The Emperor's New Car

A critique of the economic and environmental value of electric cars

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Disclosure of interest

The author of this report does not work for, nor is he associated with, directly or indirectly, any interested parties. Likewise, the author of this report has in no way been paid or otherwise offered inducements, directly or indirectly, by any interested parties for the content of this report or the positions taken within it.

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Statistics

• **Note: our quoted statistics were correct at the time this report was assembled.** There may be minor differences between our assumed figures and figures published after our report was assembled (new information is being released by governments and other bodies all the time). Also, because illustrations and graphs tended to be inserted after the report was complete, there may also be minor differences between the figures in the illustrations versus the figures we have assumed for the rest of the report.

Advisors

All of the following advisors below generally agree on most of the basic facts underlining this report and most agree with the report's general direction. Each consultant has his own perspective and not all the consultants agree with our methodology, all of our conclusions, or the manner in which we have expressed them.

This report was three years in the making. Please note that, as is almost always the case, this report was constantly modified and corrected as new information became available, right up to the deadline for publication. Given the vast amount of information required to prepare this report, it is highly unlikely to be 100% correct in all matters. Therefore, although all consultants have read at least one of the versions of this report, it is entirely possible that the final version contains errors or omissions that the respective consultants were not aware of, because these errors or omissions were not present in the version they read. Therefore, the consultants cannot be held responsible for any errors or omissions in this report.

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- **NOTE: This report contains extensive web-based references. These hyperlinked references are highlighted in blue text, which will only display onscreen.**

All links were active at time of release.

All truth passes through three stages. First, it is ridiculed. Second, it is violently opposed. Third, it is accepted as being self-evident

Schopenhauer

Summary

There are credible reasons for gradually converting the world's car fleet from fossil-fuel-powered vehicles to electric vehicles, on the grounds of economic and environmental efficiency. These advantages can be summarised as:

1. Electric cars improve the security of vehicle energy supply by avoiding liquid fuels that are often imported from hostile or politically volatile countries and are being discovered at a slower rate than they are being depleted.

2. Electric cars offer much improved air quality in cities.

3. Electric cars offer drastically reduced traffic noise.

4. Electric cars offer less CO_2 emissions if the electricity comes from nuclear, hydro, solar, wind or perhaps biomass.

5. Electric cars are sometimes more efficient than petrol or diesel cars.

However, these advantages appear to be equally balanced by the disadvantages:

1. Globally, most electricity is produced using highly environmentally damaging sources, and much of it is produced from fossil fuels. There is unlikely to be a significant change in the way this majority of electricity is produced in the foreseeable future.

2. Although there are alternative forms of electricity production that cause less harm to the environment than conventional forms, these forms are invariably far more expensive, and are therefore unlikely to be adopted *en masse* in the near future. Thus, the central premise behind the electric car movement – that electric cars will be powered primarily from 'green'

sources – is essentially wishful thinking. The car driver generally has no control over how and where the electricity that powers his car is generated. Electric cars do not stop environmental damage: rather, they tend to merely move it out of sight, from the highways to the power plants.

3. Cars – electric or otherwise – are most efficient when used for special trips on empty roads. However, most cars are used as a form of mass transport on congested roads, a task for which they are manifestly unsuited. Compared with efficient electric buses and trains, in most cases there is little economic or environmental justification for electric cars as a form of mass transportation.

4. Most commentators agree that, regardless of what form the energy takes, there is currently a serious global shortage of accessible energy. The electric car scenario, as promoted in movies like '*Who killed the electric car?'* is built upon the assumption of a vast resource of cheap, abundant, electrical energy, in precisely the same manner as the petrol car model is built on the assumption of a vast resource of cheap, abundant petroleum fuel. Both models erroneously assume that a ready supply of cheap, accessible energy will somehow be available to maintain the current Western lifestyle and the lifestyles of emerging nations, which are essentially copies of the Western way of life.

5. While electric cars are sometimes (but not always) more efficient than their petroleum-powered rivals, this greater efficiency will not significantly ease the current global energy-environmental crisis. This is because the private car, regardless of how it's powered, appears to be an intrinsic part of an unsustainable economic model. Improving efficiency, by itself, will not help in a society that is set up with an expectation of perpetual growth, because any efficiency improvements will inevitably be overtaken by this growth.

6. The main driving force behind the current rush to produce electric cars is coming from both the motor industry and the electrical generation industry.

As sales of conventional vehicles falter due to economic recession and tougher environmental standards, the car and power companies hope to gain government subsidies for electric vehicles in order to maintain sales volumes and to capitalise on these tougher environmental laws. Many governments have shown themselves to be more than willing to spend taxpayers' money on what is essentially a bailout of ailing car companies, under the guise of environmental concern.

7. Most electric vehicle advocates see these vehicles as part of a transition towards affordable, sustainable personal transport. However, there's an inherent 'Catch-22' in this equation. Globally, and, in most cases, nationally, 'green' energy is such a minor proportion of total energy production, that electric vehicles will invariably be powered by unsustainable and heavily polluting fuels, thereby negating the basic premise behind these vehicles. This harsh reality is unlikely to change substantially for the foreseeable future. Conversely, if unsustainable fuels were eliminated from the generation equation, the price of energy would rise so dramatically as to make personal transport unaffordable for most people.

8. While a shift to electric cars is perhaps inevitable, it does not currently appear to be either physically possible, nor desirable, to simply exchange a global fleet of oil-powered cars used as mass transport, for a global fleet of electric-powered cars used as mass transport.

9. China is likely to be the main beneficiary of the electric car movement. Due to massive government investment, China is likely to be the first country to mass-produce electric cars at prices that are competitive with conventional petrol and diesel engines. However, these cars are likely to be produced using environmentally destructive materials and techniques, in factories that are powered by non-renewable and heavily polluting forms of energy.

Cars and the American Dream

Cars, as a form of mass transport, make very little sense from a scientific point of view. However, humans are not laboratory rats; they act according to a complex set of challenges and rewards.

To say that people drive cars in order to move from place to place is as naïve as saying that recreational fishermen go fishing in order to catch fish. To view cars merely as a form of transport is a hopelessly simplistic view: in order to understand the hold that cars have on the world, one must first understand people's motivation for both using them and clinging to them in face of global environmental crisis.

Electric cars have been around for a long time. They enjoyed a brief vogue in the early twentieth century, before cheap oil and improved petrol engines spelled their doom. They surfaced again during the 1970s oil crisis, but their limited power and range doomed them once more once the crisis passed. Long after the major manufacturers abandoned battery-powered vehicles, however, enthusiasts and environmentalists built homemade electric cars and railed against the major car companies that ignored or ridiculed their efforts.

In recent times, the oil price crisis, growing awareness of climate change, combined with a rush of public sympathy that followed the movie *Who killed the electric car?* pushed the electric car from the sidelines to the mainstream, and made it a potent symbol of positive environmental change.

Many nations' rationale for switching to electric vehicles is based on the triple concepts of oil shortage, energy security and a desire to reduce pollution.

It is widely acknowledged that oil is a finite commodity that must run out one day. Also, even though oil is still relatively abundant, oil reserves tend to be concentrated, with the exception of Canada, in countries with unstable governments or governments hostile to the West.

However, the world's oil shortage can be more usefully described as an energy shortage. Oil is just another way of heating things and making things move. There are many other ways; it's just that for the last hundred years oil has been the cheapest and most convenient form of energy in many countries.

Even the term energy shortage is not quite accurate: globally, the problem is not merely lack of energy, but wastage of energy, and the pollution that arises as a result of this wastage. For example, much of China's electricity is produced in crude, inefficient and polluting coal-powered stations.

> "The vast majority of China's coal-burning power stations…are not technologically sophisticated and remain highly polluting."

Arguably, China is merely following America's example: the US, with 5% of the world's population, uses 23% of its energy.

It has also been pointed out that much of the West's energy lifestyle relies on the East staying poor and undeveloped.

> "75% of the world's population - more than 4.5 billion people - live on just 15% of the world's resources, while we in the West gorge on the remaining 85%.
>
> The world simply does not have the resources, renewable or otherwise, to sustain Western lifestyles across the globe."

Whether a nation squanders oil or coal or biodiesel, there's still a high cost; in nature, nothing comes free. There is abundant evidence that there simply isn't enough energy to support the current lifestyle of the West, let alone the rest of the world that is increasingly trying to adopt a Western lifestyle, or, to put it more accurately, an American lifestyle.

> "the average American consumes five times more energy than the average global

> citizen, 10 times more than the average Chinese, and nearly 20 times more than the average Indian.[1]"

It's no accident that the car became the vehicle of choice for many Americans; early twentieth century America had a lot of apparently empty land, an apparently limitless supply of oil, and a car industry aimed at putting a vehicle into the driveway of every home.

Now that life in America is built around the private car, it's very hard to reverse the process. However, the problem is not merely that America's towns and cities were largely built around the car. The problem is that Americans – along with the countries that copy America – have grown so used to using cars as their primary form of transport that they are both unwilling to change and often frightened of any alternative.

For Americans, and those who copy Americans, cars have traditionally represented freedom.

Most positive discussions about the practicality and pleasure of car ownership tend to focus on the car when it is not being used as a form of mass transport (see link above).

For example, many people's fondest memories of car use revolve around recreational trips, such as a picnic, a drive in the country or a romantic date.

However, for many Americans, the car's single biggest purpose is simply getting to and from work – a task for which the private car is often manifestly unsuited.

Arguably a person sitting in a train carriage that glides quickly past a traffic jam has more freedom than the person stuck in the traffic jam. However, reality is not the issue here: the real issue is the *sense* of freedom that a car brings.

[1] This quote is now several years old and may no longer be strictly accurate. The basic premise, however, is still clearly valid.

Perception versus reality

There is a clear assumption behind the electric car movement that the widespread use of electric cars will ease America's wasteful energy use. This is not true. The private electric car cannot solve America's energy and pollution problem because the private car is not the biggest waster of energy in America. Rather, it's both the cause and the symptom of a much bigger problem.

Before the private car, new American suburbs at the turn of the twentieth century tended to be built around trains or, more often, around "electric trolley car systems, also known as inter-urbans, though they seldom connected cities... Interestingly, Los Angeles, pre-eminently the city of the automobile, had one of the most extensive street rail systems in the world.

> "The importance of the trolleys can scarcely be over-emphasized. Every city of any size wanted to have a system in the nineties, and by 1900 they were everywhere. And, what is now largely forgotten, they drove the American market for private housing, and, to a considerable extent, the entire manufacturing economy of the world's premier industrial power. Owners of electrical utilities frequently owned the trolley lines as well, and they built rails out into the countryside around major cities where they collaborated with real estate developers to build the first modern bedroom communities…"

However, these suburbs, aimed at the working man who wanted to move his family away from the dirty, crime-ridden inner city slums, often offered something of a false promise.

> "The suburbs tended to be constructed quickly, and tended to lack much of what people expected a township to provide…[such as] shops, churches, recreational facilities, schools, and social centers, and they were limited in their physical extent because the rail line passing through them did not provide for internal transportation… Streetcar suburbs were not remembered with much affection by those Americans – nearly all deceased today — who grew up in them. They were full of what is known in the parlance of today as 'starter homes'… Almost half of

> such homes were at least partially constructed by the owners, an arduous process performed by the man of the family and perhaps a few friends or relatives in summer evenings after the conclusion of the ten hour work shift. Meanwhile, the family literally camped out on the mostly vacant lot. Normally what would happen was that the hapless home constructor would throw up his hands after several weeks of brutally hard work and attempt to secure a further loan to hire a professional builder to finish the job. With luck the house might be sufficiently completed to occupy before winter… Enthusiastically embraced by American workers beguiled by the dream of home ownership, streetcar suburbs proved less attractive after about 1910, and few new ones were constructed. Most of the construction occurred over a period of about a dozen years from the early nineties to the middle of the next decade. Not coincidentally, street rail construction largely ceased about the same time..."

In Europe, where houses tended to be smaller and close together, light rail was a cheap and practical solution to the daily commute, and thus never died out. In America, however, the advent of car-based suburbs removed the need for public transport as the basis for a new housing development. It also removed size and space restrictions on new homes. Developers would simply buy a farmer's field a few miles from town, bulldoze it flat and start building streets and houses. Because a large house could be sold for more than a small house, the houses in the car-based suburbs grew exponentially in size, assisted, after World War II, by government-backed home loans.

Also, because of the lax building codes of the day, these larger houses were generally poorly designed and poorly insulated by modern standards, and thus became a major source of energy wastage. In fact, despite the perception of most Americans, American homes consume more energy than American cars.[2]

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[2] This scenario is not necessarily true for all countries: for example, in New Zealand, residential energy use for transport is about the same as energy use for housing in low income families. However, due to New Zealand's comparative geographical isolation, energy use for transport is higher for high income families (mainly due to the energy use by and emissions produced by air transport).

> "In reality, the USA residential sector ranks as the single largest energy consumer in the world, and homes worldwide account for 25% of total energy use, according to a May 2007 report from the McKinsey Global Institute titled: *Curbing Global Energy Demand Growth: The Energy Productivity Opportunity*. In addition, according to the USA Energy Information Administration, residential and commercial buildings are responsible for almost half, (48%), of greenhouse gas emissions in the USA
>
> "'Many homeowners don't realize that a typical house releases almost twice as much carbon dioxide annually as a typical car,' said Kateri Callahan, president of the Alliance to Save Energy."

However, globally, the problem of domestic energy wastage is getting worse, not better. The *New York Times* recently reported that:

> "Electricity use from power-hungry gadgets is rising fast all over the world. The fancy new flat-panel televisions everyone has been buying in recent years have turned out to be bigger power hogs than some refrigerators.
> The proliferation of personal computers, iPods, cellphones, game consoles and all the rest amounts to the fastest-growing source of power demand in the world.
> Americans now have about 25 consumer electronic products in every household, compared with just three in 1980.
> Worldwide, consumer electronics now represent 15% of household power demand, and that is expected to triple over the next two decades, according to the International Energy Agency, making it more difficult to tackle the greenhouse gas emissions responsible for global warming.
> To satisfy the demand from gadgets will require building the equivalent of 560 coal-fired power plants, or 230 nuclear plants, according to the agency.
> Most energy experts see only one solution: mandatory efficiency rules specifying how much power devices may use."

None of the experts quoted in the New York Times article advocated that Americans learn to practise restraint in their purchases of consumer electronics.

Nor is the problem restricted to housing: recent research has shown that a major cause of pollution in Los Angeles is not from the cars, but from the ships that visit the port.

Moreover, the ships that will eventually carry electric cars to America from countries like China appear likely to cause more environmental harm than the polluting vehicles that the electric cars are supposed replace.

For example, in November of 2009 it was reported that 16 ships create as much pollution as all the cars in the world.[3]

What are these ships carrying? Mostly freight, generally consumer goods for Americans, built in Third World countries with poor environmental and labour laws, and exported to a country where consumption is the primary source of gratification for many of its citizens.

Only a minority of the consumer items on those ships appear to serve much useful purpose or provide any long-term satisfaction or pleasure. If the interior of a Wal-Mart store is anything to go by, most items serve primarily to provide instant, temporary gratification, to be quickly replaced by another item of instant, temporary gratification once the gratification of the first item wears off. For example, plastic children's toys typically don't last long and end up as trash a few hours, days or weeks after purchase, to be quickly replaced by the next novelty item that catches the eye of the child or parent. In 21st century consumer culture, even ostensibly useful items like running shoes and cars, are frequently replaced, not because they are worn out, but because they no longer produce sufficient gratification in the form of status or novelty.

Thus, for America and the countries that wish to emulate America, the problem is not so much the car by itself, but a package deal of wasteful cars, wasteful suburbs based around cars, together with a wasteful society based around consumption, with the car as the most obvious symbol of this waste. Changing the way that American cars are powered will not solve the built-in problems of the American system of over-consumption.

[3] There appears to be a large amount of journalistic licence in this claim. Aside from CO_2 emissions, much of the pollution being produced from these ships is only sulphates – something that (non-diesel) cars produce almost none of. Also, the implication is that any 16 ships produce this much pollution. In fact, it's the world's 16 biggest ships.

‘Green’ business groups often promote the idea that it is both possible and desirable to maintain and expand the present Western lifestyle globally, using hitherto undiscovered or unperfected resources. Central to this impression is the idea that the massive global trade in items aimed at providing temporary gratification, together with the high energy usage associated with these activities, is essential if the world is to maintain business activity and employment.

This argument, while appealing, doesn’t stand much scrutiny. First, there don’t appear to be the resources to maintain, let alone expand, the current system. Second, if we followed the argument (that an expanding destructive activity is okay as long as it maintains economic activity and keeps people employed) to its logical conclusion, then we would also advocate an increase in criminal activity in order to maintain the justice system and keep policemen employed.

Wishful thinking

Alternative energy enthusiasts frequently appear somewhat naïve about alternative energy sources, often quoting figures such as: "There is enough wind power throughout the world that: if only 20% of that power was captured, it could produce seven times the global demand for energy."

Such figures tend to be fanciful rather than practical. At its purest level, the universe is nothing but energy. However, it is useful to compare energy to money: it is all around us in great abundance, yet it proves frustratingly difficult to gather and accumulate it for our own benefit.

In reality, 'green' energy sources are next-to-insignificant under the present system: the global use of 'dirty' energy like coal continues to outstrip the growth of alternative energy sources in many places. The only way the current, planned or feasible future sustainable energy resources could conceivably take the place of fossil fuels is if the global trade in items aimed at providing temporary gratification, together with the high-energy usage associated with these activities, was reduced substantially from its current level.

Even then, the growth of an American-style consumer lifestyle in countries like China would soon outstrip any environmental gains made within the West.

It is difficult to over-estimate how serious the global problem of energy wastage is: in September of 2009, the American magazine *Foreign Policy* reported that: "China is expected to built more square feet of real estate in the next 15 years than the United States has built in its entire history, and [China] has no green building codes or green building experience."

Moreover, past experience in China suggests that – even where building codes exist – they are easily overcome with the right amount of bribery and/or political pressure.

The indirect consequences of the West's addiction to its lifestyle are also frightening in their magnitude. For example, without the West's addiction to cheap goods, it is likely that China's path to growth would have been far slower, better planned and less environmentally damaging. However, China's growth has been exponential, and has been powered mainly by coal. China's addiction to cheap energy in the form of coal is alarming in itself. However, there is the equally alarming factor of uncontrolled underground fires caused as a result of China's insatiable demand for coal.

> "Uncontrolled underground coal fires, some of which will burn for decades, have become an enormous environmental problem in China, consuming an estimated 200 million tons of coal annually—an amount equal to about 10% of the nation's coal production. These ultra-hot fires can occur naturally, but most are caused by sparks from cutting and welding, electrical work, explosives, or cigarette smoking. Across the northern region of Xinjiang, fires at small illegal mines have resulted from miners using abandoned mines for shelter, and burning coal within the shafts for heat. China's underground coal fires make an enormous, hidden contribution to global warming, annually releasing 360 million tons of carbon dioxide — as much as all the cars and light trucks in the United States."

America and personal space

Because many early Americans emigrated from poor and unpleasantly overcrowded countries, the acquisition of secure personal space has always been an American obsession. Not only do Americans and their admirers see it as their right to travel in isolation from their fellow countrymen, they now seem terrified of sharing space with strangers.

Obesity is considered to be one of the leading causes of preventable deaths in America, yet if you watch American television you might rapidly form the view that America is a war zone. In a city of, say, one million homes, there is inevitably going to be a small group of violent people at any one time. Therefore, the chance of one million homeowners becoming involved with that small group of violent people is actually quite low. However, in any city in America, countless television sets beam graphic images of this small group of violent people into a million homes, creating the impression that the violence is occurring right outside their doors. Therefore, the million television viewers become convinced that it's no longer safe to go outside.

This perception of threat induced by the news media appears to be a global problem. For example, a recent survey in New Zealand showed that, while the murder rate had halved in twenty years, most people believed the rate of violent crime had in fact gone up.

> "A… survey of 1400 people in four parts of New Zealand - including [rough areas like] South Auckland - found that 80% agreed or strongly agreed that the country's crime rate was rising. Only 4% disagreed.
>
> "Yet the same survey… found that only a quarter of the people surveyed believed crime was rising in their own neighbourhoods.
>
> "When asked where they got their information about the national crime rate, people said from the media."

In terms of cold, hard data, cars are a far greater threat to Americans than guns. Around 30,000 Americans die from gun injuries every year.

However, over 43,000 Americans from all walks of life die in motor accidents each year.

Yet the same Americans, who are terrified to walk the streets due to a fear of being a victim of crime, use their cars to give themselves a false sense of security, freedom and isolation from danger.

A further perception in America is that public transport stations are dangerous places where criminals and lunatics lurk. However, many American car parks would appear to be far more dangerous than their local train or bus station.

> "Wal-Mart has become a national stage for almost every kind of human drama: domestic violence, stalking, murder, rape. It all happens in Wal-Mart parking lots. It also happens in *Target* parking lots, *Home Depot* parking lots, and other sprawling roadside attractions. But it happens more often at Wal-Mart because it controls more than 4,000 U.S. parking lots that make very convenient staging areas: they are crowded, they are near the interstate, and they are easy targets…
>
> "Wal-Mart has been less than forthcoming about the extent of its crime problem. But the subject has been a sore point for more than a decade. In 1996, the company's Vice-President for Loss Prevention admitted that "80% of crimes at Wal-Mart were occurring not in the stores, but outside their walls, either in the parking lots or in the exterior perimeter of the stores."

Losing weight without dieting

For many people, the difficult and often dangerous process of immigration to America was, and often still is, driven by extreme poverty. Therefore, to most Americans, the acquisition and consumption of material possessions is their primary focus in life.

Speaking of America just before the recent financial crash, Andrew Gumbel commented:

> "The United States is a place where the prevailing instinct is to want it all, no matter the consequences. Sure, there may be wars in the Middle East, Islamic militants on the march, smog in the air, pollutants in the water, hurricanes, floods and other tangible side effects of global warming but that's not going to stop most people from hankering after a big car and a big house with state-of-the-art gadgets.
>
> "Cutting back is not cool or sexy. Given the choice between laboriously reviving old city centres with apartment renovations and corner shops, or ripping up cornfields to create suburban developments with huge houses and monster shopping malls, most Americans opt for the monster.
>
> "People certainly have mixed feelings. At the height of the Iraq war, it was not uncommon to see huge, gas-guzzling four-wheel-drives sporting "No Blood for Oil" stickers. Americans aren't happy about their obesity epidemic or their tendency to overspend in grocery stores or over-order in restaurants, even while they consume 200bn calories a day more than they need and throw away around 200,000 tons of edible food each day."

As a result, America uses a hugely disproportionately high percentage of the world's available energy: The US - with 5% of the world's population - uses 23% of its energy.

This obsession with consumption applies to food as well: Americans are the most obese nation on earth.

Aside from greed, one of the reasons Americans are so obese is that they tend to drive rather than walk, and many Americans simply won't willingly change their car-based lifestyle. That is, while some Americans may be reluctantly facing the reality that their car-based lifestyle contributes to the global energy shortage and perhaps climate change, most of the proposed American solutions focus on maintaining the current car-based system, using different forms of energy.

America, arguably, is addicted to excess consumption as a way of life, and has successfully exported this culture around the world. Even when America tries to deal with the consequences of excess consumption, it deals with these consequences in ways that don't really address the main problem.

For example, the reason so many Americans are chronically obese is – in addition to driving rather than walking – they simply eat far too much. No amount of fad diets, weight-loss drugs, exercise machines or weight loss clinics can solve the problem, because few of these 'solutions' deal with the real issue.

It should come as no surprise, therefore, that science shows quite clearly that the only real way to lose weight is to eat less.

This is very easy to say, but hard to do for many Americans, because many Americans get their daily gratification through consumption. Remove this gratification and you remove the prop that holds up their lives.

As American writer Bill Bryson put it:

> "You have a sense in America of being amongst millions and millions of people needing more and more of everything, constantly, infinitely, unquenchably[4]."

The only way an obese person can really lose weight is to diet. The only way that a society hooked on excess energy consumption can solve the problem of excess

[4] Bill Bryson, '*Notes From a Big Country'*

energy consumption is to reduce its energy consumption to a sustainable level.

This is a really depressing concept for many Americans. It means smaller houses, less consumer products, and it means giving up the daily commute by car. That is, instead of hundreds of millions of people spending hours every day in frustrating traffic jams, the same people need to share some form of efficient mass transport, or perhaps, work from home, as many of their ancestors did.

Many Americans do not believe that such a system is possible in the modern world. However, the Japanese have somehow combined a love of cars with a recognition that cars are best used for trips that cannot be easily made by mass transport. Thus the private car and mass transport exist comfortably side-by-side, or as comfortably as they can in a country as tiny and crowded as Japan.

Other than size, the essential difference between the American view of life and the Japanese view is simple, yet major: many Americans see society as a series of competing individuals, with the winners rising to the top and the losers sinking to the bottom. The Japanese see society as a series of cooperating individuals, who all gain – both as individuals and as a whole – by this cooperation.

