

What Will it Take to Stop Global Warming— The Case for Electric Cars

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Abstract: This paper examines the issue of CO₂ emissions as the leading cause of global warming and the consequent need to eliminate fossil fuels from energy production and transportation to stop global warming. The paper contends that 100% conversion to electric cars, combined with electricity generated by renewable energy sources, is a feasible path to stopping global warming.

The Problem

First an “admission”—greenhouse gases are a good thing. Without 280 parts per million (ppm) of CO₂ in our atmosphere, the earth’s average temperature would be near zero degrees Fahrenheit, instead of earth’s present day balmy 60 degrees.¹

But like chocolate sundaes, too much of a good thing is bad. Too much CO₂ could lead to catastrophic warming with melting of much of the polar ice caps and flooding coastal cities where over half of earth’s population lives. The international scientific consensus, ratified in Copenhagen in December, 2009, is that temperatures must not be allowed to rise more than 2 degrees centigrade to “stave off the worst effects of climate change.”² The Intergovernmental Panel on Climate Change (IPCC), in its Fourth Assessment Report, indicated that achieving the 2°C target will mean stabilizing CO₂ concentrations in the atmosphere at about 400 – 450 ppm, not far from the current level of 390 ppm.³ However, this CO₂ target is a matter of on-going debate (see below).

Stopping the rise in CO₂ is clearly a daunting task, so it is important to understand the issue and to understand why electric cars are a key part of the solution.

The Evidence

The correlation between temperature, sea level, and CO₂ goes back hundreds of thousands of years as shown in Figure 1 taken from NASA climate scientist James Hansen’s book, *Storms of my Grandchildren*—see end note 1.

A look at the average temperatures over the last 60 years shows that the temperatures are rising along with CO₂ levels. See figure 2, from *Moving Cooler*.⁴ If we take the years from 1950 to 1980 as an average, we have had 30 straight years above average; that’s like tossing a coin 30 times and getting all heads, if it were purely random. Temperatures are not only rising, but the rate of temperature increase is increasing as well.

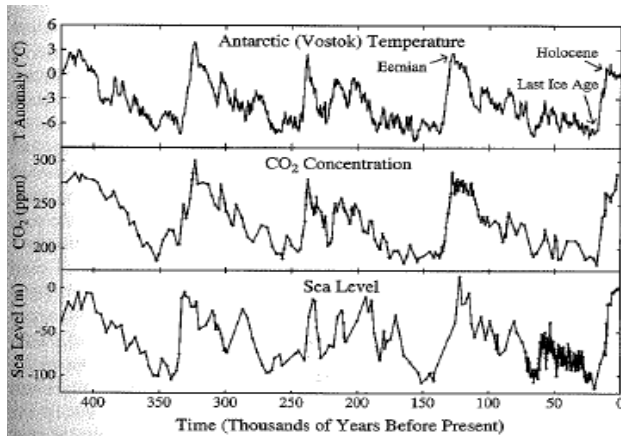


Figure 1—Correlation of Temperature, Sea Level and CO₂

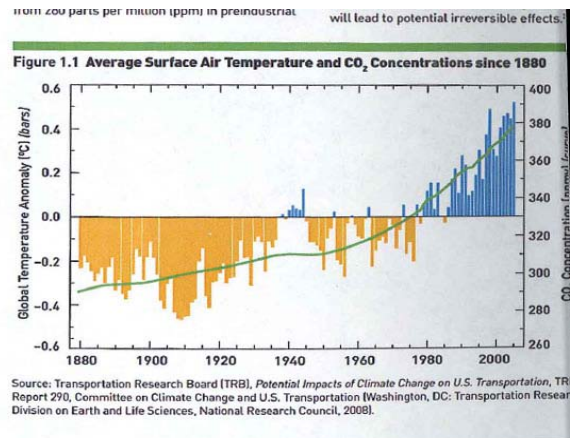


Figure 2—Recent CO₂ and Temperature Trends

How much do we need to cut CO₂ emissions?

