks. Vehicle sales are assumed to increase throughout the period by 140,000 per year, the proportion of new light trucks and automobiles is the same as in 2003, vehicle survival rates are the same as for 1990 vehicles. The "No Actions" or base case has MPG for new vehicles the same as in 2003. "Jorge's choice" phases in by 2015 new vehicle improvements of 4.8 MPG for light trucks and 2.8 MPG for automobiles. "Moderate action" has new vehicles achieving the NRC 'Path 1.5' emission reductions by 2015 and 'Path 2.5' by 2030. "Strong action", in addition, introduces advanced hybrid-electric vehicles beginning in 2015 achieving 20% of the fleet by 2030 and 40% by 2050, and hydrogen-powered vehicles beginning in 2030 and achieving 30% of the fleet by 2050.

"Can the need for efficiency be 'sold' to the public? There are going to be costs, and inevitably there will be impacts on vehicle performance. I remember back in the 1970s when the gas guzzlers were replaced, there was grumbling about things like the removal of a full spare tire and such things. But people accepted the changes, because they had gone through the gas lines of 1973."

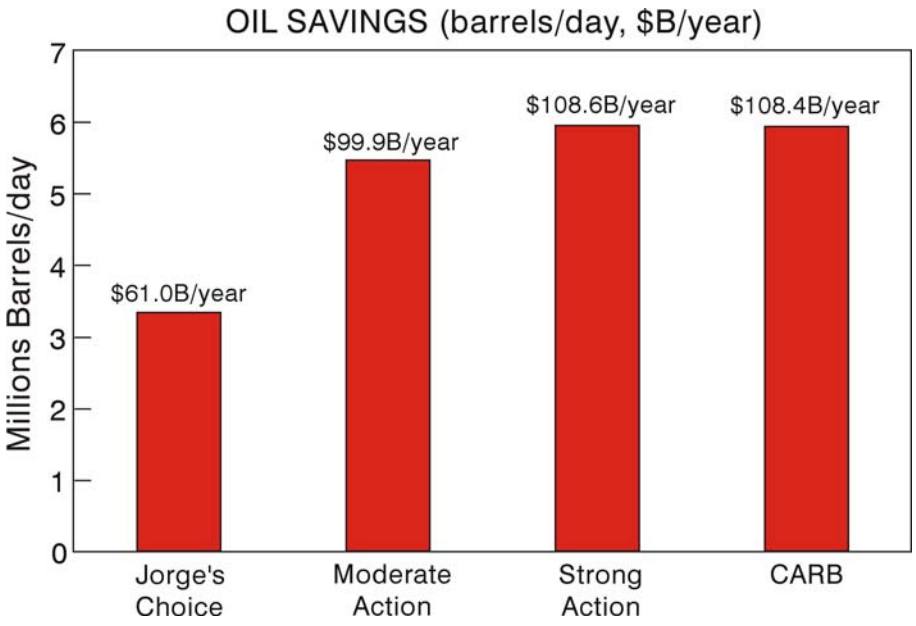

Figure 6. Saving in United States oil use in 2030 due to alternative automobile efficiency improvements. Dollar savings are for oil at $50/barrel and can be scaled for alternative price assumptions. Annual savings increase with time as indicated in Figure 5.

"Too bad we haven't had gas lines recently. The need for massive oil imports is causing a lot of serious problems, not just $3 gas, but the connections may not be so obvious to the person in the street."

"I guess it will take a pretty strong leader to explain the need for efficiency and to take on the special interests who always defend the status quo. But aren't we getting out of our area of knowledge? We did our best. Let's give the report and the Auto CO_2 Tool to the Secretary. He can take it to the Cabinet Task Force."

DEBRIEFING BY THE SECRETARY.

This part of the parable of the Secretary is imagined, but not devoid of reality. This final sequence in the parable, let us hope, is not cast in stone.

The A-Team waited nervously for the Secretary to return from a meeting of the Cabinet's Special Task Force on Energy and Climate. What could be taking so long?

When he finally came down the corridor, their faces fell, as he bore an uncharacteristic and distant scowl. Seeing them, he brightened and said "why so glum? The Task Force members expressed enthusiasm about your report and agreed with the thrust of it. They were impressed by your work."