The American electric vehicle movement is based around the belief that it's going to be possible to continue the American car-based lifestyle of the twentieth century by changing the form of energy used to power it.

Arguably, that's equivalent to a fat person trying to lose weight by switching from hamburgers to french fries. The basic problem – unsustainable over-consumption – is never addressed.

How 'Green' is That Electricity?

The most obvious example of inaccurate perceptions about the benefits of electric cars can be seen in the American Tesla electric vehicle; it's a quick-and-slick two-seater sportscar that costs about the same as a house and has the stated purpose of: "Reducing [America's] dependence on foreign oil." Note that this statement of purpose doesn't talk about reducing America's overall energy consumption.

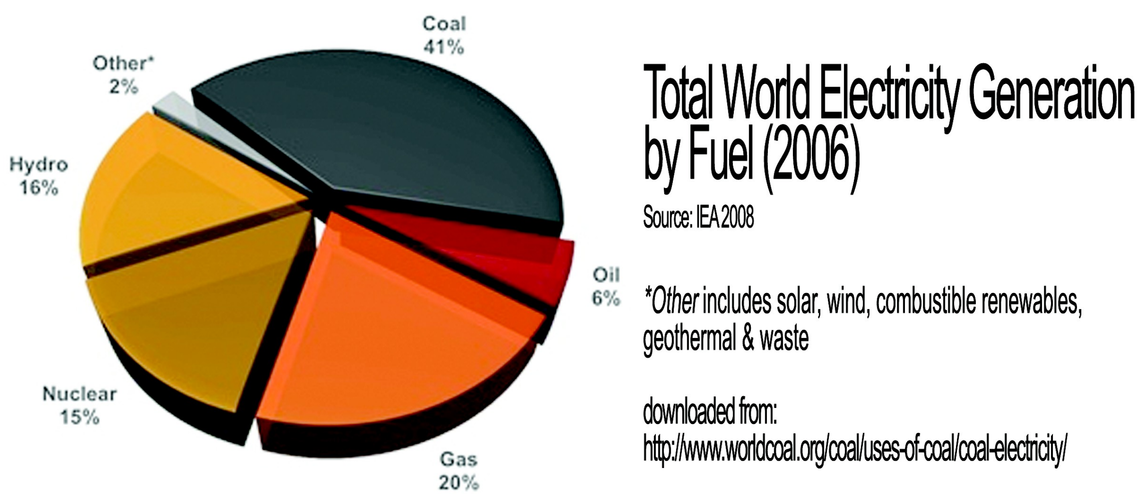
For electric car enthusiasts, the Tesla is a dream come true. It's stylish, incredibly fast, and apparently safe, and reports suggest it is being ordered by dozens of film stars and Silicon Valley executives.

The problem with car projects like the Tesla is that they send out the message to America and the world that it's acceptable to squander energy and spend your life sitting in traffic jams as long as your car is not actively puffing out emissions or relying on imported oil.

However, there is a great deal of evidence that cars like the Tesla are really just putting off the day when Americans must reduce their excessive consumption. Moreover, despite 'green' claims, cars like the Tesla sometimes consume more energy and are more environmentally damaging than many of the cars they replace (see Appendix V).

The energy gap

Most electric vehicle advocates see these vehicles as part of a transition towards affordable, sustainable personal transport. However, there's an inherent 'Catch-22' in this equation. Globally, and, in most cases, nationally, 'green' energy is such a minor proportion of total energy production, that electric cars will invariably be produced and powered by unsustainable and heavily polluting fuels, thereby negating the basic premise behind these vehicles. This harsh reality is unlikely to change substantially for the foreseeable future. Conversely, if fossil fuels were eliminated from the generation equation, the price of energy would almost invariably rise so dramatically as to make personal transport unaffordable for most people.



This is all the more obvious when one considers that [the US Department of Energy expects global energy consumption to rise 77% by 2030].

[The Energy Information Administration] expects global coal use to rise by nearly 50% by 2030.

"Coal's share of world carbon dioxide emissions grew from 39% in 1990 to 42% in 2006 and is projected to increase to 45% in 2030."

We are unaware of any credible 'green' energy strategy that can feasibly maintain current levels of production, let alone increase them to the projected 2030 levels.

For example, New Zealand, with its small population (around four million) and long coastline regularly buffeted by strong winds, would seem an ideal candidate for wind power. Yet the most positive projections for wind power in New Zealand suggest that wind power could provide just 20% of New Zealand's electricity needs, excluding all political considerations (such as the ongoing objections to new wind farms from local residents).

Currently, wind power produces less than 2% of global electricity. The news media has correctly pointed out that this sector is growing at an exponential pace, but it's relatively easy for a sector to grow at an exponential pace when its current total production per country is often measured in fractions of a percent. Moreover, recent studies suggest that the output of wind farms is far less than was promised by wind power's enthusiastic advocates.

What about the other promising sources of alternative energy?

See ***Appendix I – Oil and its Alternatives*****,** summarised as follows:

• **Oil**: The world is not running out of oil, it's running out of *cheap* oil. Most of the oil that's left is either difficult to extract or it's in a form that requires energy intensive processes to refine, such as tar sands.

• **'Green coal'**: The viability and supposed benefits of improving coal plants are frequently disputed. So far, CO_2 trapping technology is a costly, unproven theory.

• **Solar power**: One of the most costly technologies, and largely restricted to places of high available sunlight. It is also dependent on daylight hours and weather conditions. Currently very inefficient. Emerging technologies may improve efficiency, but are unlikely to be the 'silver bullet' that solves the energy crisis.

• **Wind power**: There's simply not enough viable space available to accommodate the amount of wind generators that would be needed to fill the world's electricity demand. There are also objections to the appearance and noise of wind generators; the technology is costly; dependent on specific wind conditions; takes up valuable space that is often also valuable for another reason, such as coastline.

• **Tidal power**: Tidal power is mostly unproven technology that is either uneconomic or marginally economic. The technology is very expensive, maintenance would be expensive due to salt water corrosion, etc. It is unlikely to ever replace oil as a cheap source of energy.

• **Geothermal generation**: vastly over-hyped as an energy source. Geothermal power stations are expensive to set up and prone to expensive technical problems. Geothermal steam reservoirs are likely to gradually empty with time. Geothermal water-injection systems (where water is forced into geothermal fissures to produce steam for generation) are potentially very dangerous.

• **Hydrogen**: Hydrogen is not a form of energy, it's a means of storing energy, and there are considerable energy losses in making the hydrogen. It's like a bank account that pays back only 60-80% of the original investment.

• **Natural gas**: It's expensive, dangerously flammable and it will eventually run out, just like oil.

• **<u>Biofuels</u>**: Generally, the farming of crops for fuel means there is less land available for growing food, which drives up the price of food; forests are being cleared to make room for growing these crops, contributing to global warming.

> • **Ethanol**: It often requires more energy to produce the ethanol than is returned in the fuel. Many forms of ethanol are environmentally destructive and/or compete with food crops.
>
> • **Biodiesel**: More efficient than ethanol, but often requires more energy to produce the biodiesel than is returned in the fuel. Many forms of biodiesel are environmentally destructive and/or compete with food crops.
>
> • **Algae**: Unlike the others, algae farming doesn't displace food crops, however, its conversion into usable energy is not currently economically feasible.
>
> • **Jatropha**: Can be grown on marginal land not suitable for food production, but it's a highly poisonous plant and consumes huge amounts of water; already banned in Western Australia.

• **Nuclear power**: Very, very expensive, and most plants end up costing many times the original estimated cost. Nuclear plants also frequently take far longer to commission than was initially promised. This means that, even in the best-case scenario, if nuclear power were adopted in place of fossil fuels, the planet would miss its emissions deadlines by a long margin and still fall far short of meeting the expectations of energy consumption. There is still no guarantee of the safety of nuclear power plants and still no proven long-term method of safely disposing of the waste; expert reports suggest there is not enough uranium left to provide for the world's energy demands.

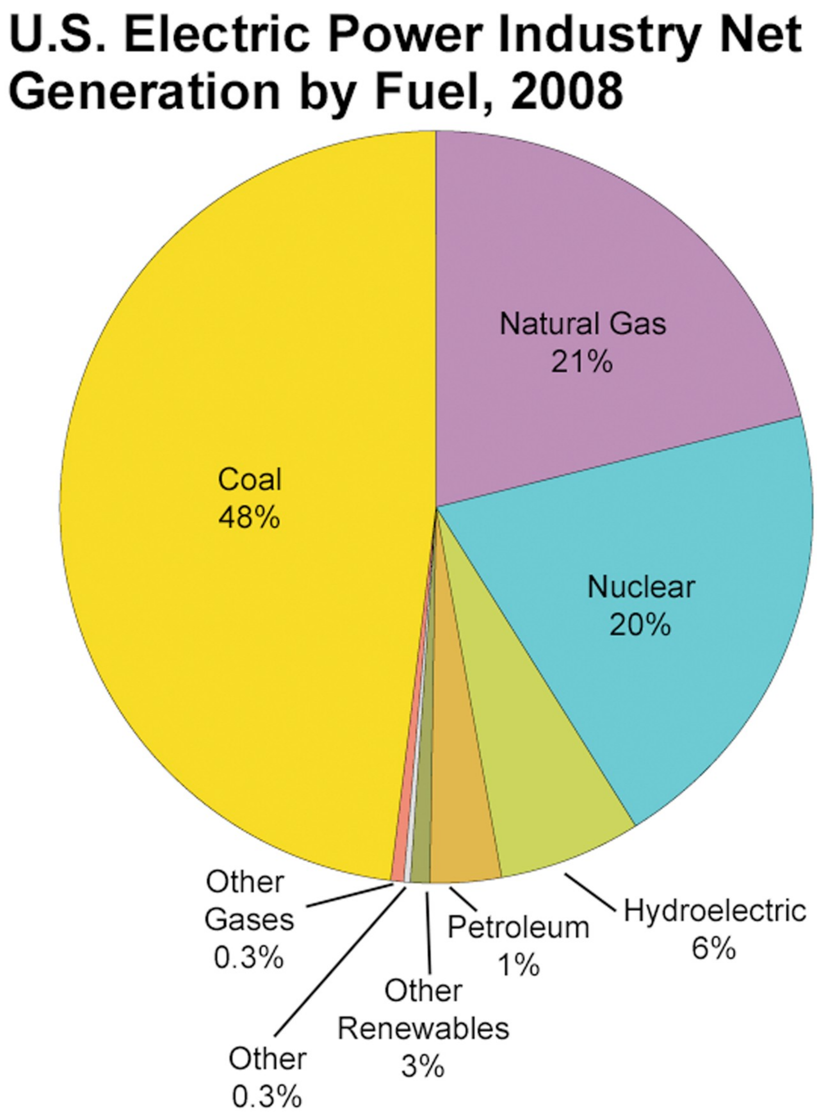
The harsh reality of a coal-powered world

Of all the fuels used to power the planet, the single most-utilised fossil fuel is coal. (41%)

> "Coal is primarily used as a solid fuel to produce electricity and heat through combustion. World coal consumption is about 6.2 billion tons annually, of which about 75% is used for the production of electricity. China produced 2.38 billion tons in 2006 and India produced about 447.3 million tons in 2006. 83.2% of China's electricity comes from coal. The USA consumed about 1.045 billion tons of coal in 2007, using 93% of it for generation of electricity."

> "China accounts for 74% of the total increase in the world's coal-related carbon dioxide emissions from 2006 to 2030, and India accounts for 7%. For China alone, coal-related emissions are projected to grow by an average of 2.7% annually, from 4.9 billion metric tons in 2006 to 9.3 billion metric tons (or 52% of the world total) in 2030. India's carbon dioxide emissions from coal combustion are projected to total 1.3 billion metric tons in 2030, accounting for more than 7% of the world total. In the United States—the world's other major coal consumer—coal-related carbon dioxide emissions rise more slowly, by 0.7% per year, to 2.5 billion metric tons (14% of the world's total coal-related carbon emissions) in 2030."

> "Nearly 50% of electricity consumed in the United States comes from coal-fired power plants, a figure Energy Department analysts expect to grow to 57% by 2030."



Source: U.S. Energy Information Administration, *Electric Power Annual* (2010).

This means that for every ten miles the American electric car owner travels, nearly five of these miles have been powered by coal. This may worsen in the near future.

While overall carbon emissions in the US have dropped significantly since 2007, much of this can be traced back to economic recession.

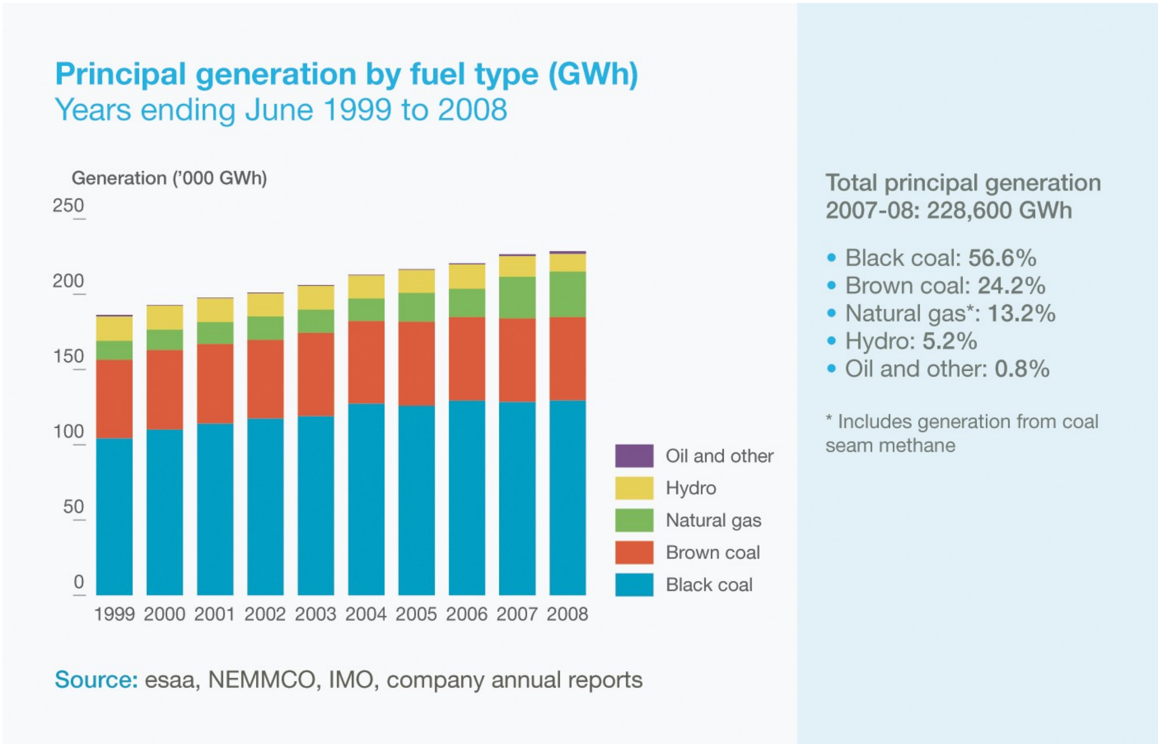
Also, while the amount of coal-based electricity generation has dropped along with economic growth, the Energy Information Administration expects this trend to reverse:

> "Projected increases in electricity demand and natural gas prices will contribute to coal regaining a larger share of base load generation in 2010. Nearly 4,300 megawatts of new coal-fired generation, online by the end of 2010, will add to the demand for coal. Projected coal consumption in the electric power sector increases by almost 5% in 2010."

The fact remains that under the current global energy system, coal remains one of the cheapest forms of energy, if immediate cost alone is considered. Therefore, it is likely to remain the most popular form of energy, except for those who have to face the immediate consequences of its use. The bottom line, therefore, is this: any electric car scenario based on a steady, forthcoming reduction in fossil fuel use, is essentially wishful thinking.

Australia also generates the vast majority of its electricity by burning coal[5], generally in highly inefficient plants. Although alternative power generation is growing rapidly, it is such a small percentage of Australian generation as to be insignificant compared to fossil fuels. Use of natural gas, which is a far cleaner fuel than either form of coal, is rising slightly, but coal-based generation is not dropping to compensate. The sobering fact is that the use of renewable energy sources, as a percentage of Australian power generation, has actually dropped (see chart below).

[5] From *Facts in Brief*, 2009 edition (data for FY 2007-08) the figures are; coal just under 81%, all fossil fuels 94%.



Australian power generation by type

Source: the Energy Supply Association of Australia (esaa)

Although modern coal-based power stations are more efficient than their predecessors, they are still heavily polluting, both in terms of environmental toxins (e.g., mercury, sulphur and soot) and greenhouse gases such as CO_2.

> "A modern, ultra-super-critical coal-fired power plant has an efficiency of 46% and in the future may be 50%. That would give the electric car an efficiency of close to 33%, by keeping the other figures the same."[6]

However, it is worth noting that there are very few of these modern, ultra-super-critical coal-fired power plants globally, and the vast majority of coal-powered plants in America, Australia and around the world use conventional 'dirty' coal technology – even many new coal plants. America's power industry is currently rushing to build large numbers of conventional power plants before such technology is banned. Therefore the pollution caused by electricity generated from coal is actually likely to get worse, not better, for the foreseeable future.

[6] Dr. Jacob Klimstra, independent energy and engine consultant.

Moreover, while the coal industry tends to showcase modern coal plants that are more efficient and less polluting, the costs of achieving this improvement are very high.

Efficient coal plants are extremely expensive, which is why most power companies are reluctant to build them, especially during times of economic recession. Many older plants cannot be retrofitted with the cleaner technology because they were not designed to allow for such upgrades.

Despite promises by the coal industry of huge improvements in the near future, many environmentalists are openly sceptical of 'green' coal technologies.

Further, many so called 'clean' coal plants that remove the pollutants from their smoke, often simply discharge the same pollution in the form of water.

Moreover, plans to store massive amounts of coal-generated waste CO_2 underground are unproven and appear to be facing significant difficulties.

In 2008 the US government withdrew its support for a public-private partnership to investigate the storage of CO_2.

The plan was resurrected in 2009 after it was discovered that an accounting error had exaggerated the costs of the project.

The *New York Times* recently reported on an attempt to store CO_2, at the Mountaineer power plant in Virginia, despite a number of concerns, including both the effectiveness and economic feasibility of the scheme.

> "The economic viability of the Mountaineer plant's new technology, known as carbon capture and sequestration, remains uncertain.
>
> "The technology is certain to devour a substantial amount of the plant's energy output — optimists say 15%, and sceptics, 30%. Some energy experts argue that it

> could prove even more expensive than solar or nuclear power.
>
> “And as with any new technology, even the engineers are unsure how well it will work: will all of the carbon dioxide stay put?
>
> “Environmentalists who oppose coal mining and coal energy of any kind worry that sequestration could simply trade one problem, global warming, for another one, the pollution of water supplies. Should the carbon dioxide mix with water underground and form carbonic acid, they say, it could leach poisonous materials from rock deep underground that could then seep out.”

It seems that this process has never been successfully completed on any significant scale. It remains an unproven idea.

It must also be firmly kept in mind, assuming CO_2 storage actually works, that, in order to produce the same amount of energy, 15–30% more coal will have to be mined and 15–30% more coal-powered generating stations will need to be built in order to make up the 15–30% energy loss from the CO_2 storage process (see quote above). Therefore, the probable consequences of CO_2 storage will be a substantial increase in coal-powered electricity generation, with no credible assurance that the process of CO_2 storage will actually work, either in the short or longer term.

Coal-based pollutants

The pollution caused by internal combustion engines has been well documented and well publicised, and is thus a powerful argument for ‘greener’ electric cars.

The electric car lobby generally reluctantly acknowledges the inefficiency and pollution inherent in the majority of coal-powered power plants. However, the claim has been repeatedly made that an electric car, even when powered by a conventional coal-powered plant, is both more efficient and less polluting.

As we shall see below, this claim is largely untrue. Moreover, while fossil-fuel-powered vehicles produce a cocktail of toxic substances, coal-burning creates a plethora of far more hazardous chemicals, mercury being amongst the worst.

> “Mercury is a toxin that has been found in increasingly high concentrations in fish and poses human health risks, including neurological disorders in children. The nation’s coal-fired power plants produce 48 tons of it a year, a little more than 40% of the total mercury emitted in the United States.”

According to the Union of Concerned Scientists:

> “ In an average year, a typical coal plant generates:
>
> - 3,700,000 tons of carbon dioxide (CO_2), the primary human cause of global warming – as much carbon dioxide as cutting down 161 million trees.
> - 10,000 tons of sulfur dioxide (SO_2), which causes acid rain that damages forests, lakes, and buildings, and forms small airborne particles that can penetrate deep into lungs.
> - 500 tons of small airborne particles, which can cause chronic bronchitis, aggravated asthma, and premature death, as well as haze

obstructing visibility.

- 10,200 tons of nitrogen oxide (NO_x), as much as would be emitted by half a million late-model cars. NO_x leads to formation of ozone (smog), which inflames the lungs, burning through lung tissue [and] making people more susceptible to respiratory illness.

- 220 tons of hydrocarbons, volatile organic compounds (VOC), which form ozone.

- 170 pounds of mercury, where just 1/70th of a teaspoon deposited on a 25-acre lake can make the fish unsafe to eat.

- 225 pounds of arsenic, which will cause cancer in one out of 100 people who drink water containing 50 parts per billion.

- 114 pounds of lead, 4 pounds of cadmium, other toxic heavy metals, and trace amounts of uranium."

‘Green’ countries

Some countries, such as New Zealand, have the good fortune of a small population combined with abundant wind and rainfall. Therefore, New Zealand is able to generate a large percentage of its energy from renewable, relatively non-destructive sources such as – primarily – massive hydroelectric power stations. New Zealand also has a promising, but minor, wind power generation system.

Therefore, New Zealand is able to generate about two thirds of its electricity needs without burning fossil fuels. This makes New Zealand an ideal showcase for electric cars, because these cars can be demonstrated to run efficiently on ‘green’ energy.

There are, however, a number of concerns associated with using New Zealand as a bridgehead for green car technology:

1) New Zealand is not typical of the global situation. Like a compassionate street gang or an honest politician, it runs contrary to the basic real-life system under which the planet operates. Most of the world – and especially most of the car-driving world – does not enjoy a low population plus abundant wind and rainfall from which to generate sustainable electricity.
2) Even in New Zealand, a significant percentage of the electricity is generated by burning fossil fuels. Domestic energy consumption is rising steadily in New Zealand. The growth in New Zealand’s total electricity consumption outstripped the increase in supply capacity by 30% in the eight years to March 2004. Given that New Zealand has little spare electrical energy, the question arises as to where the extra energy to run electric cars would come from. Electric car advocates have suggested that the extra energy could come from wind farms. However, wind farms currently produce only a tiny percentage of New Zealand’s total electricity requirements and proposals for new wind farms consistently face stiff opposition from local interest groups.
3) While it is undoubtedly true that the widespread use of electric cars

would significantly reduce New Zealand's dependency on imported fossil fuels, it would not reduce New Zealand's dependence on imported motor vehicles, which are a significant and ongoing contributor to New Zealand's balance of payments deficit.

4) While it is also undoubtedly true that the widespread use of electric cars powered by renewable energy could significantly reduce New Zealand's transport CO_2 emissions, transport CO_2 emissions are actually a small part of New Zealand's emissions footprint. The farming industry is the primary contributor to greenhouse gas emissions in New Zealand.

5) It is estimated that if the entire New Zealand vehicle fleet were replaced with electric cars, the amount of electricity New Zealand needed to generate to power this fleet would be increased by about 60%. Only a small percentage of this electricity could be produced sustainably; the balance would probably have to be generated by burning coal.

6) For the foreseeable future, affordable electric cars will have a reduced range, due to the constraints of battery technology. Therefore, electric cars would be unsuitable for many rural dwellers. It seems likely that electric cars would simply change the way New Zealand's urban gridlock is powered, without altering the basic premise under which this system operates.

7) Arguably, the widespread introduction of electric cars in New Zealand would legitimise the use of such vehicles in the vast majority of other nations that practise an unsustainable system of energy production and wastage.

How ‘green’ are electric cars?

1. Are electric cars efficient because they’re electric, or because they’re small and light?

Many small electric cars offer impressive fuel economy. However, this impressive figure has more to do with the size and weight of the vehicle than the means of powering it. Any well-designed small, lightweight vehicle that operates at low speeds will produce impressive fuel economy.

For example, the Peel P50, a tiny three-wheeled micro car manufactured in the Isle of Man during the early 1960s, is claimed to use just 2.8 litres of petrol per 100 kilometres. If this vehicle was fitted with a modern Japanese motorcycle engine it is likely that this efficiency could be increased by perhaps 50%.

Like many current electric cars, this miracle of efficiency is achieved by building a tiny vehicle out of lightweight materials and fitting it with a tiny engine.