There is a genuine debate among scientists about how many ppm is a safe level. As noted, the IPCC recommends a target between 400 and 450 ppm. Some leading experts such as James Hansen of NASA say that 350 ppm is the threshold.⁵ Some feel that there is only a 50% chance of catastrophe even if CO₂ goes as high as 560 ppm⁶. This line of discussion, however, is alarming; if you were told that an airplane had a 50% chance of crashing would you take it?

Even to limit the CO₂ increase to 560 ppm will take a massive change in our transportation and energy systems. Last year humans emitted 31.5 billion metric tons of CO₂, including about 20 tons per person in the U.S. Of this about 18 billion tons stayed in the atmosphere. We know this for a fact since the CO₂ level increased by 2.3 ppm and it takes 7.81 billion tons to raise the CO₂ level by one ppm.⁷

Even if we reduce emissions to 13 billion tons, about half of that would stay in the atmosphere, leading to an increase in CO₂ by about 1 ppm. Unless some new method of geo-engineering, such as promotion of growth of phytoplankton, is developed, only an increase in forestation will increase the earth's ability to absorb CO₂. That scenario is very challenging given human patterns of increasing development and consumption. Given the uncertainty of all of this, Joseph Romm, author of *Hell and High Water*, recommends a goal of eight billion tons of CO₂ per year as a maximum emission level.⁸

Coincidentally by 2030 there will be about 8 billion people on earth. This means that we need to limit CO₂ emissions to one ton per person on earth to stabilize the climate. California, the most aggressive state in the U.S. in pursuit of legislation to stop climate change has set a goal that comes to about three tons per person by 2050. Federal legislation aims for a goal similar to California's, but this has not passed the Senate.

How do we stop the CO₂ build-up?

From the U.S. current level of 20 tons per person, how can we possibly get to three tons, let alone, two or even one ton? To do this we must essentially eliminate fossil fuels from transportation and electricity generation. Electricity generation accounts for 33% of greenhouse gas (GHG) emissions, mostly CO₂, while transportation account for 28%. Trucks and cars account for 79% of the transportation related GHG emissions; these percentages are illustrated in Figure 5. If we can eliminate all of that CO₂, we will be more than half way there in our efforts to stop global warming. Is this doable?-- let's examine some alternatives.