"The Chairman?"

"The Chairman liked it too. He agreed with most things that you wrote. He will adopt much of the language in future positions and official statements. He sends his sincere thanks for your efforts."

"You mean that actions will be taken? Does he expect to meet the CO_2 emissions in the A-Scenario? How will it be done?"

"I am afraid that will not be in the plans. He agrees with the need for technology development. Maybe in the future it will be possible to slow emissions."

"But you said he agreed with our analysis and would adopt the language in official statements. We showed that it was practical and beneficial to reduce emissions with existing technology, no?"

"Well, he did not entirely agree with the report. He did not think that energy needs would be slowed or that CO_2 emissions could be reduced."

"But didn't we show that it was possible with existing technology? What did he say about that part of the report?"

The Secretary paused. "He said that part of the report was….naïve."

"Well," the professor interjected, "there are other important components to energy use and CO_2 emissions. What about energy efficiencies in households and buildings?"

"The Task Force agrees that there is great potential for savings in the United States. It will be up to Congress and the States to lead the actions. The administration will cooperate with Congress, especially on gasohol."

"Gasohol?"

"Yes. Didn't you agree that it came out on the positive side?"

"We didn't spend much time on it," Jorge said. "Yes, it seemed to us that the assumptions of the Berkeley professor, who had argued that it took more energy to produce the gasohol than it provided, were slanted against it."

"But," said the professor, "gasohol is surely a minor player in the overall energy and CO_2 problems. Why give it priority?"

The Secretary looked away and didn't answer. He seemed to be musing about the larger picture.

A long period of silence was broken by the professor. "What are you going to do now?"

"I don't know," the Secretary said thoughtfully. "We are all team players."

Naomi ended another period of silence, asking "Do you think we are naïve?"

The Secretary hesitated, but he had regained his composure. "Naïve is an interesting word. It has more than one connotation. Perhaps we were all naïve."

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Appendix A: California Air Resources Board Regulations

On September 24, 2004 the California Air Resources Board (CARB) approved a regulation requiring automakers to begin selling vehicles with reduced greenhouse gas emissions by 2009. The regulation requires that greenhouse gases from new automobiles and light trucks be reduced about 22% by 2012 and 32% by 2016. CARB estimates that this will add $325 to vehicle cost in 2012 and $1050 in 2016.

The impact of this regulation, if it were successfully applied nationally, can be conservatively approximated using our Auto CO_2 Tool and entering a 30% improvement for 2015 and assuming no further increases in efficiency between 2015 and 2050. A 30% reduction in CO_2 emissions requires that the MPG (miles per gallon) increase by $[100/(1 - 0.3) - 100] \sim 43\%$. If this percentage improvement occurred equally in light trucks and autos, light trucks would need to improve from ~17.9 MPG to ~25.6 MPG and autos from ~24.6 MPG to ~35.2 MPG. Automakers may apportion the improvement differently between light trucks and autos, but we can see the impact of the regulations by inserting these changes of MPG into the Auto CO_2 tool. The MPGs refer to actual performance, not the "sticker" or EPA test values, which presumably will continue to be ~15% higher than actual performance, on the average, unless EPA test conditions are changed.

The impact of the CARB efficiency requirements, if realized nationally, is a savings of 5,940,000 barrels of oil per day by 2030 and an integrated savings of 7.4 ANWRs (Arctic National Wildlife Refuge). If the CARB regulations were applied only in California and the six Northeast States (New York, Massachusetts, New Jersey, Vermont, Connecticut, Rhode Island and Maine), which usually adopt California standards, and if (implausibly) there were no spillover effect on other states the savings would be ~30% of the above values, i.e., about 1,780,000 barrels of oil per day by 2030 and 2.2 ANWRs by 2050. California has almost as many vehicles as the six Northeast States, so the savings within California itself would be equivalent to approximately one ANWR by 2050.

We note that automakers are likely to dispute the CARB estimates and resist implementation of the rules. Fred Webber, president of the Alliance of Automobile Manufacturers, was quoted in the 27 September issue of Greenwire as saying "We're disappointed that California regulators have chosen to single out California drivers to pay a $3,000 surcharge with no apparent health or environmental benefit to its citizens."

