All About

Green Transport

(Sustainable Technologies)

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Sustainable Transport

Sustainable transport (or **green transport**) refers to any means of transport with low impact on the environment, and includes walking and cycling, transit oriented development, green vehicles, CarSharing, and building or protecting urban transport systems that are fuel-efficient, space-saving and promote healthy lifestyles.

Sustainable transport systems make a positive contribution to the environmental, social and economic sustainability of the communities they serve. Transport systems exist to provide social and economic connections, and people quickly take up the opportunities offered by increased mobility. The advantages of increased mobility need to be weighed against the environmental, social and economic costs that transport systems pose.

Transport systems have significant impacts on the environment, accounting for between 20% and 25% of world energy consumption and carbon dioxide emissions. Greenhouse gas emissions from transport are increasing at a faster rate than any other energy using sector. Road transport is also a major contributor to local air pollution and smog.

The social costs of transport include road crashes, air pollution, physical inactivity, time taken away from the family while commuting and vulnerability to fuel price increases. Many of these negative impacts fall disproportionately on those social groups who are also least likely to own and drive cars. Traffic congestion imposes economic costs by wasting people's time and by slowing the delivery of goods and services.

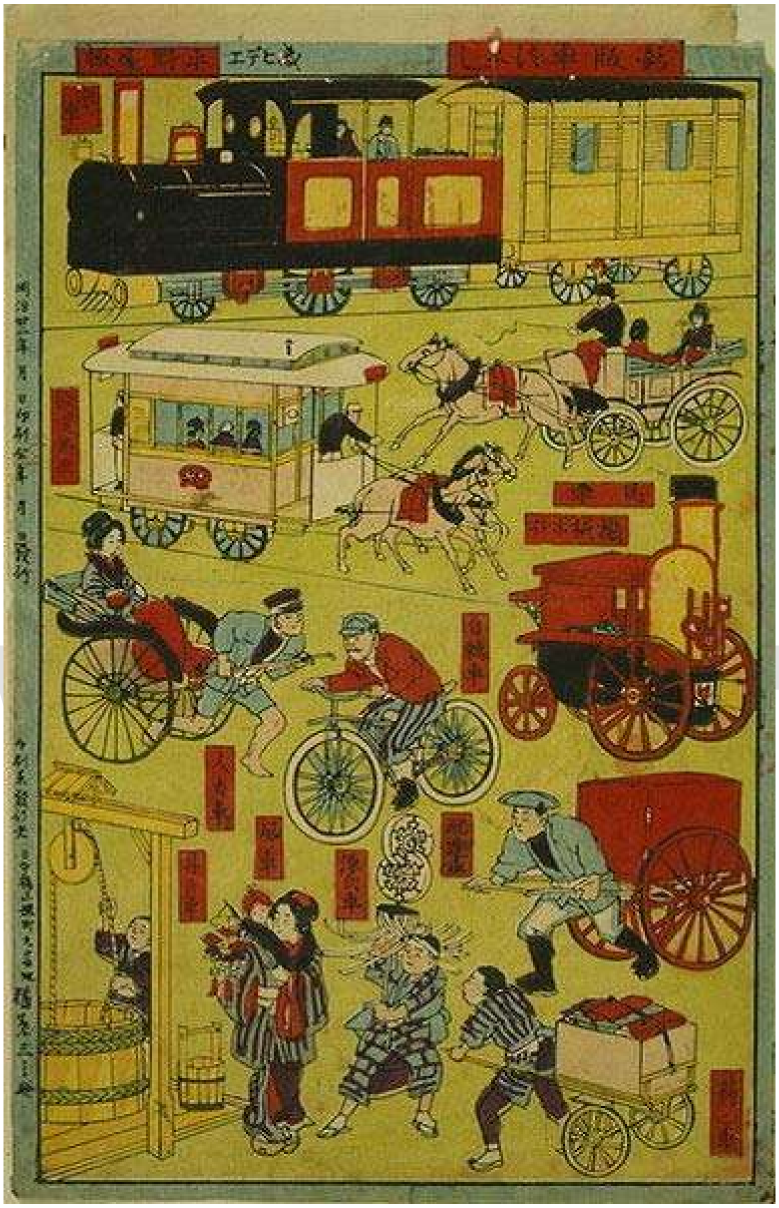
Traditional transport planning aims to improve mobility, especially for vehicles, and may fail to adequately consider wider impacts. But the real purpose of transport is access - to work, education, goods and services, friends and family - and there are proven techniques to improve access while simultaneously reducing environmental and social impacts, and managing traffic congestion. Communities which are successfully improving the sustainability of their transport networks are doing so as part of a wider programme of creating more vibrant, livable, sustainable cities.

Definition

The term **sustainable transport** came into use as a logical follow-on from sustainable development, and is used to describe modes of transport, and systems of transport planning, which are consistent with wider concerns of sustainability. There are many definitions of the sustainable transport, and of the related terms **sustainable transportation** and **sustainable mobility**. One such definition, from the European Union Council of Ministers of Transport, defines a sustainable transportation system as one that:

- Allows the basic access and development needs of individuals, companies and society to be met safely and in a manner consistent with human and ecosystem health, and promotes equity within and between successive generations.
- Is Affordable, operates fairly and efficiently, offers a choice of transport mode, and supports a competitive economy, as well as balanced regional development.
- Limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below their rates of generation, and uses non-renewable resources at or below the rates of development of renewable substitutes, while minimizing the impact on the use of land and the generation of noise.

History



Japanese print shows various forms of transportation

Most of the tools and concepts of sustainable transport were developed before the phrase was coined. Walking, the first mode of transport, is also the most sustainable. Public transport dates back at least as far as the invention of the public bus by Blaise Pascal in 1662. The first passenger tram began operation in 1807 and the first passenger rail service in 1825. Pedal bicycles date from the 1860s. These were the only personal transport choices available to most people in Western countries prior to World War II, and remain the only options for most people in the developing world. Freight was moved by human power, animal power or rail.

The post-war years brought increased wealth and a demand for much greater mobility for people and goods. The number of road vehicles in Britain increased fivefold between

1950 and 1979, with similar trends in other Western nations. Most affluent countries and cities invested heavily in bigger and better-designed roads and motorways, which were considered essential to underpin growth and prosperity. Transport planning became a branch of civil engineering and sought to design sufficient road capacity to provide for the projected level of traffic growth at acceptable levels of traffic congestion - a technique called "predict and provide". Public investment in transit, walking and cycling declined dramatically in the United States, Great Britain and Australasia, although this did not occur to the same extent in Canada or mainland Europe.

Concerns about the sustainability of this approach became widespread during the 1973 oil crisis and the 1979 energy crisis. The high cost and limited availability of fuel led to a resurgence of interest in alternatives to single occupancy vehicle travel.

Transport innovations dating from this period include high-occupancy vehicle lanes, citywide carpool systems and transportation demand management. Singapore implemented congestion pricing in the late 1970s, and Curitiba began implementing its Bus Rapid Transit system in the early 1980s.

Relatively low and stable oil prices during the 1980s and 1990s led to significant increases in vehicle travel from 1980–2000, both directly because people chose to travel by car more often and for greater distances, and indirectly because cities developed tracts of suburban housing, distant from shops and from workplaces, now referred to as urban sprawl. Trends in freight logistics, including a movement from rail and coastal shipping to road freight and a requirement for just in time deliveries, meant that freight traffic grew faster than general vehicle traffic.

At the same time, the academic foundations of the "predict and provide" approach to transport were being questioned, notably by Peter Newman in a set of comparative studies of cities and their transport systems dating from the mid-1980s.

The British Government's White Paper on Transport marked a change in direction for transport planning in the UK. In the introduction to the White Paper, Prime Minister Tony Blair stated that

We recognise that we cannot simply build our way out of the problems we face. It would be environmentally irresponsible - and would not work.

A companion document to the White Paper called "Smarter Choices" researched the potential to scale up the small and scattered sustainable transport initiatives then occurring across Britain, and concluded that the comprehensive application of these techniques could reduce peak period car travel in urban areas by over 20%.

A similar study by the United States Federal Highway Administration, was also released in 2004 and also concluded that a more proactive approach to transportation demand was an important component of overall national transport strategy.