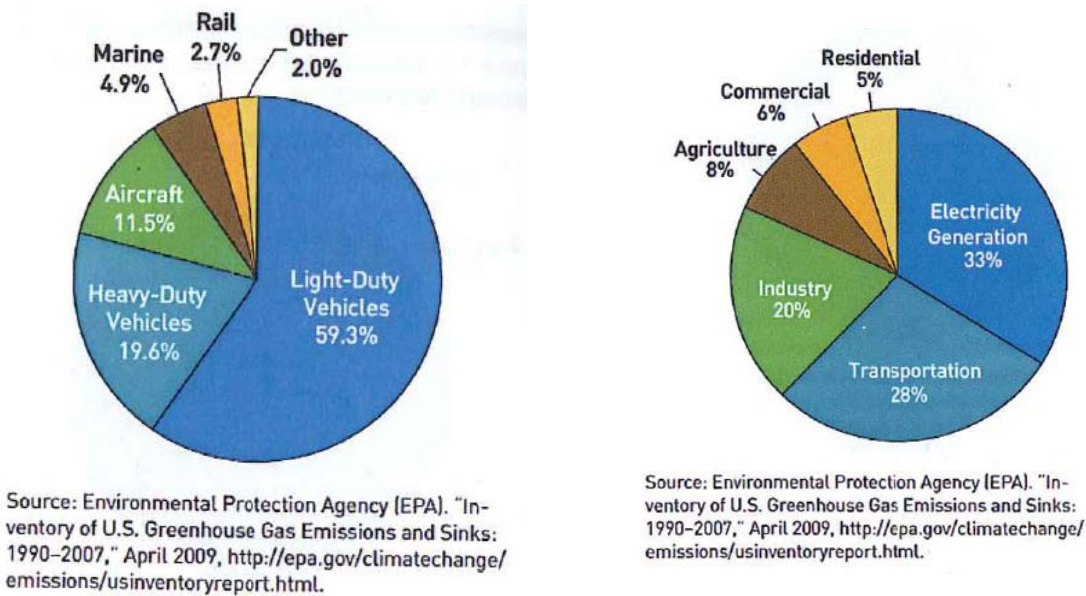


Figure 5—Greenhouse Gas Emissions, from *Moving Cooler*

Moving Cooler

The publication *Moving Cooler* explored in detail 50 strategies such as promoting traffic efficiency improvements, land use changes, walking, bicycling, congestion pricing, and gas taxes. The report concluded that an aggressive combination of such measures could reduce GHG created from the transportation sector by 18%, or as much as an additional 28% with at an equivalent of \$5 per gallon gas tax (page 81). While this is small compared to the cuts needed (see Figure 6), it would be a huge accomplishment to stop and begin reversing the steadily increasing number of vehicle miles traveled (VMT). Since 1956 VMT has increased by over 7% annually, from 600 billion miles to three trillion.⁹

Important as these measures are, they are not nearly enough. Both *Moving Cooler* and the U.S. DOT's April, 2010 report, *Transportation Role in Decreasing Greenhouse Gases*¹⁰ point out that some efficiency improvements (highway capacity expansion and bottleneck relief) actually increase VMT and greenhouse gases slightly due to induced demand. This is not to say that efficiency is not a good thing, only that it will not stop global warming. We traffic engineers love to see a good green wave on a major arterial; it promotes safe and efficient movement of people and goods, which is our mission. But it also encourages people to drive. Eighty years of great traffic engineering have not discouraged driving; we haven't even tried to do that.

Figure ES.1 **Moving Cooler Baseline: Projected On-Road GHG Emissions**

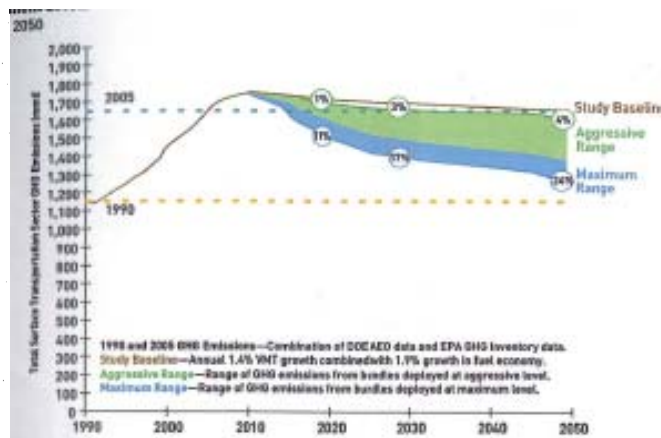
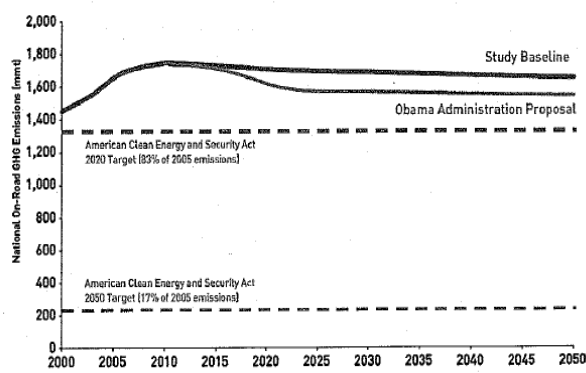


Figure 6 -- CO₂ Reductions from *Moving Cooler*. Note year 2050 target in the left figure.

What about efforts to discourage driving and provide alternatives? The main alternative is transit, which is primarily a function of density. For densities less than ten house per acre, transit is much less practical. San Francisco is one of the densest cities in the U.S. with 20 – 100 housing units per acre. Yet 62% of all trips in San Francisco are by auto.¹¹ So even if all the cities in the U.S. miraculously spend trillions of dollars to transform their land use to be as dense as San Francisco, and spend billions of dollars to build transit systems comparable to Muni, we will still need to eliminate fossil fuels from those 62% of trips by auto. Per capita emissions of CO₂ in San Francisco are about five tons per household from transportation alone, which is well below most of the U.S., but still five tons too much.