Finally, let us convert the savings of the Jorge (2.8 MPG, 4.8 MPG), moderate action, strong action, and CARB regulations (applied nationally but without further improvements beyond 2015) into a simplistic estimate of changes of the national balance of payments.

The "Jorge" savings (3,340,000 barrels of oil per day in 2030) correspond to 1.22 billion barrels per year. At a price of $50/barrel, this is ~$61 billion per year.

"Moderate action" yields 5,470,000 barrels of oil per day in 2030. At a price of $50/barrel, this is ~$100 billion per year.

"Strong action" yields 5,950,000 barrels of oil per day in 2030. At a price of $50/barrel, this is ~$109 billion per year.

"CARB regulations" yields 5,940,000 barrels of oil per day in 2030. At a price of $50/barrel, this is ~$108 billion per year.

It should not escape ones attention that such savings for the United States balance of payments and oil requirements would have positive implications for the national economic well being, as well as national security.

Our focus on the near-term (2030, 2050) causes contributions of future technologies, including perhaps hydrogen-powered vehicles, to appear to be small. On the long term, such advanced technologies are essential for achievement of the alternative scenario and avoidance of large climate change. Emphasis on the near term allows us to be quantitative with a reasonable degree of confidence. Near-term energy efficiencies are critical because they obviate the need for expansion of a CO_2-producing energy infrastructure that may soon become obsolete. It is difficult to predict long-term technology advances. Ausubel and Marchetti (2001) provide a provocative discussion of this topic.

Appendix B: Efficiencies in Residential Energy Use

The A-Team concluded that it was vital to avoid construction of new power plants that produce copious CO_2 without capture and sequestration, because of the long lifetime of power plants. With the realization that economic technologies for power plants that produce little or no CO_2 are on the horizon, they focused on finding energy efficiencies that would obviate, or at least greatly reduce, the need for near-term power plant construction.

The student-educator sub-team on efficiency of residential energy use found results analogous to those of transportation team. Efficiency improvements that would avoid the need for new power plant construction for many years are indeed possible and economic.

We summarize the approach and principal conclusions here. The team gathered data on recent and current trends in residential energy use. They found that major improvements in energy use efficiency had occurred in specific areas. For example, improvements in refrigeration technology, introduced in several steps, had reduced energy needs to a fraction of the requirements of a few decades earlier. Use of improved efficiency refrigerators was encouraged via EPA "Energy Star" labeling requirements to inform consumers of efficiencies and potential savings.

Nevertheless, despite such technological improvements, total residential energy use in the United States grew in recent decades at a rate of about 1.2% per year, as shown in Figure 4. This growth was driven by increasing population, a decreasing number of persons per household, and the increasing number of energy-using devices in households. These trends are expected to continue.

However, the A-team found that, even with these continuing sources of growth, it would be practical to flatten out residential energy use, i.e., achieve and maintain 0% growth rate until at least the 2025 time frame. Furthermore, this could be achieved with technologies that exist now and in a broad sense "pay for themselves" via reduced fuel needs.

The method of investigation was analogous to that of the transportation mini-team. Typical lifetimes of appliances, heating and cooling systems, and other household energy uses were employed, and alternative assumptions were made for the efficiency of replacement products. High efficiency replacements, which paid for themselves on the long run, were found to be capable of flattening out energy growth.

This perhaps surprising result does not mean that energy use necessarily will flatten out, because without greater incentives many consumers will not always pick high efficiency products nor high efficiency home design. Supportive government policies are needed to encourage consumers to choose high efficiency and to reward business for encouraging energy efficiency. Presently, most utilities make more money if they sell more energy, so they have little incentive to encourage consumers to save energy.

In their "strong action" scenario, the A-team found that, if incentives were provided to encourage consumers to retire inefficient systems early and replace them with state-of-the-art high efficiency products, it would be possible to have decreasing household energy use over the next two decades. The cost to the government of tax incentives or rebates should be reduced by benefits from improvements in the national balance of payments and reductions of other costs associated with large energy imports. However, the A-team did not attempt an economic analysis.