Environmentally sustainable transport

Transport systems are major emitters of greenhouse gases, responsible for 23% of world energy-related GHG emissions in 2004, with about three quarters coming from road vehicles. Currently 95% of transport energy comes from petroleum. Energy is consumed in the manufacture as well as the use of vehicles, and is embodied in transport infrastructure including roads, bridges and railways.

The environmental impacts of transport can be reduced by improving the walking and cycling environment in cities, and by enhancing the role of public transport, especially electric rail.

Green vehicles are intended to have less environmental impact than equivalent standard vehicles, although when the environmental impact of a vehicle is assessed over the whole of its life cycle this may not be the case. Electric vehicle technology has the potential to reduce transport CO_2 emissions, depending on the embodied energy of the vehicle and the source of the electricity. Hybrid vehicles, which use an internal combustion engine combined with an electric engine to achieve better fuel efficiency than a regular combustion engine, are already common. Natural gas is also used as a transport fuel. Biofuels are a less common, and less promising, technology; Brazil met 17% of its transport fuel needs from bioethanol in 2007, but the OECD has warned that the success of biofuels in Brazil is due to specific local circumstances; internationally, biofuels are forecast to have little or no impact on greenhouse emissions, at significantly higher cost than energy efficiency measures.

In practice there is a sliding scale of **green transport** depending on the sustainability of the option. Green vehicles are more fuel-efficient, but only in comparison with standard vehicles, and they still contribute to traffic congestion and road crashes. Well-patronised public transport networks based on traditional diesel buses use less fuel per passenger than private vehicles, and are generally safer and use less road space than private vehicles. Green public transport vehicles including electric trains, trams and electric buses combine the advantages of green vehicles with those of sustainable transport choices. Other transport choices with very low environmental impact are cycling and other human-powered vehicles, and animal powered transport. The most common green transport choice, with the least environmental impact is walking.

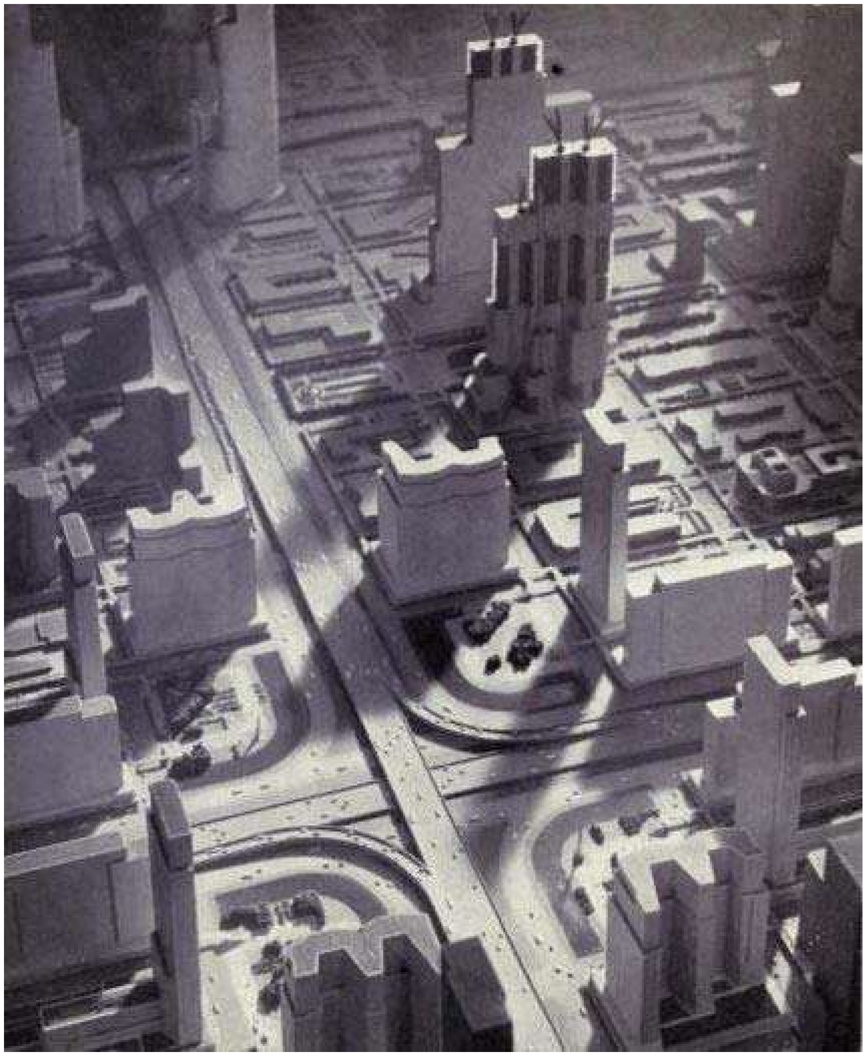
Transport and social sustainability

A tram in Melbourne, Australia

Cities with overbuilt roadways have experienced unintended consequences, linked to radical drops in public transport, walking, and cycling. In many cases, streets became void of "life." Stores, schools, government centers and libraries moved away from central cities, and residents who did not flee to the suburbs experienced a much reduced quality of public space and of public services. As schools were closed their mega-school replacements in outlying areas generated additional traffic; the number of cars on US roads between 7:15 and 8:15 a.m. increases 30% during the school year.

Yet another impact was an increase in sedentary lifestyles, causing and complicating a national epidemic of obesity, and accompanying dramatically increased health care costs.

Cities and sustainable transport



Futurama, an exhibit at the 1939 New York World's Fair, was sponsored by General Motors and showed a vision of the City of Tomorrow.

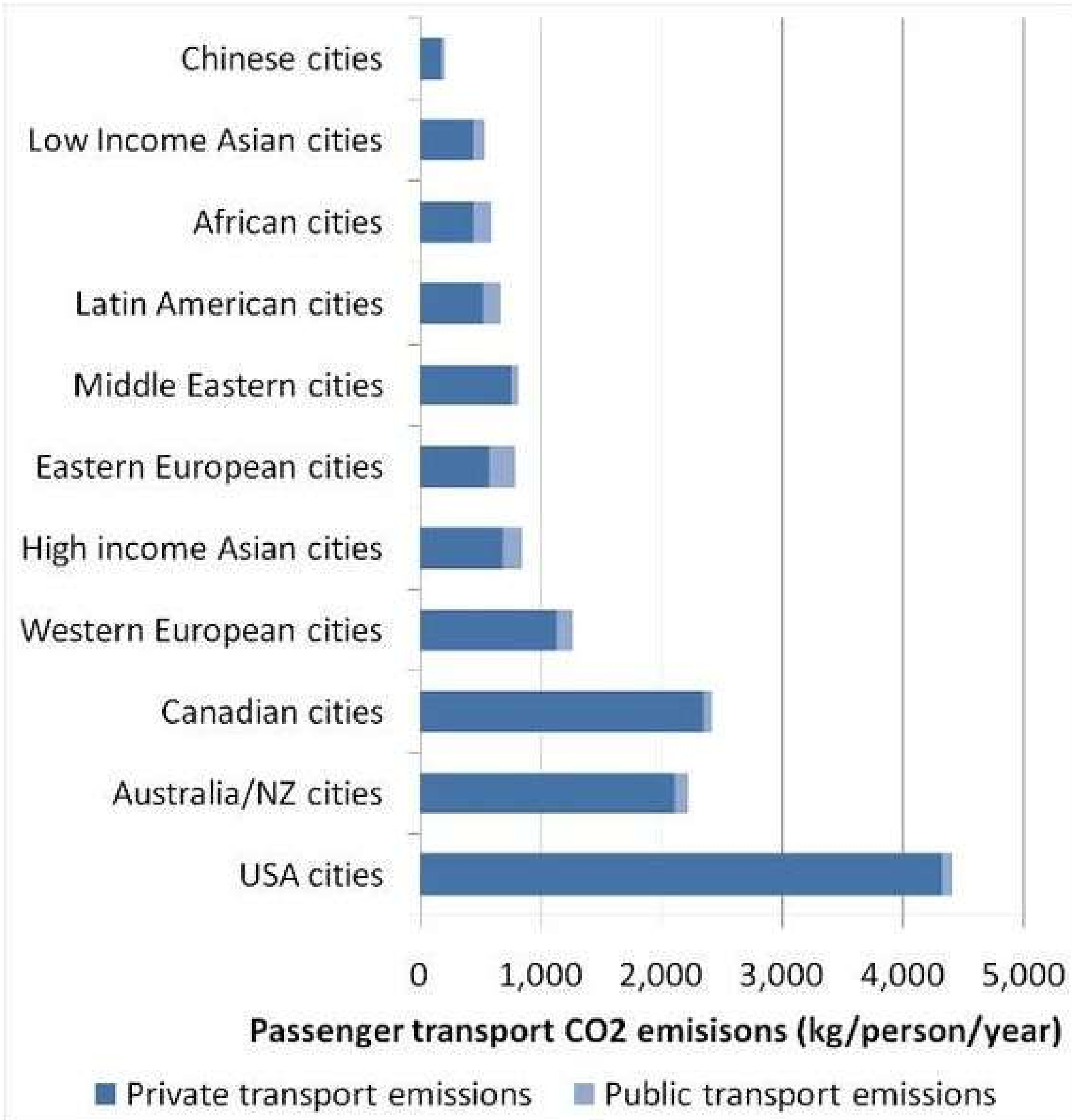
Cities are shaped by their transport systems. In The City in History, Lewis Mumford documented how the location and layout of cities was shaped around a walkable centre, often located near a port or waterway, and with sububs accessible by animal transport or, later, by rail or tram lines.