Such vehicles tend to be a safety risk, regardless of what type of engine powers them. For example, the Indian-built Reva G-Wiz, often called simply the G-Wiz, totally collapsed during a basic EuroNCAP crashtest. The only reason it was allowed on sale in England was because it was classified as a four-wheeled motorbike (this classification is currently under review by British authorities).

After the EuroNCAP crashtest, the manufacturers claimed to have strengthened the car and re-tested it safely. However, the second crashtest was in India, not Europe, and the vehicle was tested at 25mph, not 40mph as in the original test, which is a tacit admission that the vehicle simply wouldn’t pass the higher speed EuroNCAP crashtest.

The first problem with lightweight materials is simply one of cost: cars are made of steel because it’s cheap, easy to work with and easy to recycle. Virtually all other possible materials have significant problems.[7]

The second problem with using lightweight materials is that their production process tends to be either toxic, energy-intensive, or both.

The generally understood rules of sustainable manufacture require that the main materials used within the vehicle are recyclable into substantially the same form as their original use, can be safely disposed of, and/or will naturally degrade harmlessly. Neither fibreglass nor carbon fibre come close to meeting these requirements.

Fibreglass used to be a favourite of low-volume carmakers due to its high strength, low weight and ease of manufacture. However, due to the high costs associated with the mass production of fibreglass components, compared to components made of steel or aluminium, fibreglass is almost never used for production cars.

High-strength fibreglass matting can't readily be recycled back into high strength fibreglass matting. Once fibreglass has been cast into its final shape using resin, the resultant material cannot readily be used again for a similar high strength application. End-of-life or waste fibreglass castings are generally either discarded into landfill or ground up and recast for lower-strength applications such as a particle board substitute or for items such as outdoor furniture.

There are significant health issues associated with the widespread use of fibreglass: In the USA, fibreglass has recently been listed by the Department of Health and Human Services as a substance "reasonably anticipated to be a carcinogen"

In countries with a high environmental sensitivity, such as Denmark, fibreglass waste is being turned into building insulation. However, there would appear to be a

[7] However, it is important not to see steel as a 'green' material; "The largest carbon dioxide emitter in the industrial sector is the iron and steel industry. In addition to being tremendously energy-intensive, the blast furnace process for steel production generates carbon dioxide directly…Two-thirds of the world's steel production uses blast furnaces, including 90% of the steel made in China, which is the world's fastest-growing steel producer." http://www.eia.doe.gov/oiaf/ieo/preis.html

finite global market for items like building insulation or outdoor furniture. Accordingly, given the hundreds of millions of vehicles likely to be involved, there appears to be no feasible outlet for the masses of waste material that would arise from the global use of fibreglass for car production.

In countries with low environmental sensitivity, such as China, it is likely that end-of-life fibreglass would simply end up being dumped into landfill if a suitable alternative use could not be found.

The heat required to form the glass strands makes fibreglass a high-energy product and the toxic resin that is used to bind the glass fibres together is typically derived from oil.

There have been various attempts to replace oil-based resins with resins derived from plants, but these attempts appear to have fallen far short of the necessary strength and durability required for automotive structural applications that meet vehicle safety requirements. Cost appears to be a significant factor in the choice of resins, and in most cases oil-based resins are simply cheaper. At time of publication we were not aware of any vehicle manufacturer using either natural fibre or natural resins for anything other than non-critical applications, such as headlinings, headrest, armrest, seat cushions, structural foam and carpet backing.

We also pass on, without comment, the criticism that:

> "With the exception of cellulose, most bioplastic technology is relatively new and is currently not cost competitive with petroleum-based plastics (petroplastics). They do not reach the fossil fuel parity. Many bioplastics are reliant on fossil fuel-derived energy for their manufacturing, reducing the cost advantage over petroleum-based plastic."

Carbon fibre – a lightweight and immensely strong fibre that is currently used to make the bodies of expensive sportscars – is expensive to produce, extremely energy intensive and is derived from oil.

As with fibreglass, the toxic resin used to bind carbon fibre mat into moulded shapes is also typically derived from oil.

Carbon fibre can be partially recycled in a high-energy process but the resultant fibre is not recommended for high-strength applications again. As with fibreglass, carbon fibre is likely to pose an ongoing disposal problem if it becomes widely used for vehicle manufacture. With a significant input of energy and new resin, it can be usefully employed to make less important objects, but these objects too will one day pose a disposal problem.

Unless this recycling problem can be somehow cleanly and effectively overcome – which seems highly unlikely at this stage – the widespread production of either fibreglass or carbon fibre vehicles seems likely to result in a global disposal crisis as those vehicles reached the end of their useful lives.

Plastic, another favourite for building lightweight cars, is also generally derived from oil and is toxic during both production and any subsequent re-melting. Most plastics are not suitable for high strength applications such as vehicle frame manufacture. High strength plastics are considerably more expensive than steel and generally can't be used again for the same application. This, once more, poses a huge potential disposal problem.

There have been numerous attempts at making 'green' plastics that aren't derived from oil, but none, to date, have been used commercially on any electric car. Few commentators expect any real progress in the near future. Aside from the issue of high cost, there is the issue of long-term strength: in many electric cars, the plastic components are part of the vehicle structure. As the plastics that make up this structure degrade, the vehicle loses strength. Oil-based plastics are a known quantity and such factors as ultra violet damage can be controlled. As things stand, 'green' plastics are simply an unknown entity at a higher cost.

Aluminium is another favourite of lightweight carmakers and can be endlessly recycled. However, aluminium consumes six times the energy of steel in its production. It also requires vastly more raw material to make aluminium than to make steel, meaning more environmental damage and higher transport costs.

> "Primary aluminium production consumes 2% of the worldwide electricity supply, and one-third of the total energy consumption in primary aluminium production comes from coal-generated electricity. Air pollution from primary smelting includes hundreds of thousands of tonnes of carbon dioxide and nitrogen oxide."

However, pure aluminium can be easily recycled. Whereas it requires 45 kWh to produce 1kg of primary aluminium, the same amount of secondary aluminium produced from recycled metal requires only 2.8 kWh. However, this figure assumes that the aluminium to be recycled is in a relatively pure form, such as soft drink cans. Moreover, up to 15% of the aluminium is lost as dross (a toxic, ash-like oxide).

> "White dross from primary aluminium production and from secondary recycling operations still contains useful quantities of aluminium which can be extracted industrially. The process produces aluminium billets, together with a highly complex waste material. This waste is difficult to manage. It reacts with water, releasing a mixture of gases (including, among others, hydrogen, acetylene, and ammonia) which spontaneously ignites on contact with air; contact with damp air results in the release of copious quantities of ammonia gas."

Most car manufacturers bond (glue) the aluminium parts such as the chassis to the carbon fibre structural panels. Therefore, either the aluminium or the glue has to be melted or chemically extracted from the vehicle before the aluminium can be recycled. This is likely to significantly increase the cost of recycling, both due to the energy and or chemical input required and because of the need to subsequently remove impurities from the aluminium.

Given that there are an estimated 700-800 million cars on the planet, the energy and disposal costs of lightweight car materials cannot be underestimated. Whereas steel car bodies are widely and effectively recycled, the widespread use of the lightweight materials described above seems likely to trigger a severe, worldwide environmental crisis.

Availability of resources

It is ironic that the production of electric cars, thus far, has involved vast amounts of resources, many derived from unsustainable sources, including fossil fuels. However, there is a number of other resource issues that are of concern, including the possibility of material shortages associated with electric vehicle production.

The production of electric car motors will require either huge quantities of copper or aluminium, or both.

2. Will electric cars reduce greenhouse gas emissions?

The short answer is: no, unless the current global electricity generation system changes virtually beyond recognition.

> "A 2009 WWF study into the impact of electric cars on CO_2 emission looked into emissions savings that could result from 1, 10 or 20 million electric cars in Germany. The study assumes that the average car's CO_2 emissions in 2020 will be around 130g/km and further assumes that [electric vehicles] are fuelled exclusively from renewable energy sources, thus having 'real zero emissions'. Every kilometre driven using electric power, under this calculation, will thus save 130g CO_2. Yet even according to the study's best-case scenario – 20 million electric cars on German roads by 2030 – the overall greenhouse gas emission saving to the country would be just 2.4%."

How to Avoid an Electric Shock UK Transport and Environment Environmental Transport Association report, 2009

Similarly,

"Electric car use must be backed by clean energy production and a change in legislation, a new report concludes.
Commissioned by jointly Friends of the Earth Europe, Greenpeace, Transport & Environment (T&E) and WWF Germany, the new research undertaken by Dutch consultancy CE Delft concludes that without the decarbonisation of electricity production, electric cars will not truly be 'zero emission' vehicles. Additionally their use should be backed by the development of smart grid technology and EU standardised electric car charging facilities.
The report entitled 'Green Power for Electric Cars' found that while electric cars had a number of advantages over conventionally fuelled vehicles including substantially improved efficiency, the ability to use renewable power sources and no direct emissions; without a change in EU law, they could still be indirectly responsible for a rise in greenhouse gas emissions."

http://www.thegreencarwebsite.co.uk/blog/index.php/2010/02/08/eu-electric-car-law-flawed/

Efficiency of electric cars compared to conventional vehicles

Determining efficiency

Wherever possible figures used are from engineering or trade textbooks and/or websites that are widely accepted as being accurate. We have quoted from credible web-based sources such as Australian and American official statistics and recognised industry figures. Accordingly, we believe that the efficiency figures quoted below are both accurate and credible.

This accuracy is important, because electric car enthusiasts and electric car manufacturers frequently quote efficiency figures for technology that does not presently exist or technology that has not been independently tested. This makes it difficult to do reasoned comparisons between the conventional and electric vehicles.

Note on well-to-wheel efficiency

The efficiency of any vehicle cannot merely be measured by how much fuel it uses during any given journey. Fuel has to come from somewhere, and regardless of the type of fuel, there are considerable energy and environmental costs in the gathering and refinement of any energy source.

There's a significant difference in the efficiency of any vehicle when the overall energy required to power the vehicle is measured back to its source. In conventionally powered cars, this is known as 'well-to-wheel' efficiency, that is, the efficiency from the oil well, through the various stages of storage, refinement and transport, until the final fuel is burned in the vehicle and the vehicle achieves motion. Well-to-wheel efficiency is notoriously difficult to calculate accurately, due to the large number of factors, together with the equally difficult decision as to where to draw the line. For example, does the scientist measure the energy used to extract, process, transport and store oil-based fuels, or should he also measure the energy used in the exploration of this fuel? Or the energy used in the office where the discussions were held? All these factors affect the outcome, and yet not all factors can be realistically included.

The overall efficiencies of the various forms of energy are outlined in:
Appendix III: *Sources, assumptions and qualifications.*

Comparative engine efficiency figures:

- The average efficiency of the modern petrol engine is 28-32% [at peak efficiency]
- The average efficiency of the modern diesel engine is 35-40% [at peak efficiency][8]
- Electric motors are far more efficient: electric motors generally operate at an efficiency of between 78–92.4%; the larger the motor, the greater the efficiency.

[8] *Total Automotive Technology*, fourth edition, page 209

Efficiency of electric vehicles

> "An electric car motor can have an efficiency of close to 90%. Because of the high torque in a wide speed range, less gearbox effort is needed. Moreover, an electric motor does not consume energy when the car is at standstill. Charging and discharging the batteries might theoretically have an efficiency of 85% [although few cars currently achieve this figure]. Moreover, an electric car can use brake energy recuperation by using the motor as a generator and feeding the brake energy back into the batteries." (Paraphrased)[9]

For the purpose of this comparison, we will assume an average electric car motor efficiency of 90%, as per Dr. Klimstra's advice.

This high level of engine efficiency is widely quoted by the electric car lobby as proof that electric cars are more efficient than petrol cars. However, missing from the calculation are the energy costs of generating and distributing the electricity, and the losses getting the electricity in and out of the electric car.

Electric car batteries are getting better all the time, but there are still considerable energy losses due to the complex procedure required to input and output the energy.

Moreover, while the battery on an electric car might have a high theoretical efficiency (that is, its ability to store and discharge electricity efficiently), in practice, few batteries appear to meet their makers' claimed efficiency figures. Battery charge and discharge is heavily influenced by factors beyond the control of the manufacturers, such as ambient air temperature and the manner in which they are operated. Also, all batteries deteriorate with age; that is, the efficiency degrades to the point where replacement is required. Therefore, the theoretical efficiency quoted by the battery manufacturer is likely to be an optimistic, laboratory-sourced figure for a brand new battery, which in practice may fall far short of the real-world average figure over the entire life of the product.

[9] Dr. Jacob Klimstra, independent energy and engine consultant.

There is also the complex process of taking everyday electricity and turning it into electrical energy within a battery, then extracting the electricity again to turn an electric motor. Briefly, this involves the following process:

1. Converting the domestic energy supply (which uses AC current) into DC current for the purposes of charging the DC battery. There are considerable energy losses in this process.

2. Converting the electrical energy in the DC current into stored energy within the battery. This is a complex chemical process that also results in significant energy losses.

3. Converting the electrical energy stored within the battery back into useable current. This, once more, is a complex chemical process that also results in significant energy losses.

4. There are also minor losses in the cabling that links the various parts of this system.

Electric car theorists predict that that the energy losses between the electric car owner's wall socket and the electric motor in his car are likely to be in the region of 15%.

According to Dr. Klimstra:

> "A typical electric vehicle might need about 0.3 kilowatt-hours per kilometre, or about 1.1 megajoule /km since 1 kWh = 3.6 megajoule …This might vary depending upon vehicle mass, wind, landscape and traffic. With a battery charging efficiency of 85% and a power station efficiency of 33%, there are consequently 3.8 megajoule of fuel for the power station needed to let the vehicle travel 1km."

We will use his theoretical figure of 15% energy loss charging and discharging the batteries, given that such a system is likely to eventually exist. However, it is worth noting that we are unaware of any current electric car that achieves anything like this 15% figure outside of a laboratory; the Tesla electric car has nearly double this energy loss.

A litre of petrol contains about 34 megajoule, and a petrol-fuelled car running 12 km on a litre needs therefore 2.84 megajoule /km.

Using these theoretical figures, therefore, a petrol-powered car is actually more efficient than an electric-powered car if the electricity is generated in a conventional coal-powered plant. However, there are a number of qualifications that need to be added to this assumption.

If the same electric car is powered by a natural-gas-driven plant, then it is significantly more efficient than the equivalent petrol car, but of course, it is still being powered by irreplaceable fossil fuels and will still produce vast amounts of CO_2.

According to Dr Klimstra:

> "With a natural gas-fired combined cycle, having 55% efficiency and using 8% transmission and distribution loss, just 2.2 megajoule of fuel needed per km."

The efficiency of an electric car is relatively consistent, whereas the efficiency of a petrol-driven car varies according to how and where it is driven. To crudely summarise: on the open road at a constant, optimum speed, a modern petrol car is more efficient than the equivalent electric car if the electric car's energy was produced in a conventional coal-powered generation plant. If the same two vehicles were sitting in a traffic jam, the electric car would be the more theoretically more efficient. However, the equations above are based on theory, and the real world does not always confirm to theoretical models.

Cost of energy

One reason that electric cars are often cheaper to power than the equivalent petrol cars is partially because petrol is often heavily taxed whereas taxes on electricity are generally far lighter. Also, because coal is cheaper than oil – even before it is taxed – the electricity produced by burning coal is also cheaper.

Brown coal

> "Conventional power stations powered by brown coal operate at about 30% efficiency in converting fuel energy into electricity, while black coal power stations are typically 35-36% efficient. This figure applies to most current coal-fired power stations."[10]

Conventional power stations using brown coal operate at around 30% efficiency. So if we start with 100% of the energy that was in the original coal, 70% is lost when the coal is burned at the power plant, leaving roughly 30% of the coal's original energy. A further 10% of this 30% is lost in spinning reserve, leaving 27%[11]. A further 7.5%[12] is lost in getting the energy from the plant to the consumer. This means that, starting with the 100% of energy that was in the original coal, about 25% makes it through to the consumer. If a further 15% is lost in the electric car's batteries and then 10% in the electric motor we end up with 19.1% of the coal's original energy making it through to the wheels of the electric vehicle – assuming that the vehicle does not have a transmission. In electric vehicles with transmissions, efficiency drops further due to energy losses within the transmission.

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[10] Dr. Jacob Klimstra, independent energy and engine consultant.
[11] See Appendix Two – Electricity Generation: 'Surplus' Capacity and Spinning Reserve.
[12] Dr. Jacob Klimstra suggested that this is a credible figure. However, it is a global figure, and must therefore be only an approximation. In some places energy losses in transmission may be higher (eg, China). In other places, such as Australia, the typical energy losses may be slightly lower, assuming that the official figures are accurate.

Black coal

Conventional power stations using black coal operate at around 35-37% efficiency. We will assume an average of 36%. Starting with 100% of energy that was in the original coal, 64% is lost when the coal is burned at the power plant, leaving roughly 36% of the coal's original energy. A further 10% of this 36% is lost in spinning reserve, leaving 32.4%. A further 7.5% is lost in getting the energy from the plant to the consumer. This means that, starting with the 100% of energy that was in the original coal, about 30% makes it through to the consumer. If we lose another 15% in the electric car's batteries and then 10% in the electric motor we end up with about 23% of the coal’s original energy making it through to the wheels of the electric vehicle (but see comments on transmissions above).

The energy efficiency of electric cars improves dramatically when the plant is more modern and efficient.

Efficiency of modern petrol vehicles

One Imperial gallon (4.55 litres) of petrol contains approximately 156 megajoule of energy[13].

The average efficiency for a modern petrol-powered car engine is 28-32%[14], so we will assume an average of 30%. While petrol engine efficiency can drop well below 30%, it can also rise well above it (34-36%) when the engine is operating under optimum conditions. Without doubt, the worst efficiency occurs during idling.

However, one also has to look at the cycle efficiency. The automotive industry uses typical cycles (for example, a town trip, a long distance trip, a hybrid trip) because normally a car never runs at constant speed and load.

One can therefore only compare energy consumption of different vehicle propulsion systems by carrying out a typical cycle that, as closely as possible, replicates real-world conditions.

A typical town trip of an internal combustion engine vehicle is very inefficient due to:

1. **The energy lost during the heating up of the engine**. A cold engine runs rich and, during the start-up period. Much heat is lost into the coolant. The engine's lubricating oil also imposes a significant drag on the engine because, when cold, engine oil is very viscous.

2. **Stopping and low speed driving**. Most fossil fuel-powered vehicles perform poorly at idle. Fuel economy in petrol engines is especially poor at idle, partially due to throttling; a diesel does not have a throttle, which is one reason diesel engines offer superior economy.

[13] This figure is rounded upwards and must necessarily be approximate, as petrol energy content varies from batch to batch and depending on the type of petrol.
[14] *Total Automotive Technology* textbook

3. **Braking**: on a conventional internal combustion engine, all the vehicle's kinetic energy turns into heat at the brakes.

An electric motor does not have to heat up, has no energy consumption at standstill and can recuperate braking energy.

However, modern petrol cars are being rapidly adapted to deal with the above difficulties. While there is no doubt that an electric motor is more efficient in the slow moving or stop-start traffic that typifies most urban travel, this is only a comparison between a very inefficient form of personal transport and a less inefficient form of personal transport.

This is very similar to comparing the energy-efficiency of bottled water in glass bottles to the energy-efficiency of bottled water in plastic bottles; it misses the main point, that a well-organised piped water supply system will almost always be more efficient than a water supply system that delivers its water in bottles, regardless of what the bottles are made of.

When either a petrol or electric powered car is compared against the alternative (such as modern, efficient urban electric trains), it becomes immediately clear that the real issue is not so much how the car is powered, but the use of the private car versus efficient mass transport.

Efficiency gains and losses in modern passenger vehicles

Newer technologies such as variable valve timing and direct fuel injection allow a petrol or diesel engine to be operated more efficiently under all conditions, but especially during times when a conventional engine would be struggling, such as during idle and stop-start driving.

One key to efficiency appears to lie in the drivetrain: modern multi-geared transmissions allow the engine to operate at near-optimum conditions for a far greater percentage of the time.

There are also significant energy losses incurred while a vehicle is idling. However, because we are assuming that the electric vehicle in our comparison is using the latest technology (some of which does not currently exist) to achieve the efficiencies assumed in our comparison, then it is important that we compare this latest generation electric vehicles to the latest petrol-powered vehicles, which do exist. For example, BMW's Auto Start Stop function automatically switches off the engine when the car is at a standstill and in neutral, then restarts it as soon as the driver presses the clutch pedal again. According to various research studies, vehicles are at a standstill for one-third of the time while in urban areas. Some manufacturers estimate that stop-start systems can boost fuel efficiency by a fifth. According to the US government, such systems can improve the efficiency of a petrol engine by 8%.

Therefore the energy losses due to idling in stop-start traffic are reduced to the energy losses caused by the restarting of the engine again. It is widely (but erroneously) believed that the process of restarting the engine may cause significant inefficiency. However this loss is very small compared to the energy loss when idling, even for old engines. The only real exception is where an engine is fitted with a carburettor that has no form of pressure relief. On such systems the pump pressure will continue to feed small amounts of fuel through the carburettor even when the engine is stopped. This mildly floods the engine and causes a delay in the restarting of the engine, combined with a small cloud of unburned hydrocarbons when the engine finally starts. This style of car is essentially obsolete.

Moving from a standing start up to optimum speed is relatively efficient on a modern internal combustion engined vehicle, provided the vehicle is driven sensibly. That is, provided the driver accelerates to optimum revs and changes gear at the appropriate time, the engine will actually perform better than at cruising speed, when engine torque is relatively low and hence the friction and throttling losses are relatively higher. This is opposite to the common belief: many people think that slow acceleration gives lower fuel consumption.

However, it is true that fast acceleration at high engine revs at any speed will result in higher fuel consumption, due to higher friction losses. Even these losses can also be substantially reduced, both by modern engine technology, an efficient transmission (which keeps the engine speed closer to optimum levels), and also by energy regeneration when decelerating or braking. The essence of good fuel economy with a petrol engine is to ensure that the engine delivers high torque but minimum revolutions at any speed. At higher revolutions there are massive energy losses due to friction.

Some modern vehicles can lightly mimic the regenerative braking that makes hybrids and electric vehicles so attractive. BMW claims that its Brake Energy Regeneration system improves fuel efficiency by up to 3%. This is achieved by disconnecting the alternator when the vehicle is accelerating and reconnecting it while braking or decelerating.

However, there are still significant losses of efficiency in a conventional car's drivetrain, which is basically everything that moves between the engine and the wheels, including the gearbox, differential and axles. A widely quoted figure for energy losses due to drivetrain is 5.6%. However, this figure predates many modern drivetrain systems, so we will assume a figure of 5% for drivetrain losses.

Please note that some (but not all) electric vehicles don't have gearboxes and many theoretical designs have their electric motors in the wheels themselves, eliminating the majority of drivetrain losses associated with conventional cars. However, any electric vehicle that uses a conventional drivetrain system is likely to be significantly less energy-efficient than the ideal electric vehicle used for these comparisons.

Some electric cars (such as the Tesla sportscar) have a transmission. Because of its wider power band, an electric engine can use a simpler and more efficient transmission. Accordingly, we will assume a figure of 4% for drivetrain losses on electric vehicles.

Starting with 100% of energy that was in the original petrol, 70% is lost when the petrol is burned in the engine, leaving roughly 30% of the petrol's original energy. Because we are assuming an ideal electric car, we will assume an ideal petrol vehicle. Thus we will assume that 5% is lost during idling. A further 5% is lost in the drivetrain, leaving 20%. This means that about 20% of the petrol's original energy makes it through to the wheels of the vehicle.

Therefore, in terms of engine efficiency, the petrol engine has a slightly higher efficiency than an electric engine powered by burning brown coal in a conventional plant, and lower efficiency than an electric engine powered by burning black coal in a conventional plant.

However, the theoretical petrol-powered model above would only apply if the vehicle was working at a relatively constant speed. An electric car would operate at far greater efficiency in stop-start traffic. It would also operate with greater efficiency if the electric power source was more efficient.

Efficiency of modern diesel vehicles

Modern diesel engines are vastly more efficient and less polluting than their ancestors. The energy content of diesel is approximately 186 megajoule per Imperial gallon. The average efficiency of the modern diesel engine is 35-40% at optimum torque. Outside its optimum torque, the diesel will be less efficient[15].

We will assume an average peak efficiency of 37.5%.

Because diesels are more efficient than petrol-fuelled engines, they emit less CO_2

[15] *Total Automotive Technology*, fourth edition, page 209

per mile travelled, but still put out more CO_2 per gallon. However, this difference is slight.[16]

Of greater concern are the other pollutants in diesel, such as nitrogen oxide and tiny particles that can be breathed in and absorbed into the human body (although, strictly speaking, neither nitrogen oxide nor particulates are pollutants *in* diesel, but rather pollutants resulting from the combustion of diesel fuel).