But what if we go even further, as we are striving to do here in San Francisco to nearly double our transit trips from 17% to 30% and increase bike and pedestrian trips to 40%, instead of their current 25%? This would be comparable to Copenhagen, one of the greatest bicycling cities in the world. But in Copenhagen, which has as many if not more trips by bicycle as by car, autos still account for four times as many vehicle miles as bikes (see Table I).¹² This is because cars are used for longer trips. So even Copenhagen generates too much CO₂ from fossil fuels to stop global warming.

Bicycle account for	2000	1998	1996	1995
Number of kilometres cycled, major roads (million km)	0,96	0,84	0,85	0,73
Number of kilometres driven by car, major roads (million km)	4,43	4,28	4,05	3,92

Table I—Kilometers by Car vs. Bicycles in Copenhagen

Perhaps the greatest example is China where cars account for less than 10% of the trips, and transit, bikes, and pedestrians cover 90%. But even China emits about 4 tons of CO₂ per person, and needs to cut that by 75% to do its share to get the world to a stable climate.

What more is needed?

So moving cooler can stem the growth in CO₂ but can't stop global warming. What will eliminate about half of CO₂ emissions are two additional steps:

1. Convert all cars to run on electricity, or plug-in hybrids which use bio-fuels instead of fossil fuels
2. Replace all fossil fuel electricity generation with renewable energy such as solar, wind, hydroelectric, and geothermal.

It is quite likely that if we achieve these goals, there will be an induced increase in VMT. If electric cars only cost a few cents/mile to operate, driving will be even more attractive. Just as high speed internet results in an increase in internet traffic. Also, the production of cars and paving of streets involve greenhouse emissions, so this also needs to be taken into account. Therefore, it is important to continue working to support transit, bikes, and pedestrians to make for more dense, livable, and vital cities. These actions are essential, but are not sufficient to solve the problem.

Electric Cars

The film, “Who Killed the Electric Car”, showed that automakers were unwilling to market a car that could only go 50 or so miles on a charge. The film makes the case that many drivers would be willing to buy such cars, since most trips are well under 50 miles. It seems reasonable that such a car could fill in as a second car for local trips, given that most U.S. households have two or more cars. Also, Nissan claims that its Leaf, due out in 2011, will get about 100 miles per battery charge. Plus, the recent announcement by the Chinese carmaker BYD that their electric car will go 205 miles on a charge very well may open up this market.

So all-electric cars can play an important role, especially if they are priced competitively. However, they will not be able to replace the family’s primary car since most people do want to be able to drive their car longer distances. The group Better Place envisions a quick changing battery system that would enable all electric vehicles to travel cross country, but this is a major infrastructure investment that may not happen, or happen soon enough.

Economics of plug-in hybrid electric vehicles (PHEVs)

What will answer the automakers concern about limitations on electric vehicles is the arrival of plug-in hybrids or plug-in extended range cars such as the Chevy Volt in the near future. The extended range Volt uses a small engine to charge the battery, rather than an internal combustion engine to back-up the electric motor. The Volt claims to get 50 miles per gallon after the 40 mile limit of the electric motor is reached. If drivers make 80% of their mileage in trips less than 40 miles, and drive 1000 miles per month, that would leave 200 miles on the gas powered generator at 50 mpg for a total of about four gallons for 1000 miles—250 mpg. This would certainly end the U.S. dependency on imported oil, and would eliminate air pollution from auto exhaust, both major benefits not even counting the issue of global warming.

Manufacturers coming out with plug-in electric hybrids include Hyundai, Chrysler, Ford, Volkswagon, Mercedes, Toyota, Audi, Volvo, Nissan, and Jaguar, among others. Cal-cars.com is an excellent source of news regarding the emergence of plug-in hybrid electric vehicles (PHEVs).