In 1939, the New York World's Fair included a model of an imagined city, built around a car-based transport system. In this "greater and better world of tomorrow", residential, commercial and industrial areas were separated, and skyscrapers loomed over a network of urban motorways. These ideas captured the popular imagination, and are credited with influencing city planning from the 1940s to the 1970s.

The popularity of the car in the post-war era led to major changes in the structure and function of cities. There was some opposition to these changes at the time. The writings of Jane Jacobs, in particular The Death and Life of Great American Cities provide a poignant reminder of what was lost in this transformation, and a record of community efforts to resist these changes. Lewis Mumford asked "is the city for cars or for people?" Donald Appleyard documented the consequences for communities of increasing car traffic in "The View from the Road" (1964) and in the UK, Mayer Hillman first published research into the impacts of traffic on child independent mobility in 1971. Despite these notes of caution, trends in car ownership, car use and fuel consumption continued steeply upward throughout the post-war period.

Interstate 10 and Interstate 45 near downtown Houston, Texas

Mainstream transport planning in Europe has, by contrast, never been based on assumptions that the private car was the best or only solution for urban mobility. For example the Dutch Transport Structure Scheme has since the 1970s required that demand for additional vehicle capacity only be met "if the contribution to societal welfare is positive", and since 1990 has included an explicit target to halve the rate of growth in vehicle traffic. Some cities outside Europe have also consistently linked transport to sustainability and to land use planning, notably Curitiba, Brazil, Portland, Oregon and Vancouver, Canada.



Greenhouse gas emissions from transport vary widely, even for cities of comparable wealth. Source: UITP, Mobility in Cities Database

There are major differences in transport energy consumption between cities; an average U.S. urban dweller uses 24 times more energy annually for private transport than a Chinese urban resident, and almost four times as much as a European urban dweller. These differences cannot be explained by wealth alone but are closely linked to the rates of walking, cycling, and public transport use and to enduring features of the city including urban density and urban design.

The cities and nations that have invested most heavily in car-based transport systems are now the least environmentally sustainable, as measured by per capita fossil fuel use. The social and economic sustainability of car-based urban planning has also been questioned.

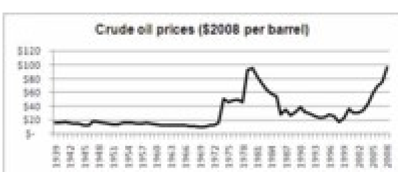
Within the United States, residents of sprawling cities make more frequent and longer car trips, while residents of traditional urban neighbourhoods make a similar number of trips, but travel shorter distances and walk, cycle and use transit more often. It has been calculated that New York residents save $19 billion each year simply by owning fewer cars and driving less than the average American.

The European Commission adopted the Action Plan on urban mobility on 2009-09-30 for sustainable urban mobility. The European Commission will conduct a review of the implementation of the Action Plan in the year 2012, and will assess the need for further action. In 2007, 72% of the European population lived in urban areas, which are key to growth and employment. Cities need efficient transport systems to support their economy and the welfare of their inhabitants. Around 85% of the EU's GDP is generated in cities. Urban areas face today the challenge of making transport sustainable in environmental (CO_2, air pollution, noise) and competitiveness (congestion) terms while at the same time addressing social concerns. These range from the need to respond to health problems and demographic trends, fostering economic and social cohesion to taking into account the needs of persons with reduced mobility, families and children.

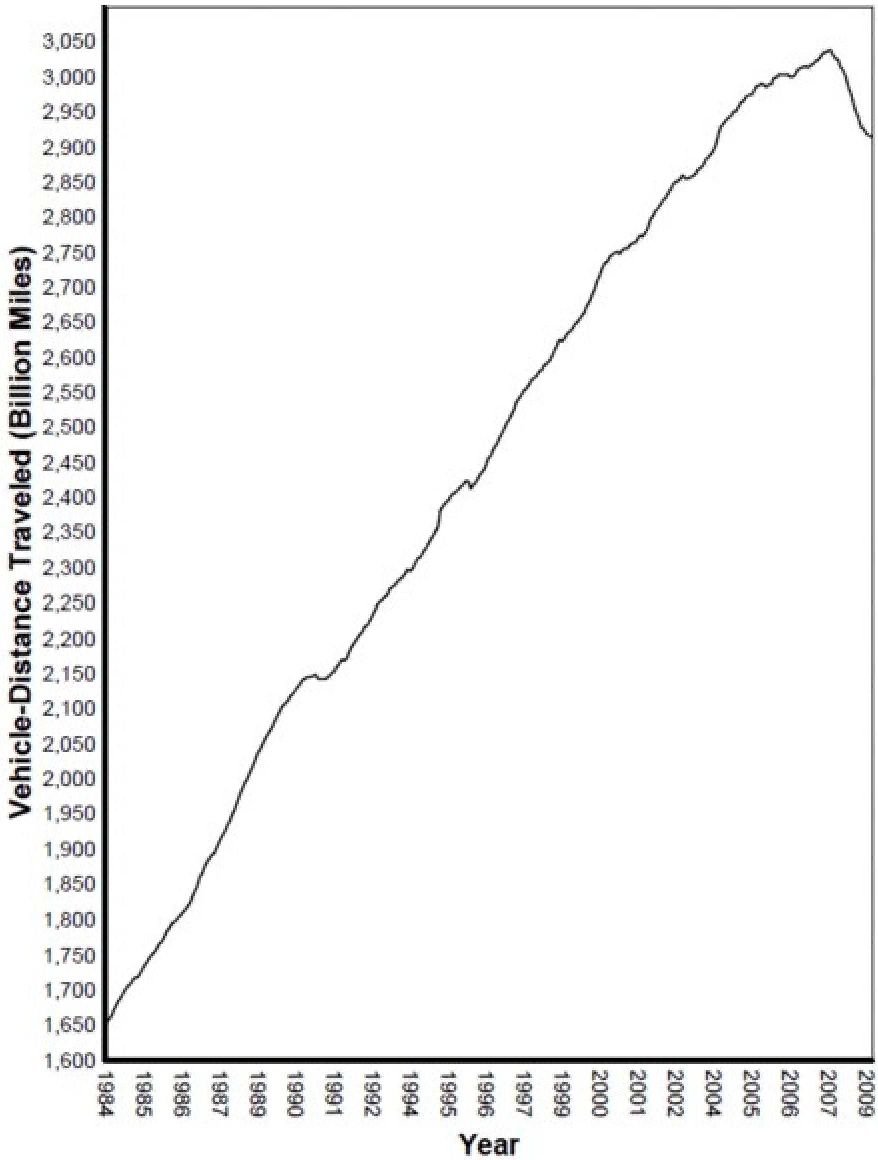
Sustainable transport policies and governance

Sustainable transport policies have their greatest impact at the city level. Outside Western Europe, cities which have consistently included sustainability as a key consideration in transport and land use planning include Curitiba, Brazil, Bogota, Colombia Portland, Oregon and Vancouver, Canada. The state of Victoria, Australia recently passed legislation - the Transport Integration Act - which introduces sustainability measures into transport policy, planning and operations.

Many other cities throughout the world have recognised the need to link sustainability and transport policies, for example by joining Cities for Climate Protection.



Oil price trend, 1939–2007, both nominal and adjusted to inflation.