Moreover, the widespread use of filters on the current generation of diesels can reduce these toxins down to a tolerable level, but only when pollution-control systems are working efficiently. Although systems such as particulate filters can efficiently filter harmful pollutants from the exhaust, particulate filters do not work with complete efficiency from cold. Therefore there is likely to be significant release of pollutants during that vehicle's warming up period.

Starting with 100% of energy that was in the original diesel, 62.5% is lost when the diesel is burned in the engine, leaving roughly 37.5% of the fuel's original energy. Because we are assuming an ideal electric car, we will assume an ideal diesel vehicle. Thus we will assume that 5% is lost during idling. A further 5% is lost in the drivetrain, leaving 27.5%. This means that about 27.5% of the diesel's original energy makes it through to the wheels of the vehicle.

Therefore, in terms of engine efficiency, the diesel engine has greater efficiency than an electric motor powered by burning either burning brown or black coal in a conventional plant. A more efficient electricity plant will tilt the equation significantly back in favour of the electric car.

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16 . Diesel and petrol produce about the same CO_2 per megajoule. So, if it weren't for the fact that diesel engines are a bit more efficient, they'd emit exactly the same CO_2 per km. However, diesel fuel has higher energy content than petrol (39 vs 35 MJ/litre), therefore giving better fuel economy. Diesel also produces more carbon dioxide per litre (2.7 vs 2.3 kg/litre), so even if a diesel car gets better fuel economy than a comparable petrol one, it will not necessarily improve CO_2 emissions per km.

Empirical realities

While it is useful to theorise about future electric cars, it is wise to also look at the reality of the current situation. In real life, recent electric cars appear to be falling far short of claimed and theorised levels of efficiency. For example,

> "It works out to 75kWh of alternating current (AC) for a full recharge. Our ESS (battery) produces direct current (DC) and holds 53kWh. The difference between these two numbers is due to charging inefficiencies, including the use of air-conditioning to thermally-manage the battery during charging. Our ESS (battery) produces direct current (DC) and holds 53kWh. The difference between these two numbers is due to charging inefficiencies, including the use of air-conditioning to thermally-manage the battery during charging."

Therefore the Tesla, has nearly double (29%) the theoretical loss of efficiency in the process of battery charging and discharging.

Further, it appears that most reports on the feasibility of electric cars have been based on similarly optimistic premises that often don't appear to reflect any current scientific reality. As we shall see below, the real-life Tesla does not come close to meeting the claims of its makers and – in most countries of the world – the Tesla is, in fact marginally less efficient and more polluting than the vehicle it is based upon.

CO_2 emissions

Given the high percentage of the world's electricity produced by burning coal in conventional power plants, it is worth noting that, in many cases, electric vehicles will be responsible for significantly increased CO_2 emissions compared to their conventionally powered siblings.

CO_2 emissions from petroleum fuels versus coal

If we assume that both coal and petrol can be burned with 100% efficiency and measure the resulting heat energy and the resulting CO_2 emissions the results are as follows.

• One Imperial gallon (4.55 litres) of petrol contains approximately 155 megajoule of energy and weighs approximately 3.3kg, 83% of which is carbon. 83% of 3.3kg is 2.74kg, multiplied by 3.67 (the weight conversion factor for C to CO_2), which equals about 10.05kg CO_2 per gallon (or about 65g/megajoule).

• One Imperial gallon of **diesel** contains 186 megajoule of energy and weighs about 3.95kg, 85% of which is carbon. 85% of 3.95kg is 3.36kg, multiplied by 3.67 (the weight conversion factor for C to CO_2), which equals about 12.32kg CO_2 per gallon (or about 66g/megajoule).

To generate the same amount of energy as one Imperial gallon of petrol (4.55 litres, 155mj) using conventional coal-powered plants, given an energy content of 23 megajoule per kilogram for black coal we need to burn 6.74 kg. As you need to burn 40% more brown coal to get the same amount of energy we would need to burn 9.43kg of brown coal.

• **Brown coal** is around 74% carbon so our 9.43kg coal has 6.98kg of carbon.

Multiply this by the conversion factor for C to CO_2 (3.67) and we get 25.61kg CO_2.

• **Black coal** is around 82% carbon so our 6.74kg coal has 5.53kg of carbon. Multiply this by the conversion factor for C to CO_2 (3.67) and we get 20.28kg CO_2.

Therefore, to produce the equivalent energy to one Imperial gallon of petrol (4.55 litres) by burning coal in a conventional generation plant will theoretically double the CO_2 emissions produced as a result.

However, the above figures for petrol, diesel and coal, are only accurate when measured at the point of combustion. There are significant upstream energy losses in the location, extraction, processing and transportation of both coal and petroleum oil-based fuels. In practice, it costs about 1-4.5% of the original energy of coal for the process of extraction, processing and transportation, while it costs approximately 15% of the energy present in the original crude oil for the process of location, extraction, processing and transportation of the fuel from source to the point of combustion. These figures are taken into account in the energy efficiency / CO_2 output spreadsheet that accompanies this report.

Therefore, assuming a 96.5% transportation/extraction efficiency for coal and an 85% transportation/extraction efficiency for petrol, our figures are altered somewhat:

Petrol:	11.82kg CO_2 per gallon (or about 65g/megajoule)
Brown Coal:	21.015kg CO_2
Black Coal:	26.54kg CO_2

While more modern coal-powered plants will theoretically output significantly less CO_2 than conventional coal-powered plants, the fact remains that, for electric cars to offer any substantive improvement in CO_2 emissions over petroleum-powered vehicles, the vast majority of their energy would have be generated using greener – and therefore generally more expensive – technologies.

It is also worth noting that storing CO_2 as a means of solving these increased emissions seems certain to result in a significant reduction in energy efficiency.

Commenting on current plans to store CO_2 emitted from the Mountaineer power plant in Virginia, the *New York Times* reported:

> "The technology is certain to devour a substantial amount of the plant's energy output — optimists say 15%, and sceptics, 30%."

Therefore, as mentioned elsewhere, between 15– 30% more coal would have to be mined, transported and burnt in order to power electric vehicles if the CO_2 emissions were to be reduced using this system.

Other factors affecting vehicle efficiency

Moving a vehicle from stationary requires large amounts of energy. In stop-start traffic situations, hybrid-electric and electric vehicle are undoubtedly more efficient, due to the inherent characteristics of electric motors; that is, their ability to operate with high efficiency even at low speeds. However, the energy requirements to move an electric vehicle from stationary are still high and this energy needs to be generated somehow. This is the law of physics, one cannot get something for nothing. Therefore, electric cars do not so much solve the problems of inertia as deal with them more efficiently.

Regenerative braking works by using the energy of braking to charge the car's batteries. Regenerative braking (on both electric and conventional systems) will recover some, but not most, of the energy required to move the vehicle from stationary.

This inability to recover large amounts of energy using regenerative braking is due to the following factors: energy losses within the generator, together with losses caused by the conversion of electrical energy into chemical energy within the battery and, finally, the energy required to convert the chemical energy back into electrical energy to power the vehicle's engine.

Further, regenerative braking works best when the vehicle is stopped gently and often; if the brakes are applied suddenly, then the vehicle's conventional braking system comes into play, which means a substantial reduction or even elimination of the ability to generate electricity by using the vehicle's wheels to power the vehicle's electric motor, operating in reverse, as a generator.

It is estimated that even in an efficient hybrid or 100% electric vehicle, only a small percentage (25-31%) of the energy used is recovered using regenerative braking[17].

[17] However, it seems (at least in the case of the Prius) that this is partially because of the relatively small power capabilities of the battery: 22 kW on discharge, but only 14 kW on charge. Hopefully this will improve in the future.

Mark Kmicikiewicz, engineer and electric car forum moderator for the respected motor industry website just-auto.com, estimates that regenerative braking has 25% efficiency.

The environmental website beyondfossilfuel.com, estimates the efficiency to be 31%. The truth may be somewhere in between.

Given the disproportionate amount of energy used in moving a stationary vehicle of any kind, the obvious solution is to minimise the use of vehicles in situations where stop-start driving is likely. Therefore, eliminating the typical city-highway traffic jam, which is generally caused by cars being used in place of public transport, must be a high priority if energy wastage due to motor vehicles is to be contained.

This obvious conclusion appears to run contrary to the basic premise behind most electric cars. This premise appears to be: that "the typical city-highway traffic jam, which is generally caused by cars being used in place of public transport, is normal and inevitable, so let's invent ways to cater for this normal and inevitable activity by using electric vehicles."

Friction

Friction is a force that operates in resistance to movement. The greater the friction, the greater the resistance. Heavier vehicles have a greater friction than smaller vehicles.

Much of the energy loss on all types of vehicles is caused by the tyres flexing during each rotation. That loss is usually termed ‘rolling resistance’ and typically accounts for about 4.5% of the total energy loss on a vehicle, regardless of how the vehicle is powered.

Modern, low-resistance tyres can reduce this drag. We will assume a loss of 3.5% for vehicles fitted with low-resistance tyres.

This flexing of the tyres is necessary to ride in comfort, but it also partly explains why trains are more fuel-economic: the wheels are made of steel, therefore – though there is a different type of friction resistance – they don’t suffer from flex-related rolling resistance.

Some improvement can be made to the losses of rolling resistance by choosing a higher tyre pressure together with an interactive electronically-controlled suspension system (to maintain a reasonable degree of occupant comfort). However, an electronically-controlled suspension system will still require extra energy to operate, so the balance between fuel economy and comfort is a delicate one.

In all vehicles, at low speeds, friction (rolling resistance) dominates as the primary source of opposition to movement. At high speeds, wind resistance dominates.

However, with an aerodynamically well-designed car, like the Alfa Romeo 166, the wind resistance (the dominant energy consumer at higher speeds) is probably lower than for a small car with poor aerodynamics, such as a Fiat Panda or early model Suzuki Swift. Therefore, total fuel consumption per kilometre is not always strictly proportional to car mass or size.

In terms of energy saving, aerodynamically well-designed smaller vehicles tend to be both proportionately and actually far more friction-efficient than larger vehicles. For example, it has been claimed that much of the fuel efficiency of the Toyota Prius hybrid is due to its aerodynamic shape. It is however, more difficult to make a good aerodynamic design for a very compact vehicle due to its shorter length.

Weight

The greater the mass, the greater the amount of energy needed to move this mass from a standing start and the greater the kinetic energy loss involved in braking this moving mass.

In terms of any vehicle, the heavier the vehicle, the more energy will be needed to power it.

On average, one mile per gallon (mpg) is lost for every 400 pounds of extra weight on the vehicle[18].

However, this is an energy equation, rather than a petrol-versus-electricity equation. Because of the increased amount of energy required to overcome the higher rolling resistance of a larger mass, a heavier vehicle will require more energy for propulsion than a lighter vehicle, regardless of how this energy is provided. That is, a heavy electric car will still use more energy than a light electric car of similar shape and dimensions.

[18] *Total Automotive Technology*, fourth edition

Electrical accessories

Electrical accessories are a huge drain on a car's energy (about 10% in city driving).

Much of the energy used to operate modern cars – regardless of their energy source – is used to power electrical accessories such as computer-controlled suspension systems, defrosters, sound systems, heated seats and electrically adjustable seats. The drain is largest on small cars because the engine is smaller and therefore a greater percentage of the engine's power is used to power these accessories.

Although regenerative braking can recover some of this energy, it is highly likely that, in real world conditions, an electric-powered car would lose considerable amounts of energy powering unnecessary electrical devices. Conversely, any car – electric or otherwise – is likely to be far more energy-efficient if unnecessary electric devices are excluded.

Once again, the claimed energy efficiency of electric cars is not based on everyday driving conditions. The claimed mileage of the Tesla sportscar was based on a vehicle being operated:

> • Single driver ~180lbs• Soft top or Hard top on vehicle (with windows up)• No air conditioning usage• No heat usage• No headlights or cabin air blower (large 12V loads).

Air conditioning is a virtually-essential element with most modern cars. With the windows wound up the vehicle becomes uninhabitable in hot weather. With the windows wound down, the vehicle uses more energy due to aerodynamic losses. Moreover, in cold climates a heater is probably essential also; whereas heating a conventional car simply utilises waste combustion energy from the engine, some electric cars are going to have to generate most of this heat using electricity.

Ironically, the problems with electric car batteries heating up may solve one problem and create another. For example, the Tesla sportscar requires a sophisticated air conditioning system to cool its batteries. This is a major energy drain, but it is possible that some of this heat could be used to heat the passenger compartment. The bottom line, however, is that, regardless of whether electrical energy is lost during heating or cooling, it's still lost.

The Rise of China

In America and other countries, there is an underlying theme behind the electric car movement: that it will somehow halt the inexorable tide of car industry jobs from the West to the East.

For example, the American-built Chevrolet Volt is sometimes seen as [creating and protecting American jobs.]

This appears to be an extraordinarily naïve view. American consumers, like consumers around the world, will buy the vehicle that fits their budget and suits their needs. Given the Volt's high price, it is unlikely to achieve more than to gain a large amount of publicity for electric vehicles and whet the public's appetite for an affordable model.

According to a report by President [Barack Obama]'s automotive task force:

> "While the [Chevy Volt holds promise], it will likely be too expensive to be commercially successful in the short-term,"

American consumers might like the idea of buying 'green' and buying American, but they appear unlikely to pay many thousands of dollars extra for an American-built electric vehicle if a comparable Chinese-built electric vehicle is available at a far cheaper price. This has proved to be the case with the vast majority of American domestic consumer products; they're frequently designed in America, but built in China.

While the car industry is important to America, it is critical to China. As one commentator put it:

> "[China will do anything to grow its economy], as the alternatives will lead to political unrest. A lot of peasants moved to the cities in search of higher-paying jobs during the go-go times. Because China lacks the social safety net of the

> developed world, unemployed people aren't just inconvenienced by the loss of their jobs, they starve (this explains the high savings rate in China) and hungry people don't complain, they riot."

Similarly, the *New York Times* points out:

> "The Chinese car industry isn't just a way of making money, it's a way of providing jobs at a time when the Chinese economy is in trouble."

China's car industry is now larger than Japan's, and is on track to produce twelve million cars a year.

China exports most of its fully assembled vehicles to places like Russia, Ukraine and Vietnam, but customers in many countries have recently reduced new car buying. China's Great Wall Motor saw its sales to Russia drop by 40% in 2008.

At the moment China's car industry is being kept alive by government-induced sales within China, but the Chinese economy is heavily reliant on exports of all kinds and domestic demand for cars will almost certainly plummet when government incentives stop.

Moreover, China's carmakers face a huge problem: unlike America, which is built around the car, China is built around cheap and efficient mass transport. Most Chinese people generally don't actually need cars; Chinese consumers generally buy cars as a personal symbol of Chinese economic success. However, when the government incentives stop, it seems probable that Chinese consumers will revert back to their previously frugal ways, leaving the Chinese car industry with a severe shortage of domestic customers.

Given the economic and political importance of sustaining its car industry, China will shortly begin a massive export drive into Western markets. However, China's cars will be competing directly with those of manufacturers from Japan, Europe and America. China's rivals are well established and have credibility with consumers. China's cars are often poorly built, poorly styled and generally lack credibility with Western customers. Although China can produce cars very cheaply, price alone is unlikely to win market share, especially as Japan and Western countries are likely to try to protect their domestic car industries from cheap Chinese competition.

The one area where China could feasibly compete is in the area of electric cars. China's leaders are probably fairly cynical about the actual environmental benefits of electric cars.

> "…electric vehicles may do little to clear [China's] smog-darkened sky or curb its rapidly rising emissions of global warming gases. China gets three-fourths of its electricity from coal, which produces more soot and more greenhouse gases than other fuels."

Instead, China's leaders clearly see a priceless commercial opportunity. By bringing in pro-electric vehicle policies throughout the Western world, the Western governments have unwittingly created a market where China can compete at least as well as everyone else. This is because the first few generations of electric cars will be prohibitively expensive, giving China the opportunity to compete with new technology at unbeatable prices.

Whereas China is decades behind the other manufacturers in conventional car technology, there is currently no world leader in electric car technology. Except perhaps in the area of crash safety, existing car companies have no real advantage over China in the area of electric cars.

Thus, while cars like the Tesla and General Motors' Chevrolet Volt may sell the idea of electric cars to the American public, neither car is likely to sell in significant quantities due to their extraordinarily high retail price.

Given the casual Chinese attitude to intellectual property rights, it is highly likely that the Chinese will ruthlessly copy electric car technology that has been developed by companies like General Motors at the expense of the American taxpayer. Then, in three to five years' time, China could well be producing state-of-the art electric vehicles at prices that are attractive to American and other Western consumers. Unless the Japanese, European and American manufacturers can somehow find a superior electric car technology and manufacture it more cheaply than the Chinese, they will simply lose the market. Thus, the advance of the electric car, far from helping ailing Western and Japanese car companies, is likely to result in their demise.

> "China wants to raise its annual production capacity to 500,000 hybrid or all-electric cars and buses by the end of 2011, from 2,100 last year, government officials and Chinese auto executives said. By comparison, CSM Worldwide, a consulting firm that does forecasts for automakers, predicts that Japan and South Korea together will be producing 1.1 million hybrid or all-electric light vehicles by then and North America will be making 267,000."
>
> Rather more important:
>
> "due to some quirk of geology that China enjoys a virtual monopoly on special industrial metals. These sought-after resources are also found buried underground elsewhere in the world. In fact, geologically speaking, there should be no shortages at all. The availability of rare metals is more of a question of price."

There are close parallels between the current global situation and that of the fuel crisis of 1973. Before the fuel crisis, Japanese cars were widely regarded as something of a joke – tinny, ugly and unsafe. However, as most American manufacturers made only large, petrol-hungry cars, the cars from Japan suddenly became a major force. By the time the fuel crisis was over, Japanese cars had gained an unstoppable foothold in the American market.

A similar scenario is likely with electric cars: well-meaning Western governments will legislate to ensure that a significant percentage of their vehicle fleets are electric. There will be a stampede of car manufacturers competing to supply these electric cars: the Chinese may be the first to the market with cars that are affordable.

The cost of energy versus the cost of traffic jams

Inherent in the plans for a massive electric car fleet is an acceptance of the car as a form of mass transport, with traffic jams a normal part of everyday life.

From an objective point of view, this is an astonishing assumption.

According to a recent American report:

> "58% of the nation's roadways today are experiencing significant traffic congestion, compared to only 34% in 1982. Fully two-thirds of the major roads in the 75 U.S. urban areas studied were congested during 'peak travel periods,' compared to only one-third in 1982…To keep congestion from growing between 1999 and 2000 would have required 1,780 new lane-miles of freeway and 2,590 new lane-miles of streets... [however,] constructing one new lane-mile of urban freeway, on average, costs about $US300 million per lane mile…The average [annual] delay per peak road traveller in the 75 urban areas is 62 hours… the average [annual] increase in delay per traveller was 17 hours between 1994 and 2000… The peak period when traffic congestion might be encountered has grown from about 4.5 hours a day in 1982 to about 7 hours a day now…Traffic congestion is now responsible for 5.7 billion gallons of wasted motor fuel annually… The total cost of traffic congestion to the USA economy in lost productivity and wasted motor fuel is almost $68 billion—or $1,160 per traveller…without new highway investment, congestion will continue to increase, according to TTI, and the economic cost to the nation in lost productivity and wasted motor fuel will grow from $67.5 BILLION in 2000 to over $90 BILLION by 2009… By 2020, the USA Department of Transportation says, the average American motorist will spend almost 36 hours a year stuck in gridlocked traffic—up almost 5 hours from the level experienced in 2001[19]."

[19] *The Costs of Traffic Congestion in America*, Report by the American Road & Transport Builders Association

Electric cars would significantly reduce the energy wastage used by petrol-driven cars stuck in traffic jams, but would still require a massive amount of energy, much of it generated using ‘unclean’ power stations.

The solution to the traffic jams, such as the ones described above, has always been to build more roads, but this has not solved the problem.

Firstly, it’s no longer easy to build roads in existing cities. There’s no easy way around this problem; because modern cities are largely full of relatively high-density structures, there’s no easy corridor to build new roads, and the disruption and costs of either demolishing existing structures or tunnelling beneath them is prohibitive.

Secondly, the evidence suggests that decades of motorway building have in fact made the problem worse, as the above figures indicate. The problem is twofold: when a new motorway is built, it offers sudden freedom from traffic jams for a very short period. This invites more people to use the new motorway, which then reaches peak time gridlock within a few months. When more cars use new motorways, services like public transport get fewer patrons, making them less and less economically viable. As services are cut in order to save money, they become less attractive to consumers, who instead opt for the convenience of a car, and thus the downward cycle continues.

This cycle has recently undergone a sudden reversal as high fuel prices and perceived insecurity of supply has driven a significant percentage of motorists out of their cars and into public transport. Throughout the Western world there are strong calls for public transport to be made more widespread and convenient.

Running against this tide is the electric car lobby: the major personal advantage of electric cars and hybrids is that they are more efficient in stop-start traffic. Electric cars generally have a very low range. For example, General Motors’ Volt electric car has a predicted battery-only range of 40 miles (64.37kms). Assuming that the

Volt can actually achieve this figure, it is clearly inadequate for most rural dwellers. Although the Volt will have a small petrol engine as well, this offers little energy advantage once the batteries are flat, because the engine will be used for the energy-inefficient process of recharging the Volt's batteries rather than simply powering the wheels of the car.

General Motors expects the Volt to be used in cities, notably traffic jams. Given the above statistics, anyone except a car company executive would probably suggest that adding more cars to the vehicle fleet was an extraordinarily inefficient way of solving the problems of personal transportation.

While electric cars are more efficient in traffic jams, they will still consume vast amounts of energy if used as a form of mass transport. They will also consume vast amounts of direct energy in their creation together with vast amounts of both energy and money to build and maintain the roading infrastructure to support them. Above all, they will not solve the problem of traffic jams; rather they will simply change the way traffic jams are powered.

Electric cars versus mass transport

On paper, commuter trains and buses, are always more efficient than private cars. In practice, the opposite sometimes applies. This is because:

1. **Many modern passenger cars are small, modern and use very advanced technology to increase efficiency**, even if the car has only one occupant. By comparison, many commuter trains, especially in America, are old, needlessly heavy and use very dated technology to power them.

2. **Many cities, especially American cities, are built around private cars.** Public transport is seen as a poor people's alternative, and therefore occupancy rates are low. When there are only a few people on a large train, vast amounts of energy is wasted towing empty carriages.

3. **In order to make public transport attractive, it has to operate for a large part of the day and night.** Only during peak hours will trains be full. If the same trains are used throughout the 24 hour cycle, then most seats will remain empty for most of the day.

4. **In America, as well as other places, public transport is often run on a low budget** and sometimes at a loss. Therefore, the funds simply aren't available to solve the inherent problems of the system.

To be realistic alternative to private car, any mass transit system must be set up to deal with the realities listed above.

Possible solutions include:

1. **Modern, lightweight electric trains** that use effective regenerative braking to help counter the heavy energy losses caused by constantly starting up and stopping in order to pick up and drop off passengers.

2. **Commuter trains that fill up at a distant point and then travel direct to a specific destination without stopping.**

3. **City-wide transportation planning that coordinates services and avoids wasteful overlapping** (for example, a half-empty bus and half-empty train competing for passengers on the same route at the same time).

4. **Intelligent use of trains and buses so that the optimum amount of space is available at most times.** In other words, at 11am on a quiet city bus route, it may make more sense to run a 12-seater minibus rather than a full-length bus. The same principle applies to commuter trains.

5. **The use of automated carriage technology.** There is no theoretical reason for a train to be restricted to having a set number of carriages at all times. There is no theoretical reason why an intelligent control system could not calculate the tickets sold for a particular trip, then automatically load or unload the appropriate number of carriages for that particular trip. This would theoretically mean that the train was always operating at optimal energy efficiency, while having sufficient space for as many passengers as possible at peak times.

6. **The use of collective, lightweight people-carrying transport.** One of the biggest arguments against buses is that they rarely go from door to door, are slow, cumbersome and often inconvenient. It makes sense for groups that would currently own and use individual cars, such as office workers or old people who attend a social group, to share control and/or ownership of a small to medium-sized people-carrying vehicle. Ownership of this vehicle could be shared between the users, a social club and perhaps the government, which stands to benefit from less crowded roads and reduced energy use. Aside from the potential for huge energy savings, the users of this style of people-carrier would probably feel far more secure and comfortable in the presence of their own peer group than they would if they were all forced to navigate to and from their homes to their workplace or

club solely via public transport.

7. **A town planning requirement that requires functional, convenient and energy-efficient public transport as a condition of granting building permits for new housing developments.**

8. **Town planning that encourages people to work closer to home, so that long commutes are not necessary**.