There are many uncertainties in this fast developing field. Much discussion centers on the strength and life expectancy of batteries. One good source of information on that subject is the Electrification Coalition, which contends, "Based on current and expected industry costs, a PHEV-40 [40 miles per charge] will be cost effective for consumers in 2015 -- without any government subsidy whatsoever."¹³

As noted, *Moving Cooler* predicts that adding the equivalent of \$5 per gallon tax to gasoline, would result in a 28% reduction in CO₂ emissions. However, such a drastic tax would almost certainly lead to complete conversion to electric vehicles in a fairly short time. According to the calculations in the book *Sustainable Energy-- Without Hot Air*, even with the current electric grid, converting to electric cars would reduce CO₂ emissions from autos by 37%.¹⁴

A lower estimate of the break-even point, based on a host of assumptions about current costs, gas prices, electricity prices, etc, is that PHEVs start being cheaper to operate when gas reaches \$4.24 per gallon.¹⁵ In other words given today's price of gasoline at \$3.00 per gallon, an internal combustion engine (ICE) car getting 30 miles per gallon is still more economical than a PHEV, assuming the PHEV costs about \$10,000 more than an ICE car. However, with increasing costs of gasoline, improved efficiency of batteries, and lower costs for PHEV, the break-even point is not too far away.

These calculations show that the transportation industry will need to implement a new method of paying for roads and infrastructure as fossil fuels are phased out. A system of payment by vehicle miles traveled is both technically feasible with modern on-vehicle computers and consistent with economic principles that urge pricing to correspond to consumption.

Renewable Energy

Converting cars to PHEVs will not seriously slow global warming unless the electricity is generated by renewable sources. Even a 36% reduction of emissions from the transportation sector would only constitute a 10% reduction in CO₂ emissions overall (36% of 28%), compared to the 80-100% reduction that is needed. The answer is to produce all electricity with renewable sources. Clearly this is an enormous task. However, it simply has to happen if we are to reduce CO₂ emissions below one ton per person.

The generally accepted forms of renewable energy are solar, wind, hydroelectric and geothermal. Tidal energy, ocean waves, and biofuels are also renewable sources of energy that are likely to be important. Sequestration of carbon from coal is also worth researching, but it is not ready now. Similarly new nuclear plants are worth considering, but need to confront the issues of security and waste disposal.

The cover story in *Scientific American* in November, 2009 predicted that a mix of solar, wind, and other renewables could replace fossil fuels by 2030. See Figure 8 for its proposed breakdown of energy sources; during the day solar would provide most of the energy and wind would do so during the night. The article drew critics who contended, along with various other points, that the electrical power grid is not ready to transmit wind from the Great Plains to the east coast and elsewhere.

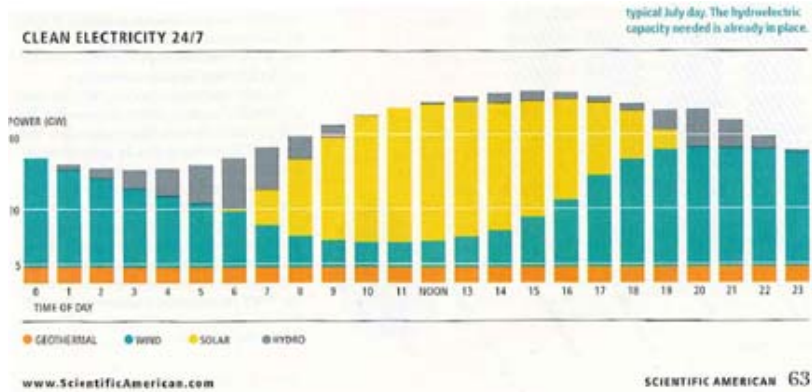


Figure 8 – Clean Electricity Distribution during the day¹⁶

Figure 7 shows that photovoltaic (PV) solar is already competitive with the peak load prices of electricity, which just happen to occur on hot summer days when solar generation is at a maximum. Given the rapid advances in solar, it appears that solar could be supplying a major portion of our electricity needs by 2020. However solar is less viable in more northerly climates.