Vehicle-miles traveled in the United States up to March 2009.

Community and grassroots action

Sustainable transport is fundamentally a grassroots movement, albeit one which is now recognised as of citywide, national and international significance.

Whereas it started as a movement driven by environmental concerns, over these last years there has been increased emphasis on social equity and fairness issues, and in particular the need to ensure proper access and services for lower income groups and people with mobility limitations, including the fast growing population of older citizens. Many of the people exposed to the most vehicle noise, pollution and safety risk have been those who do not own, or cannot drive cars, and those for whom the cost of car ownership causes a severe financial burden.

Recent trends

Car travel increased steadily throughout the twentieth century, but trends since 2000 have been more complex. Oil price rises from 2003 have been linked to a decline in per capita fuel use for private vehicle travel in the USA, Britain and Australia. In 2008, global oil consumption fell by 0.8% overall, with significant declines in consumption in North America, Western Europe, and parts of Asia.

Criticism

The term *Green transport* is often used as a greenwash marketing technique for products which are not proven to make a positive contribution to environmental sustainability. Such claims can be legally challenged. For instance Norway's consumer ombudsman has targeted automakers who claim that their cars are "green", "clean" or "environmentally friendly". Manufacturers risk fines if they fail to drop the words. The Australian Competition and Consumer Commission (ACCC) describes *green* claims on products as *very vague*, *inviting consumers to give a wide range of meanings to the claim, which risks misleading them*. In 2008 the ACCC forced a car retailer to stop its *green* marketing of Saab cars, which was found by the Australian Federal Court as *misleading*.

Sustainable transport toolbox

The EU Directorate-General for Transport and Energy (DG-TREN) has launched a programme which focusses mostly on Urban Transport. Its main measures are:

- Clean fuels and vehicles
  - Hybrid Vehicles
  - Biodiesel
  - Biogas/CNG
  - Electric Vehicles
  - LPG
  - Hydrogen vehicle
  - Human-powered transport
  - Animal-powered transport
- Sustainable (green) transport infrastructure
  - greenways and foreshoreways
  - Cycleways
  - Busways
  - Railways
- Access restrictions
  - Access management / Enforcement
  - Car Restricted Zones
- Collective passenger transport
  - Public transport
  - Bus services
  - Bus rapid transit
  - Rail transport
  - Intermodal transfers
  - Integrated ticketing
  - Marketing
  - Park & Ride
  - Demand responsive transport
  - Accessible transport systems
  - Paratransit
  - Bus rapid transit
  - Quality of service
  - Security, including Transit police
- Travel information
- Soft measures
  - Travel plan
  - Walking school bus
  - Travel blending
  - Personalised travel plan
- Transport management
  - Transportation demand management
  - Transit oriented development
  - Walkability
  - New urbanism and New pedestrianism
  - TDM Toolbox
- Sustainable Freight Transport
  - Clean vehicles / clean fleet
  - Intermodal freight transport
  - Dry port

/Living Streets
  - Multifunctional areas
  - Parking Management
  - Pedestrian zone
  - Traffic calming / Speed reduction
- Integrated pricing strategies
  - Congestion pricing
  - Integrated ticketing
  - Parking Management
  - Public transport timetable
  - journey planner
- Less car intensive lifestyle
  - Car pooling
  - Car sharing
  - Car/ driver licence exit strategies
  - Cycling
  - Bike sharing
  - Fleet management
  - Route planning
  - Transportation management

Chapter- 2

Green Vehicle

The Toyota Prius is the world's top selling hybrid car, with cumulative global sales of 2.0 million units by September 2010, and has became the icon of green cars.

A **green vehicle** or **environmentally friendly vehicle** is a road motor vehicle that produces less harmful impacts to the environment than comparable conventional internal combustion engine vehicles running on gasoline or diesel. Presently, in some countries the term is used for any vehicle surpassing the Euro6-norm such as LEVs and ULEVs, and also more informally it is used for California's zero emissions vehicles and other low-carbon emission vehicles.

Green vehicles are powered by alternative fuels and advanced vehicle technologies and include hybrid electric vehicles, plug-in hybrid electric vehicles, battery electric vehicles, compressed-air vehicles, hydrogen and fuel-cell vehicles, neat ethanol vehicles, flexible-fuel vehicles, natural gas vehicles, clean diesel vehicles, and some sources also include vehicles using blends of biodiesel and ethanol fuel or gasohol. Several author also include conventional motor vehicles with high fuel economy, as they consider that increasing fuel economy is the most cost-effective way to improve energy efficiency and reduce carbon emissions in the transport sector in the short run. As part of their contribution to sustainable transport, environmentally friendly vehicles reduce air pollution and greenhouse gas emissions, and contribute to energy independence by reducing oil imports.

Production

Part of the total energy cost can be cut by choosing smaller, lighter vehicles that use less energy to produce and to operate. Alternatively larger heavier vehicles with more efficient power systems may use less energy overall.

Energy efficiency

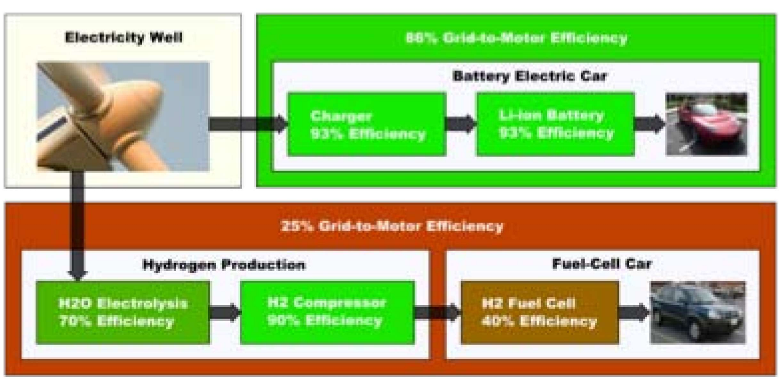
Cars with similar production energy costs can obtain, during the life of the car (operational phase), large reductions in energy costs through several measures:

- The most significant is by using alternative propulsion:
  - An efficient engine that reduces the vehicle's consumption of petroleum (i.e. petroleum electric hybrid vehicle), or, preferably, that uses renewable energy sources throughout its working life.
  - Using biofuels instead of petroleum fuels.
- Proper maintenance of a vehicle such as engine tune-ups, oil changes, and maintaining proper tire pressure can also help.
- Removing unnecessary items from a vehicle reduces weight and improves fuel economy as well.

Comparison of several types of green car basic characteristics (Values are overall for vehicles in current production and may differ between types)					
Type of vehicle/ powertrain	Fuel economy (mpg equivalent)	Range	Production cost for given range	Reduction in CO_2 compared to conventional	Payback period

Conventional ICE	10-78	Long (400-600 mi)	Low	0%	-
Biodiesel	18-71	Long (360-540 mi)	Low	100%	-
All-electric	Excluding battery cost: 99 Including battery cost: 10-50	Shorter (73-150 mi)	High	varies	-
Hydrogen fuel cell	80		High		
Hybrid electric	30-60	380 mi	Medium		5 years

Types



Comparison of energy efficiency between battery and hydrogen fuel-cell cars.

Sales of both the Chevrolet Volt plug-in hybrid (top) and the Nissan Leaf all-electric car (bottom) are scheduled to begin in late 2010.

Green vehicles include vehicles types that function fully or partly on alternative energy sources other than fossil fuel or less carbon intensive than gasoline or diesel.

Another option is the use of alternative fuel composition in conventional fossil fuel-based vehicles, making them function partially on renewable energy sources. Other approaches include personal rapid transit, a public transportation concept that offers automated, on-demand, non-stop transportation on a network of specially built guideways.

Electric and fuel cell-powered

Examples of vehicles with reduced petroleum consumption include electric cars, plug-in hybrids and fuel cell-powered hydrogen cars.

Electric cars are typically more efficient than fuel cell-powered vehicles on a wheel-to-wheel basis. For this reason, battery powered vehicles and plug-in hybrids are gaining popularity. They have better fuel economy than conventional internal combustion engine vehicles but are hampered by range or maximum distance attainable before discharging the battery. The electric car batteries are their main cost. They provide a 55% to 99.9% improvement in CO_2 emissions compared to an ICE (gasoline, diesel) vehicle, depending on the source of electricity.