9. **Making public transport environments safe and pleasant places.** This is hugely important, because both buses and bus stations, for example, are draughty, noisy, confusing and often threatening places. Even though there may be security guards present, it is just as important that surrounding streets are safe and pleasant and that there are pleasant refuges for people waiting for buses, such as waiting rooms and cafés.

Conclusion

Cars are an almost indispensable part of modern life. Their usefulness is greatest when they are used for special trips, especially special trips on empty roads; for example, taking sick children to the doctor, visiting a relative on a distant farm or safely returning from work at 3am.

However, the vast majority of private cars are used as a form of mass transport in cities, something that cars are not very good at. This is because the roading system, no matter how large, efficient and modern, is usually too small to cope with the number of vehicles that gather along main routes at busy times. Moreover, 'the daily commute' is often a highly stressful and hugely time-wasteful activity from both a personal and economic point of view. This is a global problem without any real solution other than a gradual shift away from using cars as mass transport and a gradual shift towards affordable, clean, convenient and safe mass transport.

Electric vehicles offer a useful means of transport. However, rather than private cars, the electricity (which is both economically and environmentally expensive) would be better used to power buses and trains, which, when properly utilised, are vastly more energy efficient than private cars.

The gap between the increasing demand for electricity worldwide and the urgent need for green electricity production is so vast that only by drastically reducing demand can the gap be realistically closed.

Some of this demand can be reduced by introducing stricter building codes and efficiency standards for electrical devices such as televisions. Much of the rest appears reliant on substantial lifestyle changes, especially in Western countries heavily dependent on cars.

Regardless of how cars are powered, the inevitable consequences of using private cars as a form of mass transport are traffic jams and massive energy wastage. At a time of global environmental crisis, it seems almost criminally irresponsible to propose that electric cars, powered by, and produced from, fossil fuels, could somehow be a solution to this problem.

Electric cars and hybrid-electric vehicles are only really useful in stop-start city traffic. While it is undoubtedly true that the city becomes a lot cleaner and quieter, this comfort is largely achieved at the expense of the environment somewhere else.

However, it is no longer acceptable to merely move pollution away from populated areas. The problem of pollution has moved from being a localized one to being a global one; reducing the obvious pollution within a city may still increase greenhouse gases at a global level. When pollution is a clear and obvious irritant within a city, the inhabitants have a powerful and immediate motivation to do something about it. When obvious pollution disappears from within a city, it is easy for the inhabitants to believe that the problem is solved, even though the pollution has simply conveniently disappeared from view. Thus, the city's inhabitants may put a low priority on the real issue of energy wastage and the pollution that energy wastage produces.

The problem with the American approach to energy efficiency and conservation can be summed up by former vice-president Al Gore. Gore's 2006 documentary film on climate change, *An Inconvenient Truth*, won an Academy Award for best documentary feature.

Gore has proposed a zero-emissions power supply for the US by 2020. Yet, despite his noble words, Gore lives in a 20-room mansion, and, according to his critics uses "20 times as much electricity as the average household nationwide." The group that made the criticism, the Tennessee Centre for Policy Research, appears to be funded by right-wing political groups with a history of environmental irresponsibility, but they nonetheless have a point.

Deep within the American psyche is the attitude that: "we have a right to live this way – this is the American dream.” Unfortunately, the American dream is now also the Chinese, Indian, Brazilian and Russian dream as well. It is inconceivable that any of these developing countries will rein in their energy consumption unless they see the West doing the same.

All of the noblest American plans for energy conservation and emissions reduction tend to involve the current system using different technologies. The Al Gore example suggests that the current system is the problem, not the solution.

The motor industry is a major contributor to the world’s economy. Any increase in the use of public transport must inevitably mean fewer cars sold and fewer cars used. Car companies, alarmed by a possible shift towards reduced car ownership, are seeking to repackage their products in order to maintain current high levels of car use.

Samuel Johnson is credited with saying: “The road to hell is paved with good intentions.” Nowhere is this truer than in the field of electric cars. Rather than saving the planet, they appear to be aimed at saving the traffic jam.

Appendix I
Oil and its alternatives

There are four major factors behind higher oil prices: supply, demand, speculation and terrorism. Supply is restricted as oil becomes harder to find and process. Demand is still growing, largely due to the rise of China, which is now one of the world's largest users of oil. Knowing this, speculators recently poured onto the oil market, driving up prices beyond the wildest nightmares of many motorists. Oil prices have since retreated from their record highs, but few people expect oil to remain cheap into the longer term.

Moreover, there is clear evidence that supplies of traditional crude oil are likely to run out far quicker than previously envisioned:

http://www.guardian.co.uk/environment/2009/oct/08/peak-oil-could-hit-soon

A fifth factor compounded the problem: in recent years the American dollar has dropped in value. With oil prices quoted in US dollars, this invariably pushed up the dollar value of each barrel of oil, which had a powerful symbolic effect at a global level. The more that oil was seen to rise in price, the greater the speculation and the greater the panic among motorists, businesses and governments alike.

Panic tends to produce panicked assumptions that don't always match reality. For example, analysts were recently predicting that global demand for oil could exceed supply by as soon as 2015. However, the situation is nowhere near as simple as that. First, the world isn't running out of oil; it's running out of *cheap* oil. There have been massive recent discoveries of both liquid oil and less conventional forms of oil. For example, Canada alone has around 180 billion barrels of recoverable oil from tar sands.

The problem is that a car cannot run off oil in the ground. The global oil shortage is a refining problem, not a lack of resources. As oil becomes harder to extract, it becomes more expensive. As oil becomes more expensive, major oil users look elsewhere for energy, or simply reduce their energy use. Oil is slowly running out, but it won't be in our lifetimes. Oil will remain a major global energy source for the foreseeable future, but only where there is no economic alternative.

The Chinese government is working hard to drop China's dependence on oil. Coal-fired plants may be crude and dirty, but they're cheaper to run than oil-fired plants and China is building them by the dozen. China is also investing heavily in nuclear energy, largely to break its dependence on oil.

So, will demand exceed supply in 2015? Almost certainly not. First of all, refining capacity for unconventional forms of oil is growing rapidly and will continue to grow as long as there is demand.

The other dubious assumption underlying most predictions of a continuing oil shortage is that China's economy (and therefore its oil needs) will continue to grow at present rates.

Much of China's hunger for the world's commodities has been driven by sales of manufactured goods to the West, especially America. A flood of easy money, courtesy of the America Federal Reserve, was behind much of America's spending spree in China.

The easy availability of money at low interest rates fuelled a boom in housing and then domestic spending in America, as homeowners borrowed against the rising value of their houses. This boom flowed through to China as American homeowners, flush with borrowed money, bought desirable consumer items like flatscreen televisions. When the Chinese electronic factory got more orders for flatscreen televisions, it needed more employees and more energy. Thus, the Chinese economy boomed, along with its need for oil.

The American economic boom is now over, and the US housing market is in a state of collapse, along with many of the mortgage companies that made loans to the sub-prime mortgage market.

America's problems are now being shared with the rest of the world. Because the economies of the West are consumer-driven, any problems at the consumer end must have major flow-on effects at a global level. When consumers are having trouble meeting mortgage repayments, they are quite likely to defer buying a new flatscreen television from Walmart. When Walmart starts selling fewer televisions, they order fewer televisions from China. When the Chinese electronic factory gets fewer orders, it needs fewer employees and less energy. Thus, the Chinese economy cools, along with its need for oil.

At the time of publication, the Chinese government was artificially stimulating the economy to keep it from plunging into recession, but this form of artificial stimulation cannot continue forever: the laws of supply and demand must eventually prevail.

All of these factors point to a lowering of the global demand for oil and therefore less likelihood of severe price rises in the near future. But there's one factor that no one can control: terrorism.

If terrorists knocked out one major refinery, the effect would be immediate and drastic. Not only would the price of oil rocket because a major source of processed oil had suddenly dried up, but the threat of further attacks would probably trigger a further price panic that was out of all proportion to the actual interruption to supply.

This is well understood by both governments and terrorists, and a great deal of effort has gone to efforts by both sides to thwart each other. To date the governments have won and there have been few major terrorist attacks to significantly affect oil supplies, but the threat is an ever-present one that will not really go away until either the terrorists are eliminated or alternatives to oil are found.

Oil installations in the Middle East are like war zones, with a massive military employed at all times to keep the refineries and pumping stations safe. Less safe are the installations outside the Middle East. Although American oil refineries are also protected, they are highly vulnerable to attack by a suicide bomber in a truck or aircraft. The Alaskan oil pipeline, when all's said and done, is nothing more than a large metal tube running a few metres above thousands of miles of empty tundra. A single stick of dynamite would shut it down.

So where does this leave the world's oil prices? While it is difficult to predict precisely it seems likely that the analogy of a slowly tipping seesaw is most apt. Oil prices will stay high while China's economy remains buoyant, and then fall along with the Chinese and American economies. Terrorism will endanger global oil supplies and may drive prices back up again, not in a sustained pattern, but in a series of spikes, followed by equally dramatic drops as the threat diminishes.

In the longer term the ingenious human mind will find alternative ways of gaining sustainable energy. In the shorter term we can expect an uneasy seesawing of oil prices; uncertainty seems set to be the norm.

Supply and Demand

It should be remembered that there is a huge difference between the short and long term availability of oil. There is plenty of oil still to be extracted, but you can't run your car on oil that's sitting 10,000 metres underground – it has to be processed and delivered to the consumer. Thus, any interruption to the processing and delivery of oil can have catastrophic effects, even if it's only for a short time.

For example, Hurricane Katrina wiped out 25% of America's domestic production, causing crude oil prices to leap wildly.

Very high oil prices, even if they only stay high for a short time, can have a devastating effect on a country's economy. Not only does the country suddenly have to find more money to import crude oil, but high oil prices also tend to cause rampant inflation; virtually everything in the modern world relies on oil for much of its existence so high oil prices ripple through the economy. Trucking firms put up their prices because their fuel costs more. Supermarkets put up their prices because their transport costs have gone up. Workers demand higher wages to pay for higher fuel and grocery prices, and so on.

This is well understood by economists, of course, which is why even the threat of an interruption to supply is likely to trigger a sudden rise in the price of oil, even though it's only a threat.

It's this threat to the steady supply of oil that is one of the major driving forces behind the desperate search for alternative forms of energy.

All oil isn't crude

For the past 100 years or so, crude oil has been cheap and easily extracted. However, the oil that comes gushing out of the ground isn't the only oil around. One of the largest sources of oil on the planet is shale oil.

Shale is basically a type of rock and shale oil is oil that is trapped inside shale. Known shale oil reserves are vast, especially in the US, but the amount of oil in the shale varies wildly and a comparatively small amount of the accessible shale can be easily processed. The rest will only become economically feasible if the price of crude oil continues to rise and/or if the extraction methods improve. All oil processing pollutes, but the processing of shale oil is particularly messy.

The problem with alternative forms of oil - like shale and tar sands – is that extracting the oil takes far more energy than extracting and processing conventional crude. At some point, the energy used to extract the oil from shale or tar is greater than the energy you derive from the oil at the other end of the process.

Oil/tar sands

Canada’s oil sands offer similar benefits and challenges to shale oil. The term ‘oil sands’ loosely describes a soup of water, bitumen – which is essentially solidified crude oil – sand, and other minerals. The term ‘tar sands’ is also sometimes used. The huge Athabasca oil sands has been successfully producing crude oil from oil sands since 1967, but has received an enormous boost from recent high crude prices.

A few years ago, Alberta’s government astonished the world by estimating that its oil fields were capable of producing 174 billion barrels of oil, making Canada the world’s second largest oil producing country. Even this estimate may be conservative, as oil extraction methods are continually improving and new fields may be found.

Venezuela’s Orinoco oil sand reserves are potentially even bigger than Canada’s and the oil is easier to extract.

Like shale oil, oil from tar sands is both energy-intensive and highly polluting.

Coal oil

Another source of oil is coal. Coal can be fairly easily converted into crude oil but the process is costly and is only really economic when the price of oil is high. As with shale oil, converting coal to oil is also harsh on the environment.

New avenues

Oil prices go up and down as supply and demand ebb and flow, but in the longer term the usable supply is shrinking, which means the price must stay high until a feasible alternative is found.

Over the last hundred years or so we have become more and more clever at finding energy in distant places, so it seems natural that as one source of energy runs out, another will take its place.

This has not proved to be the case; there are currently two main forms of energy on the planet (fossil fuels and electricity) and they were already in use at the turn of the last century. Coal and oil can be burnt by themselves – to heat homes and run cars – but electricity has to be generated.

Of the four major sources of energy (coal, oil, hydroelectric dams and nuclear reactors), the last two are only of value when converted into electricity. Thus, when you hear governments talk about alternative forms of energy, you should keep two facts in mind:

1. There are currently no easy alternatives to the four sources of energy described above, and,

2. The world's energy needs are currently going up, not down.

However useful electricity is, there is barely enough supply even in countries with cheap ways of generating it. There are currently no quick and clean solutions to substantially increasing electricity generation to make up for the gap left by oil.

It's easy to be hypnotised by technologies like wind and solar power. The reality, however, is that for the foreseeable future both these technologies will remain secondary electricity generation methods. Although wind and solar technology are both improving all the time, they simply don't produce enough electricity at present to compete with existing technologies. The same applies to virtually all the 'alternative' forms of energy that are constantly grabbing the headlines.

In countries like New Zealand there is abundant rainfall that is used – via the rivers it flows down – to generate clean hydro-electricity. Yet even New Zealand is facing an electricity shortage as the demand for electricity grows but the supply barely keeps up. Despite New Zealand's clean, green image, nearly one third of its energy is produced by burning fossil fuels. New Zealand also has abundant wind suitable for generating electricity, but no one expects this source of energy to be a dominant contributor to electricity generation in the immediate future. It's a useful top-up for the national electricity supply. That's all.

Now consider countries like Australia, which faces the same problem as most of the world. Although parts of Australia have good sources of water for generating electricity, the fact remains that much of Australia's electricity is generated using very dirty fuels. The vast majority of Australian greenhouses gases are produced by electricity generation.

> "Stationary energy, which includes electricity generation, petroleum refining and gas processing, accounts for 49.9 percent of emissions, or 287.4 million tonnes. Transport accounts for 14 percent of emissions, or 79.1 million tonnes. Road transport and passenger cars accounted for 12 percent of national emissions."

> "Australia's emissions of carbon dioxide during the past 25 years have risen at almost twice the world average rate, a CSIRO analysis shows…On average, each person in Australia and the US now emits more than five tonnes of carbon a year, while in China the figure is only one tonne per year."

There's a glimmer of hope through emerging technologies, such as sea power (generating electricity through the harnessing of waves or tidal currents). However, as things stand these are relatively minor players in an energy-hungry world. It's worth noting that no one, to date, has ever produced a successful long-term full-sized generating plant using the power of the sea. The ingenious human mind may be able to solve the huge problems posed by generating using sea power, but it is unlikely to be cheap or in the near future.

False Prophets

There's hardly a day goes by without an exciting new alternative energy source being announced in the news media. And, like miracle cures for cancer, most of these alternative energy miracle cures fail to deliver on their promises.

The problem with most of the 'answers' to the global energy crisis and climate change is that the scientists who came up with them were probably asking the wrong question. From an objective point of view, the right question to ask was: "how can we, as a planet, adapt to a world where energy is no longer cheap and our actions are severely impacting on the planet?"

Most objective scientific research suggests there's no quick fix to either the energy crisis or climate change. In the longer term, we're all going to have to use less energy, and that means smaller houses, less plastic junk that we don't really need and less wasted trips in our cars.

Instead of facing these grim facts, however, the question that is usually asked is: "How can we, as a planet, maintain a twentieth century American lifestyle using alternative energy sources?" The answer, of course, is: we can't. There simply aren't enough resources of land and energy around, no matter how you reshuffle the figures.

Because the wrong questions are being asked, we are continually getting dubious answers. The world is demanding quick-fix solutions to the problem, so that's where all the research dollars are going. The results of this research produce great headlines, but a closer examination of the solutions these scientists are coming up with suggests that most forms of alternative energy are like the emperor's new clothes.

For the last hundred years, the world's economy has been based around cheap energy. However, this cheap energy is gone, and none of the alternatives to oil come close to meeting the future world's energy needs unless we drastically reduce our consumption at a global level.

Technologies like biofuels currently offer a perceived benefit, and generally little else.

The fantasy behind much of the alternative energy movement says that it's going to be possible to continue the Western lifestyle of the twentieth century by changing the fuel used to power it. That's a bit like a fat person trying to lose weight by switching from hamburgers to french fries. The basic problem is never addressed.

‘Green’ Coal

Some modern coal plants are more efficient and less polluting, but the costs of achieving this improvement are very high. Many older plants cannot be retrofitted with the cleaner technology because they were not designed to allow for such upgrades.

Australia, like most of the Western world, is heavily reliant on old, messy coal-fired power plants. Despite years of attempts by the coal power industry to paint itself as progressive and ‘green’, little real progress has been made.

On July 6, 2008, The Age reported that:

> “...the spin on clean coal is wearing thin. Despite millions of dollars of taxpayer investment, the costs of retrofitting Victoria’s four brown coal power stations with technology to make them cleaner could be so high it might be cheaper to build new ones or convert them to natural gas.”

Even with new technologies, some environmentalists are openly sceptical of ‘green’ coal technologies.

It has been widely reported in the news media that, in the near future, CO_2 from burning coal will be pumped into giant underground caverns. There are significant problems with this system, which are dealt with above, under the heading: *the harsh reality of a coal-powered world.*

Solar Power

Regrettably, due to the cost of solar panels and the difficulty in harvesting the sun's rays, solar power costs much more to generate than existing technologies. In other words, solar power is generally only feasible if it's subsidised.

Although the technology for harvesting the sun's rays is getting better, the fact remains that it is very hard work to make electricity this way. There's also the problem that you can only get electricity from the sun when the sun is actually shining. When the sun goes behind a cloud the electricity production plummets and at night there's no production at all. Thus, in order to make use of solar power, you have to have a range of other ways of making power as well, or the power goes off at sunset.

Scientists at the Massachusetts Institute of Technology (MIT) have successfully created a sophisticated, yet affordable, method to turn ordinary glass into a high-tech solar concentrator, or so the headline went. However, at the bottom of the press release, and far less widely reported, was the phrase: "However, the current technology still needs further development to create a system that will last the 20-30-year lifetime necessary for a commercial product." In other words, the technology doesn't currently work and, if the press release is anything to go by, won't be working commercially in the immediate future.

Perhaps sometime soon scientists will overcome the problem of effectively harnessing and storing energy from the sun's rays. Perhaps in five years vehicles powered by solar panels on the roof might be a reality, but there are many significant obstacles to overcome in the meantime.

There are alternatives to the systems described above, which are all photovoltaic (ie direct conversion of photons into electricity). Solar thermal technology (heating water to make steam to drive a turbine) shows more immediate promise.

According to the manufacturers:

> "Unlike photovoltaic energy resources that immediately shut down during periods of transient cloud coverage, Ausra's solar steam generators retain heat, allowing for a more seamless integration with the electric grid."

While solar thermal generation systems offer hope for the future, they are still considerably more expensive than traditional systems, which is likely to limit their implementation, at least until government regulation and/or incentives make them more attractive to investors.

Wind Power

As we stated above, alternative energy enthusiasts frequently appear somewhat naïve about alternative energy sources, frequently quoting figures such as:

> "There is enough wind power throughout the world that: if only 20% of that power was captured, it could produce seven times the global demand for energy."

Such figures tend to be fanciful rather than practical. At its purest level, the universe is nothing but energy. However, it is useful to compare energy to money: it is all around us in great abundance, yet it proves frustratingly difficult to gather and accumulate for our own benefit.

> According to the International Electrotechnical Commission:
> **"**[The American National Renewable Energies Laboratory] has produced a model Wind Energy Deployment System that simulates energy capacity expansion potential in the United States up to 2030. The model demonstrates that using wind energy to produce 20% of projected electricity demand in this period would require 305 GW of technology, producing 1,200 terawatt hours (TWh) annually. At the end of 2007, 16.6 GW of wind capacity was installed and produced about 1% of national electricity demand. According to the study, "Assuming wind turbine size increases from today's average of 1.6 MW to roughly 3 MW, this would result in more than 100,000 wind turbines."

Despite the optimism, wind power currently accounts for less than 2% of the world's electricity needs. Some European countries produce more – Germany produces 7% and Denmark 18% of its total electricity needs from the wind.

And, as is depressingly common in the alternative energy sector, there are unforeseen problems:

> 1) Wind-powered generation is plagued by high start-up costs and unreliability (if the wind stops, so does the power). Significantly, the coastal regions that are ideal for wind generation are often also popular places for

people to live. Thus there are frequent objections to the building of wind generators on most coastal land, with noise, appearance and the threats to birdlife being common objections.

2) Recent studies suggest that the output of wind farms is far less than was promised by wind power's enthusiastic advocates.

In his book *Renewable Energy Cannot Sustain A Consumer Society*[20], social scientist Ted Trainer has pointed out that many pioneering wind generation plants were sited in near-ideal locations. Therefore, he argues, it is unreasonable to assume that subsequent locations will be anywhere near as ideal. This raises questions about the optimistic estimates of potential wind generation, many of which tend to emanate from interest groups and commercial interests.

3) There are currently considerable difficulties getting the energy from the wind farms to the consumer, caused by the problems of long distance power transmission (this applies to land-based wind farms also).

4) Offshore wind farms, where winds are steadier and objectors fewer, offer promise. However, offshore generators cost more, are more susceptible to corrosion due to salt, and are much more expensive to build and maintain.

New Zealand, as is often the case, appears to be the exception to the rule when it comes to wind power, but only to a limited extent:

[20] We have not yet independently verified the facts or assumptions in this publication, but found it to be interesting reading.

> “New Zealand is one of the best countries in the world to harness the wind’s power and turn it into electricity and a Ministry of Economic Development report last year estimated wind power could provide up to 20% of New Zealand’s total electricity needs. There are some limiting factors, such as variability of power produced and relatively large areas of land required for the wind turbines, but all the major generators are now getting involved.
>
> There are six wind farms operating so far in New Zealand with a combined output of 170MW, providing enough electricity for 75,000 households, according to the New Zealand Wind Energy Association. Another ten farms are either in the process of being built — like Trustpower’s Tararua 3, have resource consent, or have obtained resource consents which have been appealed and ended up in the Environment Court — like Meridian’s Project West Wind. Given that level of activity, the electricity output of wind farms should increase by up to 500MW in the next couple of years and reach around 1000MW by 2010, the association says.
>
> Why wind, and why here? “There aren’t many countries in the world with an average wind speed like New Zealand, so if wind power is going to be a success anywhere it will be a success in here,” says Peter Browne, an association director.
>
> And wind power has a remarkable synergy with hydropower, says Meridian Energy spokesman, Barry Seay.
>
> “The two go hand in hand because you can look after hydro storage when wind is blowing and when wind stops you can switch to hydro generation. Also, with our wind farm at Te Apiti in Manawatu, we are getting a capacity factor of between 45% and 50%. That is the percentage of time in a year the wind farm is generating to full capacity. The world average is 23%, so the fact that we have wind farms generating at full capacity half the time is world beating and not far off the kind of reliability of hydro.”

Yet even in New Zealand, the situation is not entirely rosy: the most optimistic projections for wind power in New Zealand suggest that wind power could provide just 20% of New Zealand’s electricity needs, excluding all political considerations (such as the ongoing objections to new wind farms from local residents). Virtually every new wind project faces a barrage of organised opposition.

Moreover, despite the positive words from power companies, wind farms currently produce only a tiny percentage of New Zealand's total electricity requirements, and there appears to be little prospect of this situation changing dramatically in the near future.

As Trainer points out, globally, the widespread introduction of wind power is unlikely to come close to solve the planetary energy needs. Like solar power, wind power is mainly a supporting technology to existing forms of generation. It survives largely on government subsidies and in an open marketplace would face an uncertain future.

Tidal & wave power

Suitable sites for new hydroelectric projects are relatively scarce in the West, and opposition to new generation stations is frequently fierce, meaning that river-based hydroelectric power generation is unlikely to substantially increase, or to increase only slowly.

The use of sea power for hydroelectric generation is therefore an exciting new development, but is currently barely commercially feasible, due to the extreme environment in which the generating equipment must operate. Assuming that the current technical hurdles can be overcome, it seems clear that electricity generated by sea power is likely to be significantly more expensive than conventional hydroelectric power.

According to the president of trade association Ocean Renewable Energy Coalition, “The total potential off the coast of the United States is 252 million megawatt hours a year.” This works out to a constant 28,000 megawatts of generation.

Tidal power has been used for power in the form of mills since the Roman Empire. However, the use of seawater to generate electricity has inherent problems: whereas fresh water is relatively non-corrosive, sea water is aggressively corrosive to most metals. In addition to the corrosion caused by the water itself, wind-blown salt spray contaminates electrical fittings and causes corrosion far removed from the water itself.

The biggest wave farm currently in use is in Portugal and produces 2.25MW; there are plans to increase this to 21MW by simply expanding the facility with more of the same.