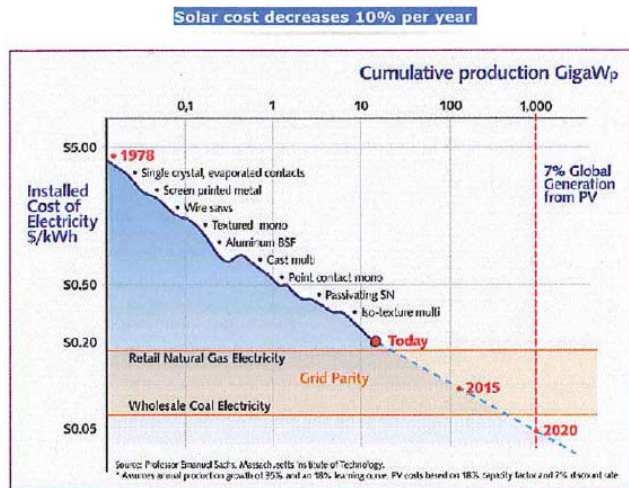


Figure 7—Declining price of solar power¹⁷

Biofuels are an important part of the solution as well. If plug-in hybrids become the standard, it will be important to use biofuels for the portion of their driving on the non-electric motor. Some bio-fuels are preferable to others in terms of CO₂ emissions; for example corn ethanol produces nearly as much CO₂ as fossil fuels. However, techniques of gasification of switchgrass and other biomass have been developed that emit virtually no CO₂.¹⁸ Also, biofuels offer a solution for airplanes and railroads where electric motors and batteries appear impractical.

Can we do this?

When the U.S. was attacked at Pearl Harbor, the nation steeled its resolve and mobilized its factories to produce jeeps, tanks, planes, and ships for the war effort at an unprecedented output

level. Today, the entire earth is under attack by the CO₂ buildup in the atmosphere. The technology exists for electric cars, plug-in hybrids and renewable energy. In fact, these are very close to being competitive in price with ICEs and oil and natural gas. Coal is still the cheapest, but it is also the biggest generator of CO₂. For the next 10 years or so, there need to be tax incentives, research subsidies, and caps on CO₂ legislated by elected officials. These actions will pave the way for the market to provide electric cars and renewable energy that eliminates fossil fuels.

One obstacle is that current energy policy in the U.S. still favors fossil fuel consumption. See Figure 8 which shows that 70% of energy subsidies go to fossil fuels. Economist Paul Krugman summed up the situation, “ We have a good sense of the costs — and they’re manageable. All we need now is the political will.”¹⁹

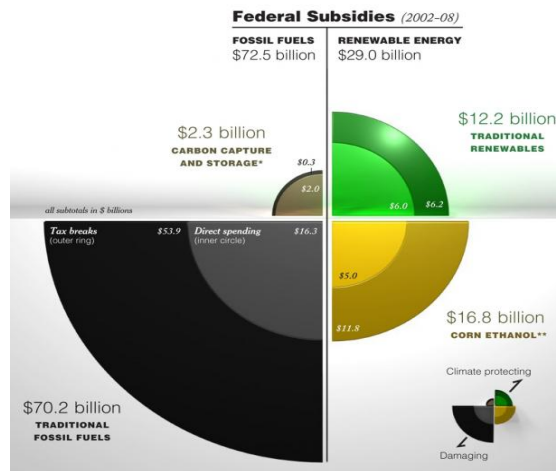


Figure 8: Federal Energy Subsidies²⁰

What can ITE members do?

Some members of our profession say, “But electric cars are not within our power to implement. We should concentrate on transit and transportation efficiency instead.” We would respond by saying that there is a lot that cities can do to encourage the necessary transformation.

Suggestions include:

- Equip public garages with plug in stations (not at parking meters, since they are for short term parking, not longer term charging)
- Work to require that all new garages have plug-in stations
- Work to develop standard plans and other assistance to building owners to retrofit off-street parking with plug-in stations
- Purchase plug-in vehicles and use low CO₂ biofuels for city fleets
- Conduct detailed carbon footprint analysis of all city-owned buildings, adding solar water heating and solar panels where feasible
- Continue support for bikes, transit, pedestrians—to stop increases in VMTs as well as to improve health, quality of life, and economic vitality in addition to

stopping dependence on oil imports and urban sprawl with its destruction of wildlife/farmlands.

- Work with the State and Federal regulators to adopt uniform standards for recharging stations and battery designs.
- Work with State and Federal elected officials to develop new pricing mechanisms to support transportation such as vehicle miles traveled fees

And both as individual concerned citizens, and as ITE chapters, we can support research, funding and tax credits for solar, wind and all renewables

Summary

Sixty one percent of the CO₂ emitted in the U.S. comes from electricity generation and transportation. Fossil fuels must be eliminated from these sources to create a sustainable environment. The other sources of CO₂ —industry, agriculture, and commercial/residential buildings—all need to develop comparable strategies, but that is beyond the scope of this paper.