Hybrid electric vehicles

Hybrid cars may be partly fossil fueled and partly electric or hydrogen-powered. They are more expensive to purchase but cost redemption is achieved in a period of about 5 years due to better fuel economy.

Compressed air cars, stirling vehicles, and others

Compressed air cars, stirling-powered vehicles, Liquid nitrogen vehicles are even less polluting than electrical vehicles, as the vehicle and its components can be made more environmentally friendly.

Solar car races are held on a regular basis in order to promote green vehicles and other "green technology". These sleek driver-only vehicles can travel long distances at highway speeds using only the electricity generated instantaneously from the sun.

Improving conventional cars

The Fiat Siena Tetrafuel 1.4 is a multifuel car designed to run as a flex-fuel on gasoline, or E20-E25 blend, or neat ethanol (E100); or to run as a bi-fuel with natural gas (CNG).

A conventional vehicle can become a greener vehicle by mixing in renewable fuels or using less carbon intensive fossil fuel. Typical gasoline-powered cars can tolerate up to

10% ethanol. Brazil manufactured cars that run on neat ethanol, though there were discontinued. Another available option is a flexible-fuel vehicle which allows a any blend of gasoline and ethanol, up to 85% in North America and Europe, and up to 100% in Brazil. Another existing option is to convert a conventional gasoline-powered to allow the alternative use of CNG. Pakistan, Argentina, Brazil, Iran, India, Italy, and China have the largest fleets of natural gas vehicles in the world.

Diesel-powered vehicles can often transition completely to biodiesel, though the fuel is a very strong solvent, which can occasionally damage rubber seals in vehicles built before 1994. More commonly, however, biodiesel causes problems simply because it removes all of the built-up residue in an engine, clogging filters, unless care is taken when switching from dirty fossil-fuel derived diesel to bio-diesel. It is very effective at 'de-coking' the diesel engines combustion chambers and keeping them clean. Biodiesel is the lowest emission fuel available for diesel engines. Diesel engines are the most efficient car internal combustion engines. Biodiesel is the only fuel allowed in some North American national parks because spillages will completely bio-degrade within 21 days. Biodiesel and vegetable oil fuelled, diesel engined vehicles have been declared amongst the greenest in the US *Tour de Sol* competition.

This presents a problem, however, as biofuels can use food resources in order to provide mechanical energy for vehicles. Many experts point to this as a reason for growing food prices, particularly US Bio-ethanol fuel production which has affected maize prices. In order to have a low environmental impact, biofuels should be made only from waste products, or from new sources - like algae.

Other

Solar vehicle.

- Public transportation vehicles are not usually included in the green vehicle category, but Personal rapid transit (PRT) vehicles probably should be. All vehicles that are powered from the track have the advantage of potentially being able to use any source of electric energy, including sustainable ones, rather than requiring liquid fuels. They can also switch regenerative braking energy between vehicles and the electric grid rather than requiring energy storage on the vehicles. Also, they can potentially use the entire track area for solar collectors, not just the vehicle surface. The potential PRT energy efficiency is much higher than that which traditional automobiles can attain.

- Solar vehicles are electric vehicles powered by solar energy obtained from solar panels on the surface (generally, the roof) of the vehicle. Photovoltaic (PV) cells convert the Sun's energy directly into electrical energy. Solar vehicles are not practical day-to-day transportation devices at present, but are primarily demonstration vehicles and engineering exercises, often sponsored by government agencies.

- Wind-powered electric vehicles primarily use wind-turbines installed at a strategic point of the vehicle, which are then converted into electric energy which causes the vehicle to propel.

Animal powered vehicles

Horse and carriage are just one type of animal propelled vehicle. Once a common form of transportation, they became far less common as cities grew and automobiles took their place. In dense cities, the waste produced by large numbers of transportation animals was a significant health problem. Oftentimes the food is produced for them using diesel powered tractors, and thus there is some environmental impact as a result of their use.

Human powered vehicles

Vélo'v bicycle sharing system in Lyon, France.

Human powered transport includes walking, bicycles, velomobiles, row boats, and other environmentally friendly ways of getting around. In addition to the health benefits of the exercise provided, they are far more environmentally friendly than most other options. The only downside is the speed limitations, and how far one can travel before getting exhausted.

Controversy

A study by CNW Marketing Research suggests that the extra energy cost of manufacture, shipping, disposal, and the short lives of some of these types of vehicle (particularly gas-electric hybrid vehicles) outweighs any energy savings made by their using less petroleum during their useful lifespan. Critics of the report note that that the study prorated all of Toyota's hybrid research-and-development costs across the relatively small number of Priuses on the road, rather than using the incremental cost of building a vehicle; used 109,000 miles (175,000 km) for the length of life of a Prius (Toyota offers a 150,000-mile (240,000 km) warranty on the Prius' hybrid components, including the battery), and calculated that a majority of a car's cradle-to-grave energy gets expended during the vehicle's production, not while it is driven.

Norwegian Consumer Ombudsman official Bente Øverli stated that "Cars cannot do anything good for the environment except less damage than others." Based on this opinion, Norwegian law severely restricts the use of "greenwashing" to market automobiles, strongly prohibiting advertising a vehicle as being environmentally friendly, with large fines issued to violators.

Benefits of green vehicle use

Environmental

Vehicle emissions contribute to the increasing concentration of gases linked to climate change. In order of significance, the principal greenhouse gases associated with road transport are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Road transport is the third largest source of greenhouse gases emitted in the UK, and accounts for over 20% of total emissions, and 33% in the United States. Of the total greenhouse gas emissions from transport, over 85% are due to CO_2 emissions from road vehicles. The transport sector is the fastest growing source of greenhouse gases.

Road transport also remains the main source of many local emissions including benzene, 1,3-butadiene, carbon monoxide (CO), nitrogen oxides (NO_x) and particulates (PMs). Within urban areas, the percentage of contributions due to road transport is particularly high - in London road transport contributes almost 80% of particulate emissions.

Health

Vehicle pollutants have been linked to human ill health including the incidence of respiratory and cardiopulmonary disease and lung cancer. A 1998 report estimated that up to 24,000 people die prematurely each year in the UK as a direct result of air pollution. According to the World Health Organisation, up to 13,000 deaths per year among children (aged 0–4 years) across Europe are directly attributable to outdoor pollution. The organisation estimates that if pollution levels were returned to within EU limits, more than 5,000 of these lives could be saved each year.

Monetary

Many fleet operators of hybrid vehicles have reduced brake maintenance costs, through less use of brake parts due to regenerative braking. The labour costs saved from this maintenance is also significant. As much as 65% of brake related costs have been saved, according to a report by the Toronto Transit Commission.

Hybrid taxi fleet operators in New York have also reported that reduced fuel consumption saves them thousands of dollars per year, as well as reduced maintenance costs.

National and international promotion

European Union

The European Union is promoting the marketing of greener cars via a combination of binding and non-binding measures. As of April 2010, 15 of the 27 European Union member states provide tax incentives for electrically chargeable vehicles and some alternative fuel vehicles, which includes all Western European countries except Italy and Luxembourg, plus the Czech Republic and Romania. The incentives consist of tax reductions and exemptions, as well as of bonus payments for buyers of electric cars, plug-in hybrids, hybrid electric vehicles and natural gas vehicles.

United States

The United States Environmental Protection Agency (EPA) is promoting the marketing of greener cars via the SmartWay program. The SmartWay and SmartWay Elite designation mean that a vehicle is a better environmental performer relative to other vehicles. This US EPA designation is arrived at by taking into account a vehicle's Air Pollution Score and Greenhouse Gas Score. Higher Air Pollution Scores indicate vehicles that emit lower amounts of pollutants that cause smog relative to other vehicles. Higher Greenhouse Gas Scores indicate vehicles that emit lower amounts of carbon dioxide and have improved fuel economy relative to other vehicles.

To earn the SmartWay designation, a vehicle must earn at least a 6 on the Air Pollution Score and at least a 6 on the Greenhouse Gas Score, but have a combined score of at least 13. SmartWay Elite is given to those vehicles that score 9 or better on both the Greenhouse Gas and Air Pollution Scores.

A Green Vehicle Marketing Alliance, in conjunction with the ONRL, periodically meets, and coordinates marketing efforts.