Whereas river-based hydroelectric stations are generally dealing with water that flows consistently in one direction only, sea-based systems are dealing with water that flows in two directions or more on a regular basis.

It's also important to distinguish between wave power systems (that work on surface water waves), and true tidal-flow generators. Tidal flow generators work below the surface (often deep below the surface) and are driven by consistent tidal flows. Such systems have the advantage that they are relatively unaffected by surface storms or surface wave events. Because tidal flows are generally consistent, power can be generated for a high percentage of the time. Many systems are adapted to deal with tidal flows in multiple directions.

There are many disadvantages as well, which can be summarised as:

1) **Cost and difficulties of construction.** Any system that operates at significant depth underwater has to be able to survive relatively high water pressures for years on end. The slightest leak of seawater into the internal mechanisms of the generator would probably render it useless within a short time. This factor, and the need to use materials that will not corrode, means that the generator has to be both heavily and strongly constructed from materials that are generally very costly.

2) **Maintenance costs and difficulties**. Because the sea often becomes violently turbulent during storms, maintenance and repairs during these times are likely to pose serious logistical and safety problems.

3) **Fouling.** Any spinning device is vulnerable to fouling due to objects that enter its path. Obviously a spinning turbine or propeller is exceedingly vulnerable to floating objects such as drifting fishing nets, boat anchors or marine mammals. One solution is to fit a screen to stop the entry of such objects. However, the screen itself is vulnerable to clogging due to the gradual growth of seaweed and also from both nets and swarms of marine creatures such as squid. Oscillating generation devices are less prone to fouling.

4) **Anchoring difficulties.** Anchoring a heavy generator to a fixed spot on the ocean floor may pose significant difficulties due to the need for both strength

and durability of the anchoring system. There will also be an ongoing need for inspection and maintenance. Any maintenance is likely to be costly due to the difficulties of access.

5) **Location difficulties.** With exceptions, the ideal sites for tidal flow generators are rarely close to the destination for the electricity they produce. Moreover, they cannot be located in sites where they are likely to be accidentally snagged by anchors, dredges and fishing nets. The further the distance from the final destination for the electricity, the greater the overall cost, both initially and as an ongoing expense.

6) **Energy transfer difficulties.** Transporting electricity over or under the sea poses huge (and therefore costly) logistical difficulties. All undersea cabling systems face this difficulty, not just in terms of up-front costs, but also in ongoing maintenance and repair. The costs of the cabling systems are high regardless of the amount of electricity that is being carried. Therefore, the costs of cabling will render low-capacity generators economically unviable, unless a series of low-capacity generators are somehow networked.

Sea-based generation currently produces only a tiny percentage of the world's electricity production, and this is unlikely to change in the immediate future. Even if the considerable technical problems associated with sea-based generation can be overcome, electricity produced this way is likely to be considerably more expensive than electricity generated using conventional systems.

Geothermal energy

Geothermal energy (ancient Greek *geo*, meaning *earth*, and *thermos*, meaning *heat*) is heat extracted from the planet.

Although geothermal energy has been utilised for heating since ancient times, its usage has always been limited to areas of natural geothermal discharge; that is, where heat or steam naturally rose through cracks or fissures in the earth.

Geothermal energy is currently used to heat homes in geothermally-active areas, especially Iceland, Sweden & Norway.

Around 24 countries generate electricity from geothermal steam. The first working plant was opened in Larderello, Italy in 1904. Rebuilt after being bombed in World War II, the Larderello plant is still operating. There are also a small number of plants in the U.S., notably in The Geysers plants in Napa, California.

However, the amount of electricity generated through geothermal activity is significantly less than 1% of the global total.

Because exploiting geothermal activity requires little external input of energy, it is attractive as an alternative to conventional forms of generation, provided that large and stable masses of geothermal energy can be tapped at reasonable cost.

Geothermal energy is generally used in the form of steam to power turbines for electricity generation. This steam is either naturally-occurring, or is created by pouring water into volcanic areas within the earth.

The advocates of geothermal energy, who see it as a way of powering the Western lifestyle without the downsides of fossil fuels, are frequently glowingly optimistic in their appraisals:

> “The potential return could be as enormous as the forces of nature at work: clean, green, unlimited energy for the rest of this geologic era.

> Unlike solar and wind, geothermal generates a steady supply of energy 24 hours a day, everyday."

However, as so often happens in the alternative energy sector, the reality has fallen a long way short of the hype:

For example, in 2009, The *New York Times* reported on [the failure of the AltaRock geothermal project in California:]

> "In addition to a $6 million grant from the Energy Department, AltaRock had attracted some $30 million in venture capital from high-profile investors like Google, Khosla Ventures and Kleiner Perkins Caufield & Byers.
>
> Some of these startup companies got out in front and convinced some venture capitalists that they were very close to commercial deployment," said Daniel P. Schrag, a professor of geology and director of the Center for the Environment at Harvard University.
>
> Geothermal enthusiasts asserted that drilling miles into hard rock, as required by the technique, could be done quickly and economically with small improvements in existing methods, Professor Schrag said. "What we've discovered is that it's harder to make those improvements than some people believed," he added.
>
> In fact, AltaRock immediately ran into snags with its drilling, repeatedly snapping off bits in shallow formations called caprock. The project's safety was also under review at the Energy Department after federal officials said the company had not been entirely forthcoming about the earthquakes produced."

In summary, regardless of the theoretical potential of geothermal energy, there are significant hurdles to overcome:

1) The number of suitable areas for geothermal exploitation is still limited. Geothermic activity is only significant near tectonic plate boundaries, and is exploitable only if accessible. If the geothermal activity is too far beneath the surface, it is likely to be uneconomic to extract it. The same restriction applies where the area of extraction is too geologically

unstable to ensure ongoing extraction.

Despite the assumption that the earth has a limitless supply of geothermal energy, in fact, accessible resources are often distinctly finite. For example, the steam pressure at Wairakei steam generation plant in New Zealand steadily reduced with time, requiring new wells to be drilled and careful management of production in order to sustain generation levels.

A similar problem occurred at the geothermal plants in 'The Geysers' region, north of the Napa Valley in California, USA. Production at The Geysers plant peaked in 1987, and has declined ever since.

As Karl Gawell, executive director of the Geothermal Energy Association in Washington, DC, put it:

“It's like a giant pressure cooker. As soon as you put the first straw in, you began to deplete the resource."

Katherine Potter, a spokeswoman for Calpine Energy, which owns 19 of the 21 geothermal power plants in The Geysers region, added:

“It is a renewable source of power, but it's renewable over geologic time, [not human time]."

There are plans to increase steam production at The Geysers plants by pumping wastewater into existing wells. The press release announcing the project stated: “The Geysers Recharge Project expansion is a key part of Calpine's renewable energy program, made possible by the long-time support of the City of Santa Rosa and this very successful private/public partnership." However, the release later added: “ Calpine anticipates the U.S. Bankruptcy Court will review the proposed agreement at the company's September 2007 hearing.”

As of February 2010, Calpine announced that: “the addition of incremental steam wells at The Geysers” was anticipated for the year ahead.

2) There are sometimes toxic chemicals present. These chemicals may affect the health of humans nearby.

3) Geothermal power plants are expensive to build, and there is no guarantee that the plant will operate effectively when it is built. If there are unforeseen problems with the supply or the nature of the energy, the plant will simply not operate effectively. For example, dry steam wells at the Wairakei steam generation plant in New Zealand occasionally discharged sub-micron sized particles of quartz, which mixed with steam condensate. This mixture destroyed the condensate drain valves in a matter of days. In the case of the Wairakei plant, this technical problem was largely solved, but other plants have not been so lucky.

4) Because natural areas of steam (as opposed to dry heat) are limited, many geothermal power stations utilise steam created by pouring water into volcanic areas within the earth. This is a potentially hazardous activity. At the extreme end of the scale, the Krakatoa volcano explosion of 1883, which killed over 36,000 people and destroyed two-thirds of the island, was apparently caused by precisely this activity: seawater poured into the mouth of an active volcano, which had sunk below sea level. This process triggered an explosion that could be heard 5000 kilometres away.

Reporting on the AltaRock project collapse, the *New York Times* noted that: “Swiss government officials permanently shut down a similar project in Basel, because of the damaging earthquakes it produced in 2006 and 2007.”

In summary, geothermal energy exploitation – especially geothermal power generation – may provide a useful contribution to closing the global energy gap. However, exploitable geothermal fields are limited, power stations are expensive to establish, with no long term guarantees of either the quality or quantity of the energy produced.

There are also significant safety concerns.

Hydrogen

According to former US President Bush, hydrogen is the fuel of the future. Every major car company has announced hydrogen-powered vehicles and many have shown actual working models. All that is required – according to media releases – is a few thousand filling stations and a few trillions in taxpayer dollars to overcome 'technical difficulties'.

When Bill Reinert, the manager of American Toyota's Advanced Technologies Group, was asked how long it would take for hydrogen-powered cars to replace petrol-powered cars, he replied, "If I told you 'never,' would you be upset?"

Many scientists are now equally sceptical that hydrogen can ever be a feasible alternative to petrol. In 2005, Ralph J. Cicerone, president of prestigious American National Academy of Sciences, told the US Senate that there were: "substantial technological and economic barriers in all phases of the hydrogen fuel cycle."

A 2007 panel of scientists, engineers and industry experts assembled by the National Academy of Sciences concluded that the hydrogen economy remains little more than a dream. Joseph Romm, a physicist who led a study into alternative fuels for former US president Jimmy Carter, was even more blunt:

> "A hydrogen car is one of the least efficient, most expensive ways to reduce

> greenhouse gases. If you want to slow down global warming, you're not going to do it with a hydrogen car… not in our lifetime, and very possibly never."

Hydrogen's most passionate advocates see hydrogen production as a way of using off-peak electricity to power cars. This electricity, of course, is mostly produced by nuclear power, burning coal, oil or in hydroelectric dams, so little real benefit is likely.

One should bear in mind that hydrogen is not a form of energy; it's a means of storing energy. Hydrogen acts as a bank account: the bank account doesn't produce the money, it simply stores it. For every hundred dollars you put into your energy bank account you get a percentage back. Although in theory you could produce hydrogen at up to 90% efficiency, real world efficiency is a low as 50%. In other words it is like putting $100 into a bank account and getting about $50 back: it doesn't represent value for money.

Scientists around the planet are trying to solve this problem, but with the best will in the world, they're only going to reduce the losses, not stop them. Thus, in an ideal world you might even get $90 back for every $100 you put into your hydrogen account, but you would still have to have the energy in the first place.

In 2009, the American Department of Energy announced it was pulling all funding for hydrogen vehicles.

> "U.S. Energy Secretary Steven Chu announced yesterday that his department is cutting all funding for hydrogen car research, saying that it won't be a feasible technology anytime soon."

Fuel cells

Wikipedia had quite a nice description of a fuel cell:

> "A fuel cell is an electrochemical cell that converts a source fuel into an electrical current and water. It generates electricity inside a cell through reactions between a fuel and an oxidant, triggered in the presence of an electrolyte. The reactants flow into the cell, and the reaction products flow out of it, while the electrolyte remains within it. Fuel cells can operate virtually continuously as long as the necessary flows are maintained.
>
> Fuel cells are different from conventional electrochemical cell batteries in that they consume reactant from an external source, which must be replenished – a thermodynamically open system. By contrast, batteries store electrical energy chemically and hence represent a thermodynamically closed system.
> Many combinations of fuels and oxidants are possible. A hydrogen fuel cell uses hydrogen as its fuel and oxygen (usually from air) as its oxidant. Other fuels include hydrocarbons and alcohols. Other oxidants include chlorine and chlorine dioxide."

Fuel cells are another headlining-grabbing technology. The Bloom Energy Corporation quote below is typical of the claims made about them:

> "Bloom Energy Corporation, a Silicon Valley-based company committed to changing the way people generate and consume energy, announced today the availability of the Bloom Energy Server™, a patented solid oxide fuel cell (SOFC) technology that provides a cleaner, more reliable, and more affordable alternative to both today's electric grid as well as traditional renewable energy sources. The Bloom Energy Server provides distributed power generation, allowing customers to efficiently create their own electricity onsite. The company introduced its groundbreaking technology at an event hosted today at eBay Inc. headquarters along with California Governor Arnold Schwarzenegger, General Colin Powell, and several of its early customers.
>
> Built using abundant and affordable materials, Bloom's fuel cell technology is

> fundamentally different from the legacy “hydrogen” fuel cells most people are familiar with. The Bloom Energy Server is distinct in four primary ways: it uses lower cost materials, provides unmatched efficiency in converting fuel to electricity, has the ability to run on a wide range of renewable or traditional fuels, and is more easily deployed and maintained.”

Technology blogger Rupert Goodwins had a more sceptical view:

> “The reason fuel cells haven't caught on yet, despite many fine promises from many fine companies, isn't the physics, it's that the engineering is difficult and involved. It is relatively easy to show a hand-crafted working model and convince others – even yourself – that it's just a matter of refinement to make it cheap enough to produce economically.
>
> So far, this hasn't worked. I've seen countless pre-production fuel cells demonstrated at conferences, shows and expositions. They've all been 12 to 18 months away from full production, but none have made it in the twenty years I've been following the scene.
>
> Is Bloom any different? It's certainly got a whole load of hype behind it, but that's a poor guide to future success. It is, like every fuel cell, so expensive that its claimed efficiency is nowhere enough to make it economical to run. On current figures, as far as can be judged, it's just about the most expensive way to generate electricity. How is Bloom going to get its technology to the point where it's worth having in every home? That's the key to success, and on that point the company – for all its massive publicity – is silent.”

Natural Gas

There are still vast reserves of highly inflammable natural gas. Australia in particular has enough liquefied petroleum gas (LPG) to last for many years, even with vast amounts being exported.

LPG is marginally cleaner burning than petrol (it's about 11% better than petrol (in kg CO_2 per MJ) and thus emits marginally less pollution. It's currently cheaper than petrol. All you need is a tank to store it in and a conversion to allow your car to run on it.

There are problems. Firstly, the conversion is expensive and you have to be driving a high mileage before it makes economic sense. Secondly, you lose a significant percentage of the engine's power; the reason appears to be less to do with energy content than is commonly believed; another scenario for the decrease in power is that, with a gaseous fuel instead of a liquid, air – which would otherwise be available for combustion – is displaced by the gas. That is, the engine capacity is effectively reduced.

Also despite claims to the contrary, LPG appears to damage some engines. This is less of an issue with many modern conversions; carmakers like Ford have introduced factory conversions that appear to have solved many of the problems of engine damage.

Lastly, there's the issue of safety. LPG is extremely inflammable and under the right circumstances can turn a car into a bomb. That's why most conversions require a safety certificate.

However, the biggest problem with LPG is simply that it's a fossil fuel, like petrol. LPG may be cheaper than petrol, but when the price of petrol goes up, so does LPG, generally. Another factor likely to drive the price up is taxes: at present many countries encourage the use of LPG by taxing the LPG at a lower rate than petrol.

However, as time goes by the tax on LPG is likely to rise to a similar level to other fossil fuels, making it less attractive.

Natural gas, while currently plentiful, is a fossil fuel and must one day run out. While estimated global natural gas reserves are 6,182.692 trillion cubic feet, natural gas production is constrained by the extreme danger inherent in collecting and transporting it.

Natural gas in distant countries (and in difficult geographical locations), carries a high cost of containment and transport.

Also, as other fossil fuels become more costly or are regulated, this is likely to increase demand for LPG. This must substantially raise the cost of natural gas in the longer term.

The long-term outlook for natural gas is that it will remain an expensive option for electrical generation. While natural gas-powered stations are able to respond much more quickly to sudden energy demands than coal plants, the increased cost means power companies are often reluctant to use it unnecessarily.

Biofuels

Biofuels are fuels produced from plants and animals. There are three main types – ethanol, biodiesel and plant-derived crude oil.

Like all the other miracle solutions to the energy crisis, biofuels have thus far failed to deliver. To date, biofuels have arguably caused more harm then good.

At its most cynical, the current biofuels movement is simply a get-rich-quick scheme promoted by unscrupulous multinational corporations, and the whole world is paying the price.

In September of 2009, the American magazine *Foreign Policy* reported that:

> "…in the theoretical world, biofuels derived from algae, trash, agricultural waste, or other sources could help [solve the energy crisis] because they require no land or at least unspecific 'degraded' lands, but they always seem to be 'several' years away from large-scale commercial development. And some scientists remain hopeful that fast-growing perennial grasses such as miscanthus can convert sunlight into energy efficiently enough to overcome the land-use dilemmas – someday. But for today, farmland happens to be very good at producing the food we need to feed us and storing the carbon we need to save us, and not so good at generating fuel…
> Instead of counterproductive biofuel mandates and ethanol subsidies, governments need fuel-efficiency mandates to help the world's 1 billion drivers guzzle less gas, plus subsidies for mass transit, bike paths, rail lines, telecommuting, carpooling, and other activities to get those drivers out of their cars. Policymakers also need to eliminate subsidies for roads to nowhere, mandates that require excess parking and limit dense development in urban areas, and other sprawl-inducing policies. None of this is as enticing as inventing a magical new fuel, but it's doable, and it would cut emissions."

Ethanol

Ethanol is a form of alcohol, produced by fermenting plant or animal matter. Ethanol is an attractive concept, because it appears to offer an endless supply of cheap fuel, but the reality does not currently match the expectations.

The first problem is that ethanol has far less energy than petrol – you need much more of it to do the same job. Secondly, ethanol is hard to store because it absorbs water and cannot simply be put into big tanks like petrol.

Thirdly, ethanol, at least in most Western countries, is, at best, only marginally economic to produce. For example, in America ethanol is made from fermented corn, in quite a similar way to moonshine whisky.

The amount of energy going into growing, fertilising, harvesting and processing the corn into ethanol currently exceeds the energy you get back out the other end. And, unfortunately, much of the energy used in this process comes from oil. In addition, the process of growing corn uses large amounts of the soil's nutriment.

To put it another way, ethanol is currently an expensive way of wasting fossil fuels. Arguably, Americans would be better off simply burning the fossil fuels in cars rather than going through the complicated and wasteful procedure of converting it, through corn crops, into ethanol. There's an equally disturbing side effect: there's only so much land available for growing food, and if enough land is growing corn to make ethanol, then there may not be enough space left to grow corn for humans.

There's a lot of research going on right now to find alternative crops from which to make ethanol, but they're a long way from being commercially feasible, with one exception.

Ethanol makes more sense in countries like Brazil because Brazil is a major producer of sugar cane. Brazil has been using alcohol as fuel for decades, so there's already a great deal of expertise. Ethanol makes up 20% of Brazil's transport fuels.

Even allowing for the fact that ethanol gets fewer kilometres per gallon than petrol, it's still cheaper for the average motorist.

As a result of its much-criticised state-funded ethanol development programme, Brazil is now one of the few nations in the world that is getting close to energy self-sufficiency. Ethanol – a clean-burning fuel – has also resulted in a steady reduction in pollution in Brazil's cities. 70% of new cars sold in Brazil are flex-fuel, that is, they can run ethanol, petrol, or a combination of both.

Naturally, both the Brazilian government and the companies making the biofuels say that there's no environmental downside to the programme. This is not strictly true. Firstly, much the existing cane plantations are grown on land that was once dense forest. Because dense forest absorbs far more CO_2 than cane fields, even the existing plantations are contributing to climate change.

Secondly, a large percentage of the new cane plantations are taking place on land known locally as *Cerrado*. The World Wide Fund for Nature (WWF) has described Brazil's Cerrado region as one of the richest savannas in the world. "The ecoregion includes one of the most diverse and intact tropical grasslands on the planet."

The Cerrado is also home to around 5% of Earth's total flora. It is also a vast carbon sink, said to be absorbing greenhouse gas emissions at a far greater rate than sugar cane.

According to WWF, "Agricultural expansion… and water projects pose major threats to the Cerrado."

South American-based journalist Chris McGowan is even more pessimistic:

> "Biofuel production will directly impact the Cerrado as sugar cane and soybeans replace native vegetation. [Biofuel production will also] indirectly affect [the Cerrado] as cattle ranching and soybean farming (for food) moves there, after being displaced [from existing farmland] by today's highly lucrative ethanol business."

McGowan is also deeply concerned by what he sees as biofuel's threat to the Amazon River region, which accounts for approximately 1/5 of the world's total river flow and more than one third of all species in the world.

> "The Amazon will be affected by the biofuel boom both directly and indirectly. Biofuel crops such as soybeans and palm oil (both used to make biodiesel) are grown on a large scale there. And, contrary to what [Brazilian] President Lula and some others have claimed, cane is indeed cultivated there. In July, Brazilian authorities raided an Amazon sugar cane plantation, in which 1,000 labourers were found working in horrendous debt-slavery conditions. The company, Para Pastoril e Agricola SA, grows cane for ethanol on a 10,000-hectare (24,700 acre) plantation in Pará state, in the Amazon."

> "Brazil's Agriculture Minister Reinhold Stephanes has announced that Brazil will restrict the planting of sugar cane in the Amazon and Pantanal in the next few years."

However, adds McGowan:

> "[Brazil's] Lula administration does not have a noteworthy environmental record."

A New Zealand company – Fonterra – is making ethanol from whey, a waste product from the dairy industry. However, Fonterra refuses to say whether the process is economically viable, quoting commercial sensitivity. Also, while the use of this ethanol will slightly reduce New Zealand's emissions of greenhouse gases from cars, this reduction is small compared to greenhouse gas pollution produced by the New Zealand dairy industry. Greenhouse gases from dairy cows have increased 70% since 1990 while emissions from nitrogen fertiliser – largely due to dairy farm expansion – have increased 500%. It's also worth noting that nitrogen fertiliser is almost always synthesised from fossil fuels.

Biodiesel

Biodiesel is diesel fuel produced from animal or vegetable matter. In recent years there have been numerous reports of ingenious and smug motorists running their vehicles on used fast food oil. This is an interesting distraction, but in reality, all cooking oil is expensive and waste cooking oil is already in high demand for making other things, such as soap.

Most waste fast food oil is not biodiesel; it's waste vegetable oil. Even though some diesels can run on it, most can't without modification. The same applies to ordinary vegetable oil, known as Straight Vegetable Oil (SVO).

Much of the fuel being described as biodiesel is not actually biodiesel; it's straight diesel fuel blended with a percentage (5–20%) of straight vegetable oil. Typically these mixes have a B at the front, followed by a number, so B20 means that the fuel contains 20% vegetable oil.

Most commercial biodiesel is made from either RME (rapeseed methyl ester), PME (vegetable methyl ester) or FME (fat methyl ester), meaning that it can be made from either vegetable or animal fat products.

Compared to ethanol, biodiesel is significantly more efficient: biodiesel has about 34 MJ/litre, and ethanol about 23.5 MJ/litre; that is, a gallon of biodiesel is worth 1.44 gallons of ethanol (assuming equal engine efficiencies).

Biodiesel is also said to be much kinder to the environment than conventional diesel when it is burned.

Pure biodiesel will generally run without problems in any existing diesel engine, but on older engines it may damage rubber parts.

Pure biodiesel has the disadvantage that, in very cold temperatures (–10 ºC), it will turn to jelly, which can lead to problems with starting the engine at such temperatures. There are various fixes being tried for this problem. Biodiesel has other problems: it absorbs moisture, which can damage internal components in the engine and fuel system. It may also cause the growth of microbes in the fuel, which may eventually clog the system. Water in the fuel also causes poor burning of the fuel, which means less power and more pollution.

The technical problems with biodiesel will doubtless be solved with time. However, there are more pressing issues relating to supply.

Despite America's predilection for junk food, used cooking oil is a drop in the ocean when it comes to supplying America's transport needs. According to a report from New York's Cornell University:

> "[Used cooking oil] has an available potential to produce almost 1.7 billion gallons of [biodiesel] [which is] 1.1% of [America's] petroleum imports today."

(A litre of cooking oil does not give out a litre of biodiesel. Much of the cooking oil used to cook French fries is eaten as part of the fries and much of the waste cooking oil left over is unusable solids.)

Because of the shortage of used cooking oils for conversion to biodiesel, there is a global race to produce vegetable oils to meet the demand. This demand has driven up food prices, making it much harder for poor people to feed their families. Also, forests are being cleared to grow crops like palm oil for biodiesel, meaning that some biofuels are actually contributing to global warming by removing forests that would have absorbed CO_2.

Biodiesel critics estimate that: "every ton of palm oil generates 33 tons of carbon dioxide emissions – 10 times more than petroleum."

The international biofuels industry is being sustained mainly by government subsidies. In other words, the taxpayers in those countries are paying to produce 'green' fuels that often result in severe environmental damage, aren't cost effective, drive up the price of food and contribute to political instability in the Third World.

Rays of hope

There are a few rays of hope: a number of experiments are currently being conducted to produce biofuels that are more energy-efficient and less destructive.