This paper cannot select a blueprint for the best choice of electric/plug-in hybrid vehicles or renewable energy, and there is much development needed. However, the direction of what needs to happen is clear—conversion to electric vehicles and plug-in hybrids powered by renewable energy. It is important for transportation professionals to add their voices and efforts to make this happen.

The traditional goals of transportation engineering are still essential, but we need to add the goal of sustainability. Providing safe, efficient, *and sustainable* movement of people and goods can be achieved by pursuing all the steps in *Moving Cooler* plus implementation of electric vehicles and renewable energy.

Authors:

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Notes:

¹ Hansen, James, *Storms of my Grandchildren*, Bloomsbury, NY, 2009, pg 224

²Press release from the UN Conference on Climate Change in Copenhagen:
http://unfccc.int/files/press/news_room/press_releases_and_advisories/application/pdf/pr_cop15_20091219.pdf

³Reported from World Resource Institute web site: <http://earthtrends.wri.org/updates/node/320>

⁴ Cambridge Systematics, Inc. *Moving Cooler, An Analysis of Transportation Strategies for Reducing Greenhouse Gas Emissions*, Washington DC, Urban Land Institute, 2009—page 11

⁵ James Hansen, *Storms of my Grandchildren*, page 164

⁶ See for example, the policy brief by Alex Bowen and Nicola Ranger, “Mitigating climate change through reductions in greenhouse gas emissions: the science and economics of future paths for global annual emissions”, by the Grantham Research Institute on Climate Change and the Environment, December, 2009

⁷ James Hansen, op.cit. page 117 Note that Hansen uses the figure 2.12 billion tons of carbon. To convert carbon to CO₂, multiply by 44/12, the molecular weights of CO₂ and carbon

⁸ Joseph Romm, *Hell and High Water*, 2006

⁹ http://www.brookings.edu/~media/Files/rc/reports/2008/1216_transportation_tomer_puentes/figure_1a.pdf

¹⁰ *Transportation's Role in Reducing U.S. Greenhouse Gas Emissions*, U.S. DOT, 2010, was mandated by the Energy Independence and Security Act of 2007. It is available on the Internet at http://ntl.bts.gov/lib/32000/32700/32779/DOT_Climate_Change_Report_-_April_2010_-_Volume_1_and_2.pdf

¹¹ San Francisco Better Streets Plan, Draft for Public Review, San Francisco Planning Department and San Francisco Municipal Transportation Agency, 2008, page 22,

¹² Cycle Policy, 2002-2012, City of Copenhagen, page 37
http://www.vejpark2.kk.dk/publikationer/pdf/413_cykelpolitik_uk.pdf

¹³ <http://www.electrificationcoalition.org>;

¹⁴ David MacKay, Sustainable Energy--Without Hot Air, available on-line at www.withouthotair.com. MacKay calculates that an electric vehicle running on grid electricity would emit 100 grams of CO₂ per kilometer, compared to an average of 160g/km for ICEs—page 122.

¹⁵ Please email Jack Fleck at jlf@igc.org if you would like to get a copy of the spread sheet used to make this calculation; all variables may be adjusted for developing conditions/assumptions

¹⁶ Scientific American, November, 2009, “A Path to Sustainable Energy by 2030”, Mark Z. Jacobson and Mark A. Delucchi, page 63

¹⁷ Professor Emanuel Sachs, MIT, <http://www.1366tech.com/v2/>

¹⁸ “New Gasification Process More Efficiently Converts Biomass to Biofuels” by Sarah Parsons, Inhabitat, 4/22/10 <http://inhabitat.com/2010/04/22/new-gasification-process-more-efficiently-converts-biomass-to-biofuels/>

¹⁹ Paul Krugman, New York Times, April 5, 2010.

²⁰ Timothy B. Hurst, Ecopolitology, March 8, 2010, <http://ecopolitology.org/2010/03/08/think-renewables-need-huge-subsidies-federal-energy-subsidies-visualized/>