Progressive Insurance Automotive X Prize

The **Progressive Insurance Automotive X PRIZE (PIAXP)** is a set of competitions, programs and events, from the X PRIZE Foundation to "inspire a new generation of super-efficient vehicles that help break America's addiction to oil and stem the effects of climate change." Progressive Insurance is the title sponsor of the prize, the centerpiece of which is the Competition Division, within which a $10 million dollar purse will be divided between the winners of three competitions.

The essence of each competition is to design, build and race super-efficient vehicles that will achieve 100 MPGe (2.35 liter/100 kilometer) and can be produced for the mass market. Within the Competition Division, there are two vehicle classes: Mainstream and Alternative. The mainstream class has a prize of $5 million. The alternate class has 2 separate prizes of $2.5 million, one for side-by-side seating and one for tandem seating.

Some of the competitors, such as Aptera and Tesla, are already taking deposits for 'green' vehicles from customers.

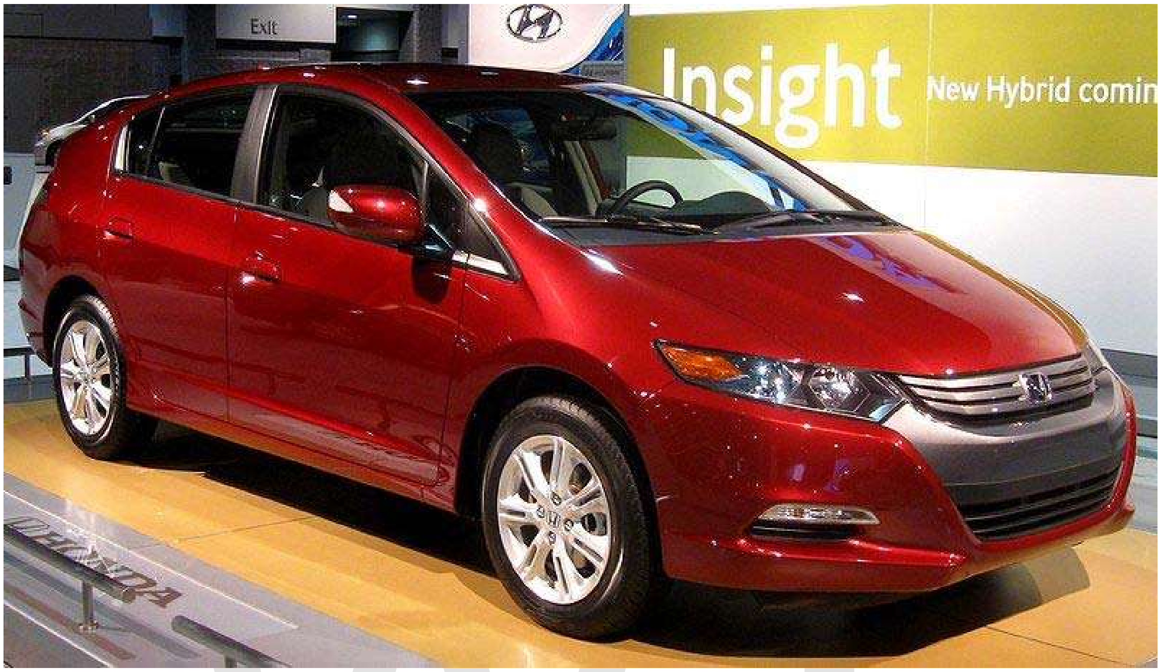
Green car rankings

VW Golf TDI clean diesel.

Honda FCX Clarity.

Toyota Prius.

Ford Fusion Hybrid.



Honda Insight.

Honda Civic GX.

Smart fortwo.

BMW MINI Cooper.

Several automobile magazines, motor vehicle specialized publications and environmental groups publish annual rankings or listings of the best green cars of a given year. The following table presents a selection of the annual top pickings.

Selected annual rankings of green cars

Vehicle	Year model	Type of vehicle/fuel	EPA Combined mileage (mpg)	EPA City mileage (mpg)	EPA Highway mileage (mpg)
Green Car Journal — Green Car of the Year					
Chevrolet Volt — 2011 Award	2011	Plug-in hybrid	Gas equivalent All-electric mode	Gasoline only mode	All-electric range
			93 mpg-e	37 mpg	35 mi

Audi A3 TDI — 2010 Award	2010	Clean diesel	33	30	41
VW Jetta TDI — 2009 Award	2009	Clean diesel	41	40	43
Green Car Journal — Green Car Vision Award					
Nissan Leaf — 2010 Award	2011	Electric car	Gasoline equivalent fuel economy		All-electric range
			99 mpg-e		73 mi
Chevrolet Volt — 2009 Award	2011	Plug-in hybrid	Gas equivalent All-electric mode	Gasoline only mode	All-electric range
			93 mpg-e	37 mpg	35 mi
World Car of the Year — World Green Car					
Volkswagen BlueMotion — 2010 Award (Golf, Passat, Polo)	2010	Clean diesel	n.a.	n.a.	n.a.
Honda FCX Clarity — 2009 Award (miles per kilogram of hydrogen)	2009	Hydrogen fuel cell	77	67	72
Consumer Reports Top Picks: Green Car Category					
Toyota Prius — Best model	2010	Hybrid	50	51	48

2010		electric			
Toyota Prius — Best model 2009	2009	Hybrid electric	46	48	45
Consumer Reports American Top Picks: Green Car Category					
Ford Fusion Hybrid — Top Pick 2010	2010	Hybrid electric	39	41	36
Ford Escape Hybrid — Top Pick 2009	2009	Hybrid electric	32	34	31
What Car? Green Awards					
Toyota Auris Hybrid — Overall Winner 2010	2010	Hybrid electric	UK combined 74 mpg$_{\text{-imp}}$ (3.8 L/100 km; 62 mpg$_{\text{-US}}$)		
Volvo S40 1.6D DRIVe S — Overall Winner 2009	2009	Clean diesel	UK combined 60 mpg$_{\text{-imp}}$ (4.7 L/100 km; 50 mpg$_{\text{-US}}$)		
Ford Focus 1.6 TDCi Style — Overall Winner 2008	2008	Clean diesel	UK combined 52 mpg$_{\text{-imp}}$ (5.4 L/100 km; 43 mpg$_{\text{-US}}$)		
American Council for an Energy-Efficient Economy Greenest Vehicles of 2010					
Honda Civic GX	2010	Natural gas	28	24	36
Toyota Prius	2010	Hybrid electric	50	51	48
Honda Civic Hybrid	2010	Hybrid electric	42	40	45

Smart fortwo (Convertible/coupe)	2010	Gasoline	36	33	41
Honda Insight	2010	Hybrid electric	41	40	43
Ford Fusion Hybrid/Mercury Milan Hybrid	2010	Hybrid electric	39	41	36
Toyota Yaris (manual)	2010	Gasoline	n.a.	29	36
Nissan Altima Hybrid	2010	Hybrid electric	34	35	33
MINI Cooper (manual)	2010	Gasoline	32	28	37
Chevrolet Cobalt (X-tra Fuel Economy) (XFE)	2010	Gasoline	30	25	37
Hyundai Accent BLUE	2010	Gasoline	31	27	36
Honda Fit automatic	2010	Gasoline	31	28	35
Mother Earth News Best Green Cars of 2010					
Ford Fusion Hybrid	2010	Hybrid electric	39	41	36
Honda Civic Hybrid	2010	Hybrid electric	42	40	45
Honda Insight	2010	Hybrid	41	40	43

		electric			
Toyota Prius	2010	Hybrid electric	50	51	48
VW Golf TDI	2010	Clean diesel	34	30	42
VW Jetta TDI	2010	Clean diesel	41	40	43
Kelley Blue Book Top 10 Green Cars for 2010					
Toyota Prius	2010	Hybrid electric	50	51	48
Honda Insight	2010	Hybrid electric	41	40	43
Ford Fusion Hybrid	2010	Hybrid electric	39	41	36
VW Golf TDI	2010	Clean diesel	34	30	42
MINI Cooper	2010	Gasoline	32	28	37
Ford Escape Hybrid	2010	Hybrid electric	32	34	31
Honda Fit	2010	Gasoline	31	28	34
BMW 355d	2010	Clean diesel	27	23	36
Toyota Highlander Hybrid	2010	Hybrid electric	26	27	25

Chevrolet Silverado Hybrid	2010	Hybrid electric	21	21	22

Green vehicle motor shows

Dedicated electric and green vehicle motor shows:

- Alternative Vehicle and Fuel Show (AVFS), Fair of Valladolid, Spain, in November.
- Green Fleet Expo, Royal Botanical Gardens (Ontario), in May.
- Green-Car-Guide Live!, Arena and Convention Centre in Liverpool, in June
- European Electric Motor Show, Helsinki Exhibition & Convention Centre, in November

Chapter- 3

Low-Energy Vehicle

A **Low-energy vehicle** is any type of vehicle that uses *less energy* than a regular fossil fuel vehicle.