For example, several companies have successfully converted algae sludge into crude oil. The process is not new; it's been tried and abandoned many times before, but the technology for converting algae into fuel is getting better all the time and may become economically feasible in the near future.

There are lots of benefits with algae: it's the most abundant form of plant life on the planet. It can be cheaply and easily grown at a rate of up to 100 tonnes per acre, per year. Even better, algae production does not displace human food crops. It can be grown in places such as sewage treatment ponds and has the positive side effect of purifying the water in the process. It also absorbs CO_2 and releases oxygen.

Jatropha – a group of approximately 175 succulent plants, shrubs and trees, is also showing increasing promise as an alternative source of energy. Because it grows rapidly, has a high oil yield and can grow on marginal land that would not be used for food production, jatropha appears to answer many of the criticisms of the first generation of biofuels.

However, jatropha is not quite the miracle it appears; the seeds are highly poisonous and one species of jatropha has already been banned in Western Australia because it is invasive and highly toxic to both people and animals.

Moreover, in a world where wars may be fought over water, jatropha is a moisture thief. Reporting in a recent issue of the *Proceedings of the National Academy of Sciences*, scientists from the University of Twente in the Netherlands concluded that jatropha consumes five times as much water per unit of energy as sugarcane and corn, and nearly ten times as much as sugar beet – the most water-efficient biofuel crop.

Study co-author Arjen Hoekstra concludes:

> "The claim that jatropha doesn't compete for water and land with food crops is complete nonsense."

Although jatropha can indeed by grown in areas of low rainfall, to flourish, the crop needs large amounts of water, he said.

> "If there isn't sufficient water, you get a low amount of oil production."

A second study, carried out by Friends of the Earth, concluded that – contrary to claims by promoters of jatropha – jatropha plantations in Swaziland run by BP and D1 Oils, were taking land and water away from food crops in a country already suffering from chronic food shortages.

The same thing happened in Myanmar, where jatropha was semi-forcedly planted on land formerly used for crops, in a mad attempt to promote independence from imported oil. *The Wall Street Journal* reported that:

> "Myanmar's badly conceived agricultural policies are compounding the country's already dire food situation."

The bottom line with ethical biofuels is this: despite the many hopeful experiments being conducted around the planet, most projects are years away from producing commercial quantities at affordable prices.

Moreover, even though this technology is a step in the right direction, there seems little prospect of ever producing really cheap biofuels. Affordable, yes, but not cheap. Cheap fuel is what powered the world's economy for the twentieth century, so these new-generation biofuels will not so much solve the energy crisis as make it more bearable.

Nuclear Power

The remaining source of energy – nuclear power – has a poor safety record and a sombre, enduring legacy.

Since their invention nuclear power stations have been enthusiastically touted as the solution to the world's energy problems, but like so many miracle cures, the reality has not always matched the hyperbole.

As the first nuclear power plants were being built in the mid-1950s, the chairman of the United States Atomic Energy Commission enthusiastically predicted that nuclear power would be so cheap to produce that it would hardly be worthwhile charging for it. He further predicted that 1000 nuclear power plants would be powering America by the year 2000.

Alas, no. From the start there were problems. The predictions of the cheap cost of nuclear power were unrealistically optimistic. This is because the figures used to justify the building of nuclear power plants assumed that the plant would produce maximum levels of power, 24 hours a day, 365 days a year. There have also frequently been massive cost overruns in building the plants, maintaining the plants and cleaning up the mess after the plant closed down.

Despite the promises, nuclear power plants rarely operated at full capacity. Moreover, the time lost in maintenance, refuelling and repairs meant that they were actually producing around half of the predicted electricity, and even then, not all the time.

Minor and more serious accidents were frequent from the beginning, but the owners saw these as teething problems. It wasn't until the serious accidents at Three Mile Island in America in 1979 and at Chernobyl in Russia in 1986 that the world began to lose faith in nuclear power.

Exactly how many lives were ruined by the above incidents is hard to tell. At the time many governments and much of the scientific community were enthusiastic supporters of nuclear power. It is likely, therefore, that they were blindly or deliberately optimistic in their analysis of the health effects of both disasters.

Speaking of the Chernobyl disaster, the Associated Press reported:

> "Researchers trying to determine death tolls – and predict deaths still to come – don't have an easy task. Soviet-era attempts to cover up the chaotic and often inhumane response made it difficult to track down victims. Lists were incomplete, and Soviet authorities later forbade doctors to cite 'radiation' on death certificates."

However, in 2006 the Ukrainian Health Minister claimed that 2.4 million Ukrainians had health problems resulting from Chernobyl. Other reports have suggested that the casualty rate was minimal. The truth, as usual, probably lies somewhere in between.

The biggest problem in assessing the risks of However, few of the people who are currently enthusiastically promoting nuclear power as the solution to the world's energy crisis seem enthusiastic about having a nuclear power plant anywhere near where they live.

Moreover, radiation affects different people in different ways. Pregnant women, for example, are extremely vulnerable to even small doses of radiation because of the likelihood of birth defects. A healthy man, however, could be exposed to radiation and show no signs of harm for decades.

It also depends on how the radiation is absorbed. For example, there is credible evidence that the use of depleted uranium by the US forces in Iraq may be causing immense health problems among veterans of the two Gulf wars. The problem – it appears – is not that the soldiers were exposed to high levels of radiation; the problem is that they breathed radioactive dust left behind by the uranium-tipped weapons. The Australian documentary *Blowin' in the wind* interviews a number of ex-US-military personnel who make it pretty clear that their government has actively sought to suppress evidence of health problems associated with depleted uranium.

It's often extremely difficult to pin down what causes people to get ill or die. For example, alcoholics frequently die of conditions like pneumonia. You can't say that alcohol causes pneumonia because there's no direct link. You can, however, say that a lifetime of alcohol abuse makes a person highly susceptible to other health problems, of which pneumonia is one.

The same applies to nuclear power. Did the old woman get pneumonia and die because she was exposed to nuclear radiation after Chernobyl or because she lived in a cold country? Did the old man in Pennsylvania get lung cancer because of radiation from Three Mile Island, or because he smoked? No one can say for sure.

The critics of nuclear power say that, with time, clear causes and effects of exposure to nuclear radiation do show up, but, like lung cancer among smokers, by the time you realise the link, it's too late, because the damage has already been done and can't be undone.

Naturally, the nuclear power industry sees no problem with the safety of its products, but it's worth looking at the track record of similar corporations. For fifty years the America tobacco, asbestos and lead industries waged a brilliantly successful media campaign, convincing both the public and the government that their products were both safe and socially desirable. It's hard to believe nowadays, but in the late 1940s, a major American tobacco company was able to get away with the slogan: "More doctors smoke Camels than any other cigarette."

Even more amazingly, the petroleum industry managed to convince the world that it was safe and desirable to add lead – a proven and potent neurotoxin – to petrol in order to make cars run smoother. Thus, for around 50 years, the air around the world's roads filled with the residues of millions of tons of lead that belched out the back of almost every car. So much lead was released in the process that even in underpopulated countries like New Zealand, the land beside a major public highway was once declared to contain enough lead to be economic for mining. Needless to say, advocates like Standard Oil pronounced lead as “a gift from God.”

Perhaps the nuclear power industry is different. Perhaps not. High costs and the perceived threat to human life have kept new nuclear power plants at bay until the recent energy crisis suddenly pushed them back onto the agenda. A new reactor – the world’s largest – is currently being constructed in Olkiluoto, Finland and many more possible plants are being built or considered around the world. However, things are often not going according to plan: for example, the Olkiluoto project is 50% over budget and several years late.

This pattern is being repeated all over the world, to the extent that Moody's credit rating agency has warned US power companies that they risk a credit rating downgrade if they build new reactors, due to the high risk of default.

> In August of 2009, The Christian Science Monitor reported: “Altogether, nuclear-industry bailouts in the 1970s and ’80s cost taxpayers and ratepayers in excess of $300 billion in 2006 dollars, according to three independent studies cited in a new nuclear-cost study by the Union of Concerned Scientists.
>
> New guarantees in coming years could also leave US taxpayers picking up the tab if nuclear utilities defaulted on their loans. In 2008, the Government Accountability Office said the average risk of default on Department of Energy guarantees was about 50%. The Congressional Budget Office projected that default rates would be very high – well above 50%.”
>
> On that basis, the potential risk exposure to US taxpayers from federally guaranteed nuclear loans would be $360 billion to $1.6 trillion, depending on the number of power reactors built, the Union of Concerned Scientists’ study found.
>
> “You want to talk about bailouts – the next generation of new nuclear power would be Fannie Mae in spades,” says Mark Cooper, senior fellow at Vermont Law School’s Institute for Energy and the Environment. Dr. Cooper is among several economic analysts who contend that – waste and safety issues aside – nuclear energy is too costly.

> “Funding nuclear power on anything like the scale of 100 plants over the next 20 years would involve an intolerable level of risk for taxpayers because that level of new nuclear reactors would require just massive federal loan guarantees,” says Peter Bradford, a former member of the Nuclear Regulatory Commission and former chairman of the New York State Public Service Commission.”

There are also large numbers of existing plants: 20% of America’s electricity is currently produced in 104 nuclear power facilities. France is highly dependent on nuclear energy, with nearly 80% of its electricity produced using nuclear reactors.

Nuclear power plants produce electricity by using atomic energy to boil water. This water turns to steam and the steam makes a wheel turn and the turning wheel generates electricity.

The advantage of nuclear power is that atomic energy can generate a great deal of heat over a long period of time, thereby providing a long-lasting, stable form of fuel from which to generate electricity. The downside is that nuclear energy is extremely difficult to control and is incredibly dangerous to humans nearby. In order to control the tiny amount of nuclear fuel that powers a power plant, a massive structure is required to cool and otherwise regulate the nuclear activity. This massive infrastructure is ruinously expensive to maintain, which has often led to the owners skimping on vital maintenance, often with disastrous results.

Modern nuclear power plants are vastly more efficient than their predecessors and reprocessing of nuclear fuel means that up to 95% of spent nuclear fuel can be re-used. However, while each generation of nuclear power plant solves some of the problems of its predecessors, it usually creates a few new ones. And problems created by nuclear power plants are very, very costly to fix.

Then there’s the issue of terrorism. If terrorists blow up an oil installation, it would be a great tragedy, but the problems the attack caused would be most likely solved within a hundred years. By comparison, a terrorist attack on a nuclear power plant could cause problems that remain long after humans have disappeared from planet Earth.

The fuel that powers nuclear plants is absolutely deadly to humans, especially if fine particles are breathed in. Even spent fuel – that is, fuel that has lost most of its energy – can kill you from one minute's exposure. In theory nuclear fuel is always well shielded in order to protect humans from harm, but as long as there have been nuclear power plants there have been accidents and damage to humans as a result.

Britain has recently announced that it would allow the construction of ten new nuclear plants, apparently without government subsidy. However, critics noted, there is still no long term plan to deal with either the existing or future nuclear waste from Britain's nuclear industry,

As the BBC recently noted: "The cost of cleaning up the UK's ageing nuclear facilities, including some described as 'dangerous', looks set to rise above £73 billion."

The Nuclear Decommissioning Authority, the body in charge of dealing with the UK's radioactive waste isn't sure how much the final bill is going to be. Jim Morse, a senior director at the authority, told the BBC:

> "I think it's a high probability that in the short term [the costs of cleanup] will undoubtedly go up."
>
> "We've still a lot to discover, we haven't started waste retrieval in those parts of the estate where the degradation and radioactive decay has been at its greatest."
>
> "When asked if the cost increases could run into billions of pounds, Mr Morse said: 'I'm sure it'll be some billions, I really don't know.'"
>
> "No-one's done this before. It's very difficult to find another measure. There's nothing in engineering terms that allows you to extrapolate from what you have today."

Morse added that the owners of newer nuclear plants would be obliged to clean up their own mess at their own expense. However, it's difficult to imagine the British government being able to avoid paying the bills once more if the owners of a nuclear plant simply walk away or go bankrupt.

Britain's nuclear industry is eager to build new nuclear plants, but appears to be showing little interest in paying to clean up the costs of the previous plants. It is widely believed that Britain's nuclear power industry would refuse to build the new plants if they were held accountable for the downstream costs associated with them. If this is true, the British nuclear industry is going to be reliant on taxpayer handouts for the foreseeable future.

Greenpeace estimates that the ten proposed nuclear plants would only reduce Britain's greenhouse gas emissions by 4%. If Greenpeace is even close to being correct, then the economic rationale for the proposed nuclear plants seems dubious at best.

Also of concern is the Russian nuclear industry, which is selling small reactors based around old nuclear submarine technology. As the *New York Times* points out:

> The design [the Russian company Akme] chose is peculiar because it is cooled with a molten lead alloy, not water. In fact, the Soviet Union was the only nation to deploy liquid metal reactors at sea. Introduced in the 1970s, they packed enough power to propel submarines more than 45 miles per hour underwater. In fact, they were so powerful they compelled NATO to design an entirely new class of torpedo.
>
> But this cold war design is not without its drawbacks. The Bellona Foundation, a Norwegian environmental group and authority on nuclear waste in the Arctic, says the lead alloy coolant tended to freeze when the reactor had to be shut down in emergencies. That turned the reactor into an inaccessible block of lead, steel and waste.

> The group documented an accidental freezing of the core on one submarine, K-123, in the early 1980s after an emergency shutdown in the Kara Sea. The vessel limped back to base. The only way to repair it, though, was to remove the reactor segment, a job that took nine years. (The former Russian naval captain working for Bellona who revealed these and other details of reactor failures in a report in the 1990s was put on trial for revealing state secrets.)
>
> The kinds of marine reactors the Russians are promoting, though, also happen to create a byproduct — used fuel — that no one knows how to handle. Right now, that spent fuel is being stored at naval yards in the Russian Arctic.
>
> In most nuclear facilities, the used fuel, which is highly radioactive, is removed from the reactor and stored in a pool of water. But in the Soviet submarine model currently advanced by a Moscow company, the spent fuel ends up frozen along with the reactor and stored away. No engineering solution has been devised yet to decontaminate the fuel.
>
> Today, hardened liquid-metal reactor cores litter the Arctic. While small, they still weigh hundreds of tons. No facility exists to melt out the lead alloy, which is itself lethally toxic, and extract the spent fuel rods. They remain an unsolved legacy of the Soviet submarine program."

There are also nuclear fuel supply problems. A report by the Millennium Project of the World Federation of the United Nations Associations concluded that:

> "For nuclear energy to eliminate the greenhouse gas emissions from fossil fuels, about 2000 nuclear power plants would have to be built, at US$5 to 15 billion per plant, over 15 years and possibly an additional 8000 plants beyond that to 2050."

The report adds that there simply isn't enough uranium on the planet to power this many plants.

Assuming that nuclear power plants can be justified on economic grounds, there are other issues that need a close inspection before proceeding. To be happy with a nuclear plant near your home you would have to sincerely believe:

1. That all the major problems with nuclear power plants have now been sorted out.

2. That the corporations who build the plants are being honest with us about the potential hazards.

3. That the governments who regulate the nuclear power industry can be trusted to do their job properly, not just now, but for the next few dozen millennia.

4. That the problems with disposing of nuclear waste have been effectively solved.

The problem with nuclear power stations is that they are generally powered by either uranium-235 or plutonium-239. Even though these fuels last only a few years, their residue will remain toxic for the foreseeable future. For example, the half-life of plutonium, that is, the time it takes for it to lose half its energy, is around 24,000 years, and for uranium-235 the half-life is over 700 million years. It will take another 700 million years to lose half of its remaining energy and another 700 million years to lose half of its remaining energy, and so on. So the waste left behind by nuclear power plants is going to be someone's problem for the next few billion years or so, long after the media used to store it have crumbled into dust.

Additionally, there is mounting, clear evidence that in addition to a gradual reduction in the availability of crude oil, uranium, coal and natural gas are also finite resources with a limited life.

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> “For nuclear energy to eliminate the greenhouse gas emissions from fossil fuels, about 2000 nuclear power plants would have to be built, at US$5 to 15 billion per plant, over 15 years and possibly an additional 8000 plants beyond that to 2050.”

The report adds that there simply isn’t enough uranium on the planet to power this many plants.

> “Eleven countries have already exhausted their uranium reserves. In total, about 2.3 million tons of uranium have already been produced. At present only one country (Canada) is left having uranium deposits containing uranium with an ore grade of more than 1%, most of the remaining reserves in other countries have ore grades below 0.1% and two thirds of reserves have ore grades below 0.06%. This is important, as the energy requirement for uranium mining is at best indirectly proportional to the ore concentration. With concentrations below 0.01-0.02%, the energy needed for uranium processing – over the whole fuel cycle – increases substantially. The proven reserves (=reasonably assured below 40 $/kgU extraction cost) and stocks will be exhausted within the next 30 years at current annual demand. Likewise, possible resources –which contain all estimated discovered resources with extraction costs of up to 130 $/kg –will be exhausted within 70 years. At present, of the current uranium demand of 67 kt/yr only 42 kt/yr are supplied by new production, the rest of about 25 kt/yr is drawn from stockpiles which were accumulated before 1980. Since these stocks will be exhausted within the next 10 years, uranium production capacity must increase by at least some 50% in order to match future demand of current capacity.”

The inevitable result of a lessening in supply must be an increase in price, especially as more and more nuclear power stations are built. Increased costs for uranium must inevitably mean increased costs for the electricity produced from the uranium.

Energy wastage

The problem for the West is that the West's economy is based on energy wastage. Therefore, most of the current energy strategies are aimed at continuing this wastage using different technologies, rather than addressing the fundamental reasons for this wastage.

For example, a visitor to a family in Las Vegas observed the wife taking the family washing out of the machine and putting it in the clothes drier.

Las Vegas is in the middle of the desert and it was 35 °Celsius outside. The wife could have thrown the whole load of washing out onto a deckchair and it would have been dry in ten minutes.

There is a deeply ingrained American attitude that says that the reward for all your hard work is the right to squander precious energy: a four-wheel drive Hummer, a fifty-room house, air conditioning in every room, a mega-sized clothes drier. If you run your clothes drier in mid-summer, the power company makes more money, the drier manufacturer makes more money, the shop who sold it makes more money, and the housewife can put her feet up and watch afternoon soap operas on her mega-sized flatscreen television. However, when you have hundreds of millions of people living this way, you end up with the current global energy crisis. What's worsening this global energy crisis is that China and India are now following America's example.

No matter how you juggle the figures, there's simply not enough energy to go around if the American lifestyle becomes a global standard.

However bitter the medicine may be, any solution to the current crisis that's not based around major energy reduction is doomed.

Because most of the world's alternative energy industry is based on quick fixes to the current system, these fixes are frequently coming apart before they even begin.

In reality, most of this alternative energy technology either isn’t economic, doesn’t work, or simply doesn’t exist and isn’t going to exist in the near future.

It disturbs us to see politicians and business leaders on television promoting fantasy technology using unrealistic economics.

There’s no quick fix to either the energy shortage or global warming. In the longer term, we’re all going to have to use less energy, and that means smaller houses, less plastic junk that we don’t really need and less wasted trips in our cars.

If we make decisions based on the wrong assumptions, we’re just going to make things worse.

Appendix II

Electricity Generation – Spinning Reserve and ‘Surplus’ Capacity

Spinning reserve

Power stations rarely operate alone: they are part of a regional or national network that links the stations and shares responsibility for maintaining stable electricity generation.

Because operators of an electricity network can never fully predict the demands that will be placed on the system, it is necessary to have reserve generating capacity available. This reserve capacity allows for the sudden demand if another power station, sub-station or power cable suddenly becomes inoperative. It also allows for times of peak demand, such as mid-afternoon in summer and evenings in winter.

Typical traditional coal-fired power plants (this applies also to steam generators in nuclear, gas and oil-fired stations) have steam boilers that cannot respond quickly to load changes, since the related thermal shocks would rapidly deteriorate the integrity of the boiler. Because these plants cannot respond quickly, there would be an unacceptably long delay before the power plant could respond to a heavy sudden demand for power.

For this reason, these power stations operate what is known as ‘spinning reserve’, which means that the boilers are kept fully operational, but a percentage of the steam is simply wasted.

> “It is normal practice for the system operator to carry sufficient ‘spinning reserve’ to cater for the instantaneous loss of the single largest (or largest two) generating plants. This reserve is not only massively oversized to cope with faults on renewable generators, but can also cope with variations in renewable energy

> output…"

The high amount of spinning reserve is largely due to economic factors: natural gas powered plants can respond far faster to a sudden demand, but these plants are far more expensive to run.

> "In practice, spinning reserve is not distributed equally across a nationwide generating network. Some plants are running at just 60% or 70% load while throttling steam while others run at full power. The choice of which plants operate at full capacity and which plants operate at partial capacity is largely a financial one: the power station operators generally choose the cheapest option.[21]"

Because the amount of spinning reserve depends on the size and number of generating stations within a network, it is difficult to express in reliable percentage terms. However, many commentators suggest that typical spinning reserve is around 5–15% of the network's capacity. We will average this to 10% for the purpose of this comparison.

[21] Dr. Jacob Klimstra, independent energy and engine consultant, (paraphrased).

‘Surplus’ capacity

In 2007, the American-government-funded Argonne National Laboratory made headlines with a claim that existing power plants could power “84% of U.S. cars, pickup trucks and sport utility vehicles (SUVs).”

This was a very convenient conclusion, and it seems clear that the power companies that cooperated with Argonne in the preparation of this report were enthusiastic supporters of the idea.

However, for whatever reason, the link that contained this claim is now missing from the website.

There are a number of problems with the scenario outlined by Argonne; the rest of this section outlines why.

In essence, the report concludes that America’s electricity networks could operate successfully at near-full capacity, and that the resultant surplus electricity could be then diverted to charging electric car batteries.

It’s worth noting that the primary motivation for expanding the capacity of the generation network is financial: that is, the power companies stand to make more money this way. This motivation calls into question the objectivity of the primary proponents of this scheme.

Moreover, the ‘cheap, off-peak electricity’ is unlikely to stay cheap for very long if the consumer demand begins approaching supply.

Reducing the surplus capacity within a critical energy network seems a dangerous strategy. The whole point of surplus capacity and spinning reserve is that it protects the integrity of the network in the event of sudden power demands and failures of critical parts of the network.

There are some high-tech solutions to the problem of system integrity: provided that the home where the electric car is being charged has the appropriate electronic controls, the car's batteries can be charged as cheap, off-peak electricity becomes available. This, in theory, reduces the cost to the consumer, while allowing the power operator to keep generation capacity available for times of peak demand.

If a power plant fails during the night, when large numbers of electric cars are being charged, the intelligent electrical system within each car owner's home can reverse the process. In times of crisis or peak demand, the batteries in the electric car can feed power back into the grid, the batteries in thousands of electric cars being used to feed the main grid instead of consuming from the grid.

There are several problems with this scenario:

1. The batteries in thousands of electric cars can feed power back into the grid only when they are plugged in, presumably at night, when there is little need for the vehicle to be used. If a problem occurs in the system during the day, when fewer electric cars are plugged in, then there are far fewer batteries to draw upon.

2. There are considerable energy losses within the various power lines linking the electric car to the grid, and also within the electric cars' battery charging and discharging systems. Although the charging and discharging of electric car batteries will undoubtedly become more efficient as technology advances, for the foreseeable future, this process is the single largest cause of energy loss within electric vehicles. As a Tesla engineer put it: in order to gain 53kWh of useable power from a Tesla's batteries, the consumer first has to put 75kWh in.

   "[The energy to recharge a Tesla road car] works out to 75kWh of alternating current (AC) for a full recharge. Our ESS (battery) produces direct current (DC) and holds ~53kWh. The difference between these two numbers is due to charging inefficiencies, including the use of air-conditioning to thermally-manage the battery during charging."

It seems certain that a similar loss of energy would be involved in feeding the stored energy back into the power grid. Also, it must be kept in mind that, even when a commercial-grade (three phase) power system is installed in a private home, it takes several hours to recharge the Tesla. Therefore, it seems reasonable to assume that for the Tesla to feed useful amounts of electricity back into the network would take a similarly long time; longer, in fact, due to the high energy losses. Therefore, despite having pulled 75kWh out of the power network, the Tesla would only be able to supply 53kWh back into it, and even then, only over a period of several hours (and considerably longer if a standard domestic power supply was installed at each home.) Given that power outages are often due to a sudden loss of generation, a break in the cabling and/or a short period of very high demand, the value of electric cars as a supplement to the power grid seems dubious from a point of both energy efficiency and technical feasibility. While a huge network of electric cars could feasibly make a small contribution to an overloaded power grid, it seems clear that the times and situations when this would be of much practical help would be few indeed. Like so many of the ideas surrounding electric cars, this one seems to be the result of optimistic thinking by electric car advocates, largely unchallenged by the harsh realities of empirical science.

During times of supply crisis, the system will simply shut off charging to the electric cars linked up to the system. So, there’s no guarantee that the electric car’s batteries are going to be charged when the owner drives to work the next morning. During times of ongoing generation difficulty, such as during a series of severe storms which disrupt power transmission by bring down power lines, there may be a prolonged period where there simply isn’t enough electricity to power the cars hooked up to the network. On a hybrid car this may not be a problem. On a purely electric car, there may be insufficient charge in the battery for the car’s owner to carry out a normal day’s activities. For example, a half-charged battery could strand an owner in the middle of a motorway traffic jam.

3. Like the proposal to store CO_2 underground, this proposal is a clever idea, untried in the real world under real world conditions.

However carefully the system is planned, a power generation system that utilises a power network to near capacity appears to be a risky proposition, if past experience is anything to go by.

The electricity industry will doubtless argue that it would not allow itself to be placed in a situation whereby such an outage could occur. However, the American electricity network is a series of cooperating private companies. Within the limits of self-interest they will undoubtedly try and avoid overloading. However, without comprehensive government control, the individual players in the network are free to act in their own short-term interests, even if this causes downstream problems. The network is only as strong as its weakest link or links.

> "The…American Northeast blackout of 2003 is a case in point. Power line failure combined with heavy demand caused by high temperatures, together with a series of system failures, to trigger a cascading effect that…ultimately forced the shutdown of more than 100 power plants[22]."

The 2003 outage occurred on a system that was designed to have a reasonable amount of surplus capacity at all times. It is reasonable to assume, therefore, that a system working at full capacity is far more likely to fall victim to a far more damaging outage.

Former power company executive John Casazza described the deregulated American power industry as: "having every player in an orchestra use their own tunes."

In 1998 Casazza warned that a serious power outage was highly likely, given the nature of the network. He was ignored, but subsequently proved correct.

[22] Natural Resources Canada - Canada-U.S. Power System Outage Task Force Interim Report

American corporations have a poor track record for making responsible long-term decisions; the recent collapse of the American mortgage finance market is a case in point. A rational economist would have concluded that mortgage companies would never have willingly set up a situation that led to their own bankruptcy, yet that is exactly what they did, despite the clear warning signs that a collapse was inevitable.

A report on the 2003 Northwest outage by the Industrial Physicist magazine concluded that the problem was caused by the deregulation of the American power industry, which greatly enriched the power generation industry, at the cost of the consumer and the integrity of the whole network.

> "Experts widely agree that such failures of the power-transmission system are a nearly unavoidable product of a collision between the physics of the system and the economic rules that now regulate it."

Given the above concerns, it is difficult to have complete confidence in the ability, or willingness of the American network operators to build and maintain the system to the standard required to operate it at near-full capacity on an ongoing basis.

To express it simplistically, only nuclear and hydroelectric generating stations ever have reliable surplus capacity, and even then, this surplus capacity will vary due to factors such as time of the day and season. All the rest of the forms of electricity generation depend either on the weather or require extra input of energy.

In practice, a power plant owner looks only at the total economy. Most of the time, it is better to run a power plant flat out because this gives maximum fuel efficiency, lower specific capital costs, together with lower specific maintenance and operation costs. Only in the case of an expensive fuel such as LPG, does the station owner limit the output to times of peak demand.

With nuclear and hydroelectric power stations, the energy source (uranium or water) is reasonably constant whether there is a demand for electricity or not.

Therefore, at periods of low demand it is possible to increase the amount of electricity generated without increasing the energy costs. In some countries these types of power stations, therefore, do have spare capacity during off-peak times. However, because nuclear and hydroelectric
Because of the inherent instability of wind or solar generators, there has to be one or more power stations in the power network that can cover for them, should their supply fail. Most of the time the rest of the electricity network can easily make up the lack of supply should the wind or solar generators cease to function. However, because of the severe consequences of even a short power outage, power systems have to be set up for worst case scenarios. Therefore, the electricity network needs to be able to cope with the worst possible loss of both wind and solar power simultaneously.

This means that, as the number of wind and solar installations grows, the more the rest of the network has to be tailored to cope with the sudden loss of power from the solar and wind generators. This restricts the ability of the network to supply power for other purposes, such as charging electric car batteries. More importantly, it increases the inherent instability of the entire electrical network. It is this instability that surplus generation capacity is designed to protect.

Aside from the sources outlined above, all other forms of electricity generation require the input of extra energy to produce more electricity. For example, a coal-powered plant needs to burn more coal in order to make more energy. Given that (other than nuclear or hydroelectric, wind or solar) all other significant forms of electricity production require the burning of fossil fuels, especially coal, it is difficult to see how an increase in the production of electricity from fossil fuels can avoid a substantial increase in environmental consequences, both globally and locally.

There is also the question of the long-term availability of the raw materials that power much of the world's electricity generation; uranium, coal and natural gas.

All these commodities are limited and will begin to run out in the foreseeable future. Even among high energy users who acknowledge this fact, there appears to be a general optimism that some miraculous new form of energy will suddenly be discovered, allowing the high use of energy to continue without negative consequences.

However optimistic one might be, banking the future on non-existent technologies is approximately the same as buying a mansion with no proven way of meeting the mortgage payments. All of the above points to a substantial increase in power generation costs in coming years, as coal and oil-based energy systems are replaced by systems powered by equally limited or costly alternative resources.

Economic recession may drive energy prices down, but for the average consumer, energy prices in proportion to income are likely to rise substantially for the foreseeable future.

Therefore, the ‘cheap off-peak energy’ that is meant to power America’s electric cars may prove to be an expensive illusion; the cost of the electricity used to power electric vehicles is likely to increase substantially, especially if there is an increase in demand, due, for example, to the rising number of electric vehicles.

It’s also worth noting that Argonne National Laboratory has a track record of drawing questionable conclusions that are welcomed by commercial interests. For example, a report by Argonne concluded that ethanol production using corn used about three quarters of a gallon of petroleum, or equivalents, to produce a single gallon of ethanol.

This conclusion was disputed by peer review and is now widely regarded as having been discredited.

The author of a report that refuted Argonne’s findings concluded

> “Argonne left out many of the energy inputs, such as the energy used by farm machinery and their maintenance. They left out processing equipment. They even

> left out the petroleum used in the production of hybrid corn… In plain words, it takes 1.29 gallons of petroleum or petroleum equivalents to produce one gallon of ethanol."

Similarly, Argonne's widely quoted GREET system, which is used to measure the cradle-to-the-grave energy used in the production of motor vehicles, excludes infrastructure. In other words, the energy used to, for example, transport vehicles around the world after production, is not included in their assessment. Nor is the energy used to create and maintain, say, a road and a fleet of trucks that constantly move between the steel mill and to the docks, where the steel is loaded into ships and moved around the planet. Neither is the energy used in, for example, the factory town that services a car factory, even if the factory town is owned by the car company for the exclusive use of its workers. Neither is the energy used to build the car factory or the town without which it cannot operate.

The omission of infrastructure would appear to question the validity of the GREET system.

Appendix IV
Sources, Assumptions and Qualifications

• **Note: our quoted statistics were correct at the time this report was assembled.** There may be minor differences between our assumed figures and figures published after our report was assembled (new information is being released by governments and other bodies all the time). Also, because illustrations and graphs tended to be inserted after the report was complete, there may also be minor differences between the figures in the illustrations versus the figures we have assumed for the rest of the report.

1) **Power generation** (sources of information).

USA
http://www.eia.doe.gov/cneaf/electricity/epm/table1_1.html

UK
http://www.greenpeace.org.uk/files/pdfs/climate/energy-gap-summary.pdf

www.parliament.uk/documents/upload/postpn268.pdf

China
http://www.eia.doe.gov/emeu/cabs/China/Background.html

http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=2&pid=2&aid=2

Australia
http://www.esaa.com.au/images/stories/FactSheets/2009facts.pdf

NZ

http://www.vuw.ac.nz/scps-demos/demos/Circuits_and_Electromagnetism/ElecticityGeneration/ElectricityGeneration.htm

2) Energy content

Certain fuels, such as coal, vary widely in energy content. An actual world average based on every possible instance is therefore impossible to calculate.

The following sources for the chemical properties of fuel types are in accordance with the wide range of global averages (maximum variance 10%):

Black Coal (combined average for bituminous and sub-bituminous)
The energy content of 1 Imperial gallon (= 4.546 litre) of petrol is 159 MJ. The energy content of black coal varies between 21 MJ/kg and 26.5 MJ/kg. If we take an average of 23 MJ/kg, then 6.9 kg of black coal has the same energy content as 1 Imperial gallon of petrol.

Because of the lower energy content per kg of brown coal, you need on average 40% more kg of brown coal than of black coal for the same amount of chemically stored energy.
(source: Jacob Klimstra)

Brown Coal
see above (black coal)

Natural Gas
http://bioenergy.ornl.gov/papers/misc/energy_conv.html

Petroleum
http://bioenergy.ornl.gov/papers/misc/energy_conv.html

3) Carbon Content:

• **Black coal** is around 82% carbon.
• **Brown coal** is around 74% carbon.
(source: Jacob Klimstra)

Natural Gas
Natural Gas is primarily methane, and therefore contains:

• (molecular weight of carbon) (12)
• total molecular weight of methane (16)

12/16=0.75 or 75% carbon

Petroleum (fuel oil)
Fuel oil is approximately 82% carbon.

http://bioenergy.ornl.gov/papers/misc/energy_conv.html
Fuel Oil weighs 3.37kg per us gallon, (2.77/3.37=0.82)

We are assuming that the properties between the various grades and types of fuel oil used for power generation are substantially the same.

4) Energy efficiency:

The following sources for the efficiency of various power generation and distribution mechanisms are accurate to within 10% of the world's averages:

Hydroelectric (82%):
http://www.hydro.com.au/education/discovery/student/efficiency.htm
http://esa21.kennesaw.edu/activities/hydroelectric/hydroactivity.pdf

Fuel Oil: 38%
http://www.e8.org/index.jsp?numPage=138

Coal

> "Conventional power stations powered by brown coal operate at about 30% efficiency in converting fuel energy into electricity, while black coal power stations are typically 35-36% efficient. This figure applies to most current coal-fired power stations."

(Source: Dr. Jacob Klimstra).

Natural gas:
• Conventional natural gas combustion power stations typically operate at 33-35% efficiency.

• Natural gas combined-cycle power stations typically operate at 50-54% efficiency.

www.npc.org/Study_Topic_Papers/4-DTG-ElectricEfficiency.pdf

(We have seen claims of efficiency as high as 60% and as low as 25% but were unable to verify these).

Dr Jacob Klimstra estimates that, because of the greater efficiency of combined-cycle plants, power companies generate approximately 2/3 of their natural gas-powered electricity using combined-cycle natural gas plants and 1/3 using conventional plants. Using these percentages, we have therefore, assumed a global average of 46%.

Nuclear:

There are currently 439 commercial nuclear reactors, which supply around 15% of global electricity, providing only 6.5% of overall energy consumption (International Energy Agency, World Energy Outlook 2008).

http://www.greenpeace.org/raw/content/international/press/reports/nuclear-power-undermining-ac.pdf

However, an alternative analysis by the International Institute for Applied Systems Analysis (IIASA) suggests that nuclear power represents only 2.2% of world energy consumption. This is because the IIASA considers the electric output of a nuclear plant a primary energy source. The IEA on the other hand considers heat [23]

(source: Robert Rapier)

Nuclear Power Plant mining milling disposal numbers

• Very efficient result 99%
http://nuclearinfo.net/Nuclearpower/WebHomeEnergyLifecycleOfNuclear_Power

• very inefficient result 84%
http://www.stormsmith.nl/

• calculator result 96.8% based on default settings
http://www.wise-uranium.org/nfce.html

[23] *Total Automotive Technology*, fourth edition, page 209

Spinning Reserve (in steam-generation systems): approximately 10% of generation capacity is lost in spinning reserve. See Appendix II – *Electricity Generation: 'Surplus' Capacity and Spinning Reserve.*

Transmission and Distribution losses: Approximately 7.5% is lost in getting the energy from the plant to the consumer. Dr. Jacob Klimstra suggested that this is a credible figure. However, it is a global figure, and must therefore be only an approximation. In some places energy losses in transmission may be higher (e.g. China). In other places, such as Australia, the typical energy losses may be slightly lower, assuming that the official figures are accurate.

5) CO_2 emissions

The fraction of carbon in carbon dioxide is the ratio of their weights. The atomic weight of carbon is 12 atomic mass units, while the weight of carbon dioxide is 44, because it includes two oxygen atoms that each weigh16. So, one ton of carbon produces 44/12 = 11/3 = 3.67 tons of carbon dioxide.

Therefore, the assumed figure for CO_2 emissions are calculated taking the carbon content of the fuel and multiplying it by the conversion factor of 3.67.

Electric cars in the real world

The Tesla sportscar is based upon the Lotus Elise sportscar, which provides a unique opportunity to compare two cars, because the primary difference between them is the drivetrain (the Tesla is electric and the Elise is powered by petrol).

However, it's worth noting that the Tesla's weight counts heavily against it: The Tesla weighs about 1220kg (2,690lbs), whereas the Elise weighs around 860kg (1900lbs). Simple physics means that the Tesla will need far more energy to move an equivalent distance.

The attached spreadsheet examines the energy usage and relative CO_2 emissions for both vehicles.

It's also worth noting that these tests were done on new or near-new vehicles. Due to the natural loosening up of petrol engines, the Elise will probably gain slightly better fuel economy with time, as losses due to friction are reduced. If correctly maintained, a five-year-old Elise should give mildly better economy than a new Elise. By comparison, the Tesla is probably losing a little of its efficiency with each trip. In five year's time the batteries will have lost a significant amount of efficiency.

Assumptions and qualifications regarding the Tesla/Elise comparison.

Fuel consumption.

Few serious motoring writers express much trust in estimated fuel consumption figures, simply because they have been almost invariably proved significantly inaccurate under real world driving conditions. This is because estimated fuel consumption figures are usually achieved in a laboratory, not on an actual road in everyday conditions. This practice of theoretical fuel consumption testing was developed by governments as an easy way of levelling the playing field between makes and models. Using a device called a chassis dynamometer, the vehicle stays still while its wheels turn. It goes through a series of acceleration and deceleration manoeuvres that are designed to imitate a daily drive. In practice, it is rare for such figures to accurately reflect real life driving.

For example, the Tesla sportscar's EPA-approved test showed a combined mileage range of 244 miles per charge.

However, an ex-Tesla spokesman has stated publicly that EPA's electric-vehicle range figures are grossly inaccurate.

> "The actual range you will get from a complete charge depends on a lot of factors, but I would say that as a general rule of thumb, if a company quotes an EPA range, you should apply a factor of 70% to that to get a realistic average range for a full charge."

Moreover, Tesla Motors freely admits that actual mileage will depend on the manner and environment in which the vehicle is driven. The American government (EPA) test assumes that no interior appliances such as heating, stereo or air conditioning are switched on, all of which would quickly drain the Tesla's batteries.

The respected American motoring website: *The Truth about Cars* estimates that the Tesla's actual range is between 50 and 200 miles per charge.

Blogs by Tesla owners suggest that actual mileages for everyday use are between 120 and 200 miles per charge. However, the tone of these blogs make it clear that, for many Tesla owners, their vehicle is an environmental statement rather than a sportscar. Therefore, while their upper mileage limits may be realistic, their lower one is not. The Tesla is a sportscar and is designed to be driven like one, and will be driven like one by many owners. The Tesla's sibling, the Elise, is also a sportscar, and the Consumer Reports review makes it clear that the test drivers drove it like one.

We have also ruled out idealised road-based Tesla figures from our fuel consumption data. That is, we have ruled out figures achieved by idealistic drivers who managed incredible mileage figures by driving long distances at very low speeds. These figures have little relevance to the reality of everyday driving; virtually any vehicle can be made to give impressive fuel consumption figures if it is driven carefully.

Similar stunts have been carried out by car companies and enthusiasts since the dawn of motoring. For example, in the 20th century, a British small carmaker – Morris Motors – ran a publicity campaign claiming that their Morris Minor car was capable of doing 100mph, gave 100 miles per gallon and cost 100 British pounds.

In practice, no ordinary Morris Minor could achieve anything like 100mph or 100 miles per gallon. The 100 miles per gallon figure was achieved by driving around a racetrack at a very low speed for a very long time. The fuel economy and performance figures achieved by everyday drivers never came close to the claims of the Morris Company.

Similarly, two independent tests of Tesla vehicles showed them averaging between 50 and slightly less than 200 miles per charge.

In February of 2010, a reviewer commented:

> "Despite Tesla's initial claim of a 250-mile charge on the battery, the upstart automaker has changed its tune to 'over 200 miles'. So why haven't we broken that mark after a full six-hour charge? According to one of Tesla's engineers, our Sport model – like all press fleet vehicles – has lived a rough life over the last year and it's taken its toll on the battery."

Throughout the five day test, the reviewer never came close to achieving 200 miles from a single charge, despite a combination of fast and slow driving.

Given that the reviewer's test was on a relatively new vehicle, it appears likely that the battery in that car will continue to deteriorate until replacement is required within a few years.

After one 28 mile burst of hard driving, the mileage-remaining indicator had dropped from 176 miles to 63 miles. In other words, 28 miles of hard driving had used up the equivalent of 113 miles – well over half the Tesla's claimed driving range.

We believe that the lower (50 mile) figure quoted by *The Truth About Cars* and the review quoted above, is accurate for "28 miles of hard driving" of the Tesla. However, the test by *Consumer Reports* of the Elise, while based on actual driving, seems unlikely to have included "28 miles of hard driving" in the same manner as the racing journalists who tested the Tesla. We attempted to find a similar, (hard-driving) consumption figure for this version of the Elise, but were unable to find a credible source (most reviews simply quote fuel consumption estimates from the manufacturer or a government department).

Therefore, in order to compare 'apples with apples', we raised the 'less economical' figure for the Tesla from 50 to 85. 85 is the average of the 50 quoted by the racing journalists, and the 120 figure quoted by Tesla enthusiasts. This seems much more fair and reasonable.

For our upper ('more economical') end of the scale we have chosen the 200 miles per charge figure quoted by enthusiasts on the Tesla website, even though it would probably require quite careful (un-sportscar-like) driving to achieve this figure in everyday life.

For our average Tesla figure we have used the average between the low (85) and high (200) figures: (142.5 miles per charge).

Lotus Elise.

We have similar reservations about the accuracy of the stated petrol consumption figures for the Lotus Elise. Official EPA figures are more pessimistic than the actual test results (that is, based on actual road tests) by the respected Consumer Reports organisation.

In addition to using the Consumer Reports figures we took their average of their city/highway figures (which gives us an average of 28.5 mpg (US) (8.25 litres/100km).

Consumer Reports actual fuel consumption figures (the figures we used):

- CR's overall mileage 29 mpg(US) (8.1 litres/100km)
- CR's city/highway 24 / 33 mpg(US) (9.8/7.1 litres/100km)
- CR's 150-mile trip 32 mpg (US) (7.4 litres/100km)

EPA estimated fuel consumption figures (not used):

- City: 20mpg (US) (11.8 litres/100km)
- Highway: 26 mpg (US) (9 litres/100km)
- Combined: 22 mpg (US) (10.6 litres/100km)

Elise well-to-tank.

Petrol does not arrive in a car's fuel tank by itself. A significant amount of the energy (about 15%) that was in the original crude oil was used up, on average, getting the petrol from the oil well to the tank of the car. This is called the well-to-tank figure. We have modified the Elise's fuel consumption and CO_2 outputs by a factor of 85% to allow for well-to-tank losses.

The amount of CO_2 produced by the Elise (from fuel burned within the car's engine) is calculated as a factor (3.67) of the total amount of carbon burnt.

The resultant figures are consistent with CO_2 emission estimates for this vehicle obtained using chassis dynamometer tests.

Table 1 Fuel production efficiencies (*all values taken from GREET unless otherwise noted*)

Engine	Fuel	NG Feedstock Production Efficiency[1]	Conversion Efficiency NG to Fuel	Fuel Storage, Transmission, & Distribution Efficiency	Efficiency of Additional Compression	**Overall Efficiency of Fuel Production**
Conventional SI	NG	95%		97%	95% [7]	**87.5%**
	H_2	95%	78.5% [2]	97% [6]	82% [7]	**59%**
Conventional Diesel	F-T Diesel	95%	72% [3]	97%		**67%**
	Dual-Fuel	95%	98% [3]	97%	95% [8]	**86%**
Hybrid SI	NG	95%		97%	95% [7]	**87.5%**
Hybrid Diesel	F-T Diesel	95%	72% [3]	97%		**67%**
	Dual-Fuel	95%	98% [3]	97%	95% [8]	**86%**
Battery All-Electric	Electricity	95%	42% [4]	93% [4]		**37%**
Fuel Cell	Methanol	95%	62.4% [5]	97%		**57.5%**
	H_2	95%	78.5% [2]	97% [6]	82% [7]	**59%**

1. 95% = 97.0% (Recovery) x 97.5% (Processing)
2. Efficiency of hydrogen production from natural gas by steam reforming [3].
3. Using data from Rentech [13], the efficiency is 75.5% = (0.544 MBtu of energy in C5+ product)/((1.0 MBtu of energy in NG feedstock) - (0.28 MBtu of NG energy needed to generate electricity)). For Dual-Fuel, the efficiency is 98% = ((1.0 no conversion needed for NG) x (92.5% NG energy fraction) + (75.5% NG to F-T conversion) x (7.5% F-T energy fraction)).
4. Combined cycle power plant efficiency y=42%, distribution losses 7%; Unnasch et al. [14].
5. Via conventional steam-reforming: Allard [15]. This value is in a similar range with GREET's 61.5% and the CEC's 68.3%. The conversion from methanol to hydrogen via on-board fuel processor is included in the stack efficiency in Table 2.
6. Assuming gaseous hydrogen from centralized plants.
7. Assuming 90% compressor efficiency, 42% conversion efficiency (NG to electricity), and 93% electricity transmission and distribution, it was calculated that 5738 Btu of NG is required to generate the electricity needed for four stages of compression of 100,000 Btu of NG and 21,520 Btu of NG is needed to generate the electricity to compress 100,000 Btu of H_2.
8. Using energy fractions of 92.5% NG and 7.5% F-T Diesel, the compression efficiency is 95% = ((95% NG compression) x (92.5% NG energy fraction) + (1.0 no compression for liquid F-T) x (7.5% F-T Diesel energy fraction)).

Data from Refs. [13–15] included in Table.

Appendix V
Actual fuel consumption and emissions of the Tesla sportscar versus the Lotus Elise (the vehicle that it is based on)

Figures for each nation are calculated based on the breakdown of different methods of electricity generation for each country.

Emissions are calculated based on the total amount of carbon burnt through the process of getting the energy from the source (e.g. mine/well) to the wheels of the car.

Energy consumption is calculated from the total amount of heat energy contained in the fuels that are consumed through the process of getting the energy from the source (e.g. mine/well) to the wheels of the car. This is measured in kilowatt-hours (kWh), which are:

USA (in miles)

Emissions (kg of CO_2 per mile)

Performance	**Tesla**	**Elise**
Average	0.520	0.345
Good	0.371	0.298
Poor	0.872	0.410

Consumption (kWh per mile)

Performance	**Tesla**	**Elise**
Average	1.732	1.480
Good	1.234	1.278
Poor	2.904	1.757

USA (in kilometres)

Emissions (kg of CO_2 per Kilometre)

Performance	Tesla	Elise
Average	0.323	0.214
Good	0.230	0.185
Poor	0.542	0.254

Consumption (kWh per Kilometre)

Performance	Tesla	Elise
Average	1.076	0.918
Good	0.767	0.792
Poor	1.805	1.090

Australia

Emissions (kg of CO_2 per Kilometre)

Performance	Tesla	Elise
Average	0.522	0.214
Good	0.372	0.185
Poor	0.875	0.254

Consumption (kWh per Kilometre)

Performance	Tesla	Elise
Average	1.124	0.918
Good	0.801	0.792
Poor	1.884	1.090

New Zealand

Emissions (kg of CO_2 per Kilometre)

Performance	**Tesla**	**Elise**
Average	0.080	0.214
Good	0.057	0.185
Poor	0.134	0.254

Consumption (kWh per Kilometre)

Performance	**Tesla**	**Elise**
Average	0.582	0.918
Good	0.415	0.792
Poor	0.976	1.090

China

Emissions (kg of CO_2 per Kilometre)

Performance	**Tesla**	**Elise**
Average	0.459	0.214
Good	0.327	0.185
Poor	0.769	0.254

Consumption (kWh per Kilometre)

Performance	**Tesla**	**Elise**
Average	1.130	0.918
Good	0.805	0.792
Poor	1.895	1.090

U.K.

Emissions (kg of CO_2 per Kilometre)

Performance	Tesla	Elise
Average	0.276	0.214
Good	0.197	0.185
Poor	0.463	0.254

Consumption (kWh per Kilometre)

Performance	Tesla	Elise
Average	1.063	0.918
Good	0.757	0.792
Poor	1.782	1.090