Higher efficiency can be achieved by changing the vehicle's design, and/or by modifying its powertrain. Energy consumption as low as 5-12.5 kWh/100 km (180-450 kJ/km) is achieved directly by battery electric microcars. When comparing the efficiency of electric cars with IC cars the efficiency of the power generation has to be considered, for example the distribution efficiency for Europe is about 40%, so the overall energy consumption of electric cars lies in the range 0.45 to 1.1 MJ/km. (Average energy efficiency of US plants 33% US DOE (ref to follow) US grid transmission loss 9.5%, UK grid transmission loss 7.4 - transmission losses not included in electric car efficiency figure.) By the year 2050, consumption levels of 1.6 l/100 km (0.64 MJ/km) in diesel-fuelled cars and 2 l/100 km (0.7 MJ/km) in petrol-fuelled cars are deemed feasible. The energy consumption figures for petrol and diesel cars also need to be increased by 18% to represent the oil used in processing and distributing oil-based fuel, to 0.75 MJ/km for diesel, and 0.82 MJ/km for petrol.

To put these consumption figures into perspective a consumption of 1000 km/litre (2350 mpg US) is 0.0344 MJ/km, excluding distribution energy. At 20 km/h it would take 50 hours to travel 1000 km, so with a 20% efficient internal combustion engine it would need to attain and keep this speed using just 38.2 watts.

Motivation

3 l-vehicle courtesy Greenfleet

LEV Twike

Reducing global energy demand might help to reduce access conflicts over oil reserves and/or environmental damage when trying to produce fuel from natural or other fossil sources. Existing published consumption figures tend to underestimate the consumption seen in practice by 20 to 30%. The reason is partly that the official fuel consumption tests are not sufficiently representative of real world usage. Auto makers optimise their fuel consumption strategies in order to reduce the apparent cost of ownership of the cars, and to improve their green image. Even one of the most fuel efficient two seater on the market - the Smart MHD consumes two or three times more energy per km than a cabin based ultralight two seater would - proven by the 1l prototype by VW. Pilot vehicles have proven that a feasible target may lie in the range of 1-2 l/100 km, or lower, or 10 kWh/100 km electricity. Available electric LEVs already use substantially less energy than available cars, e.g. 4–8 kW·h/100 km for the Twike,. Here the challenges are increasing range and lifetime of batteries, crash worthiness, passenger comfort, performance and reducing the price (which is currently about twice that of a cheap conventional **four** seater).

Energy Efficiency in MJ per km or kWh per 100 km: It is more straightforward to express energy efficiency in MJ (Mega-Joule) per km because terms like MPG (Miles Per Gallon) and litres per 100 km do not take into account what type of fuel is used and thus the numbers will be distorted for different fuel types. Diesel contains 38.7MJ per litre, Gasoline 34.6MJ per litre and Bio-Diesel 30.5MJ per litre, whereas LPG contains only 22.2MJ per liter which is why the number of litres consumed go up drastically when converting a gasoline car to LPG. This does not mean that the energy consumption goes up; it only means that there is less energy in a litre of LPG. Ethanol also contains much less energy per litre than gasoline. To compare electricity and gasoline its easier to use kWh/100 km since 1l gasoline holds around 10kWh.

Physical background

Energy demand may be kept low by:

- lower parasitic masses (compared to the average load) causing low energy demand in transitional operation (stop and go operation in the cities) $P_{accel} = m_{vehicle} \cdot a \cdot v$ where P stands for power, $m_{vehicle}$ for the total vehicle mass, a for the vehicle's acceleration and v for the vehicle's velocity. Extreme masses will go down to 300 kg from today's 1100 kg to 1600 kg. Five seaters of the sixties had 625 kg. Japanese sub-compact cars have 500-600 kg. Further mass reduction is possible by adapting the maximum number of passengers to the average occupancy rate and having removable seats. Two-seater microcars have less than 400 kg, single-seaters less than 300 kg. Further reductions are possible with very light construction, e.g. Twike. The crash protection is certainly a problem in current traffic conditions, but the low energy vehicles are driven mainly at low velocities in cities.

- low cross-sectional area and mirrors replaced by cameras causing very low drag losses especially when driven at higher speed $F_{drag} = A_{cross} \cdot C_d \cdot \frac{v_{air}^2 \rho_{air}}{2}$ where F stands for the force, A_{cross} for the cross-sectional area of the vehicle, ρ_{air} for the density of the air and v_{air} for the relative velocity of the air (incl. wind). Two seating places in a tandem (back to back or forward facing in line) arrangement drastically reduce the cross-sectional area down to 1 m². The drag coefficient C_d of the vehicle may be as low as 0.15 for very good vehicles.
- low rolling resistance due to smaller and high pressure tires with optimised tread and low vehicle mass driving the rolling resistance $F_{roll} = \mu_{roll} \cdot m_{vehicle} \cdot g$ where μ_{roll} stands for the rolling resistance coefficient, g for acceleration due to gravity and $m_{vehicle}$ for the vehicle mass. Advanced driver assistance and ABS could prevent safety problems caused by the small tires, but current light weight vehicles do not possess these systems. Values of μ_{roll} down to 0.0025 are possible but are more usually 0.005 to 0.008 for cycle-type tires and 0.010 to 0.015 for car tires.

Technological support for low energy operation may also come from driver assistance systems since driving style can be adapted to achieve lower energy consumption. Energy management becomes possible with hybrid vehicles with the possibility to recuperate braking energy and to operate the internal combustion engine (ICE) at higher efficiency on average. Hybrid power trains may also reduce the ICE-engine size thus increasing the average load factor and minimising the part load losses. Purely electric vehicles use up to 10 x less energy (0,3 to 0,5MJ/km) than those with combustion engines (3 to 5MJ/km and up to 10MJ/km for SUVs) because of the much higher motor and battery efficiencies.

Size and performance of various vehicles

Average data for vehicle types sold in the U.S.A. compared to an advanced vehicle concept, the Honda Insight:

Type	Width	Height	Curb weight	Combined fuel economy	Percent	Occupancy rate 2005 Florida
Minivans	75.9 in 193 cm	70.2 in 178 cm	4275 lb 1939 kg	20.36 mpg 11.55 l/100 km	309%	1.67
Family sedans	70.3 in 179 cm	57.3 in 146 cm	3144 lb 1426 kg	26.94 mpg 8.73 l/100 km	234%	1.35
SUVs	73.5 in 187 cm	70.7 in 180 cm	4242 lb 1924 kg	19.19 mpg 12.25 l/100 km	328%	(1.35 light trucks)
Honda Insight	66.7 in 169 cm	53.3 in 135 cm	1850 lb 839 kg	63 mpg 3.73 l/100 km	100%	n.a.
Toyota Prius	66.7 in 169 cm	57.6 in 146 cm	2765 lb 1254 kg	56 mpg 4.2 l/100 km	112%	n.a
Audi A2	65.9 in 167 cm	61.1 in 155 cm	1973 lb 895 kg	71 mpg 3 l/100 km	81%	n.a.
GM Volt	70.8 in 180 cm	56.3 in 143 cm	3790 lb 1720 kg	60 mpg 4 l/100 km	105%	n.a.

The drag resistance for an SUV, compared with a family sedan with the same drag coefficient, is approximately 30% higher, and its increased mass means that the acceleration forces has to be 35% bigger for a given acceleration. This gives a 40% increase in fuel consumption. The last column in the table demonstrates that with the exception of the Prius and the pick-ups all the alternatives have roughly the same potential fuel usage per passenger IF they were fully occupied. However the fuel usage per passenger really depends on the occupancy rate of each type. In 2000 the occupancy rate was only 1.6 in practice, decreasing each year, averaged across all vehicle types and journey types, and 1.2 for commuting.

Outlook

In the near future several low energy vehicles may be in production.

- Aptera Motors 2e with three wheels, a claimed C_d of 0.15, and a claimed energy usage of 6 kWh/100 km, is due in 2010.
- VW's 1l car
- Daihatsu UFE-III

Buying Behaviour

Whilst in many countries fuel efficiency is regulated (USA, Japan, Taiwan, South Korea, China) by law, in others there is a non perfect market, where producers tend to avoid prominence of high consumption figures in ads and thus make the procurement decisions less fact based. It is one of the reasons that energy efficient vehicles were not establishing themselves on the market in high volumes. Literature also sees higher child occupancy with SUVs. Reasons for the buying behavior are:

- Low fuel cost
- Sizing on the safe side
- Marketing driven buying
- Misconceptions

Low fuel cost

In some countries fuel cost is very relevant but not the main cost (11,000 km at 8l/100 km and 1€/l gives 73€/month only). This is lower than the investment costs per month for younger cars and leads to heavier usage of the vehicle. The technical term is least cost optimisation. If the cost operating the vehicle one km more is small then there is the tendency with the user to choose the car instead of public transport.

Sizing (Vehicle/Engine) on the safe side

If you are unsure about the final size of your family or the distances you normally drive you want to be on the safe side. Because of the big annuity or leasing rate, people tend to plan in advance and buy bigger cars.

Marketing driven buying

There is an effect on purchasing decisions (exclusive of rational considerations, emotionally laden, and influenced by perceptions of luxury appointments or particular performance features) which is deliberately aimed at by much vehicle advertising . This may be seen in the marketing campaigns of many (perhaps most) vehicle marques. To avoid giving the potential customer information on which to base a more rational decision, the ads contain only marketing emphasis as desired by the marketing department concerned. These advertisements also typically bypass any discussion of pollution or of greenhouse gas emissions.

Effect of vehicle size and engine power

Vehicles with a higher number of seats have a better fuel economy if they are fully occupied. But you don't save fuel if you drive an SUV commuting to work alone, equally, you don't save fuel if you all drive separately to the same work in hybrids. The logic leads immediately to the coach or bus public transport because here the average occupancy rate in operation (in % of the seating capacity) is much higher than for the average SUV or Minivan because its a public system. Rideshare experience is very bad because of the reluctance of people to enter someone else's car. It has also to be said that the image build up for minivans has pushed back older vehicle concepts equipping estate vehicles with a third seat row. This way you avoid the high mass and big height of a minivan. Other statements often heard are:

- *A stronger engine consumes less petrol because it works under less stress*
- *Heavier vehicles are safer*

The fuel consumption of an engine is depicted as a 3dimensional map where the consumption is shown against RPM and torque. Normally the smallest consumption is seen in the upper middle part of the diagram. For diesel engines this region is bigger to lower torque and extends to higher RPM. The choice of engine power for a given vehicle should consider the typical application - for non transient low velocity operation this leads to lower power requirements, at the cost of reduced acceleration and top speed. A hybrid electric concept allows an even lower power internal combustion engine, but the added weight pays only off if operating in stop and go conditions frequently or generally at low power, if using a series hybrid electric concept.

In a collision the occupants of a heavy vehicle will, on average, suffer fewer and less serious injuries than the occupants of a lighter vehicle. An accident in a 2000 lb (900 kg) vehicle will on average cause about 50% more injuries to its occupants than a 3000 lb (1350 kg) vehicle.

Fleet Management and Low Energy Consumption

The EU- sponsored RECODRIVE project has set up a quality circle to manage low energy consumption in fleets. This starts with energy aware procurement, and includes fuel management, driver information and training and incentives for all staff involved in the fleet management and maintenance process. Vehicle equipped with gear shift indicators, tire pressure monitoring systems and downsized internal combustion engines and for stop'n go operation also hybrid electric power trains will help to save fuel.

Chapter- 4

Alternative Fuel Vehicle

Toyota Prius, a hybrid vehicle. Museum of Toyota of Aichi Prefecture, Japan.

Typical Brazilian filling station with four alternative fuels for sale: biodiesel (B3), gasohol (E25), neat ethanol (E100), and compressed natural gas (CNG). Piracicaba, Brazil.

An **alternative fuel vehicle** is a vehicle that runs on a fuel other than "traditional" petroleum fuels (petrol or diesel); and also refers to any technology of powering an engine that does not involve solely petroleum (e.g. electric car, hybrid electric vehicles, solar powered). Because of a combination of factors, such as environmental concerns, high oil prices and the potential for peak oil, development of cleaner alternative fuels and advanced power systems for vehicles has become a high priority for many governments and vehicle manufacturers around the world.

Hybrid electric vehicles such as the Toyota Prius are not actually alternative fuel vehicles, but through advanced technologies in the electric battery and motor/generator, they make a more efficient use of petroleum fuel. Other research and development efforts in alternative forms of power focus on developing all-electric and fuel cell vehicles, and even the stored energy of compressed air.

As of July 2010 more than 40 million alternative fuel and advanced technology vehicles have been sold worldwide, compared to around 900 million cars and light trucks in use in the world in 2009. This alternative fuel fleet is made up mainly of:

- 20.7 million flexible-fuel vehicles by mid 2010, led by Brazil with 10.6 million, followed by the United States with 9.3 million, Canada (600,000), and Europe, led by Sweden (199,004). Additionally, 183,375 flexible-fuel motorcycles were sold in Brazil in 2009.

- 11.2 million natural gas vehicles by 2009, led by Pakistan with 2.4 million, Argentina (1.8 million), Iran (1.7 million), Brazil (1.6 million), and India (725 thousand).
- Between 2.4 to 3.0 million neat-ethanol vehicles still in use in Brazil, out of 5.7 million ethanol only light-vehicles produced since 1979.
- More than 3.1 million hybrid electric vehicles sold by mid 2010, led by the United States with almost 1.8 million units, followed by Japan with more than 1.1 million and Europe with around 250 thousand. Worldwide, Toyota Motor Company is the leader with 2.68 million hybrids sold by July 2010, followed by Honda Motor Co., Ltd. with more than 300 thousand hybrids sold by January 2009, and Ford Motor Corporation with more than 140 thousand hybrids sold by June 2010.

Single fuel source

Air engine

The air engine is an emission-free piston engine that uses compressed air as a source of energy. The first compressed air car was invented by a French engineer named Guy Nègre. The expansion of compressed air may be used to drive the pistons in a modified piston engine. Efficiency of operation is gained through the use of environmental heat at normal temperature to warm the otherwise cold expanded air from the storage tank. This non-adiabatic expansion has the potential to greatly increase the efficiency of the machine. The only exhaust is cold air (−15 °C), which could also be used to air condition the car. The source for air is a pressurized carbon-fiber tank. Air is delivered to the engine via a rather conventional injection system. Unique crank design within the engine increases the time during which the air charge is warmed from ambient sources and a two stage process allows improved heat transfer rates.

Battery-electric

The Henney Kilowatt, the first modern (transistor-controlled) electric car. Based on a Renault Dauphine

General Motors EV1 electric car.

Battery electric vehicles (BEVs), also known as all-electric vehicles (AEVs), are electric vehicles whose main energy storage is in the chemical energy of batteries. BEVs are the most common form of what is defined by the California Air Resources Board (CARB) as zero emission (ZEV) passenger automobiles, because they produce no tailpipe emissions while being driven. The electrical energy carried onboard a BEV to power the motors is obtained from a variety of battery chemistries arranged into battery packs. For additional range genset trailers or pusher trailers are sometimes used, forming a type of hybrid vehicle. Batteries used in electric vehicles include "flooded" lead-acid, absorbed glass mat, NiCd, nickel metal hydride, Li-ion, Li-poly and zinc-air batteries.

Attempts at building viable, modern battery-powered electric vehicles began in the 1950s with the introduction of the first modern (transistor controlled) electric car - the Henney Kilowatt,even though the concept was out in the market since 1890. Despite the poor sales of the early battery-powered vehicles, development of various battery-powered vehicles continued through the 1960 (notably General Motors with the SATURN EV1), but cost, speed and inadequate driving range continued to make them impractical. Battery powered cars have primarily used lead-acid batteries and NiMH batteries. Lead-acid batteries' recharge capacity is considerably reduced if they're discharged beyond 75% on a regular basis, making them a less-than-ideal solution. NiMH batteries are a better choice, but are considerably more expensive than lead-acid. Lithium-ion battery powered vehicles such as the Venturi Fetish have recently demonstrated excellent performance and range, but they remain very expensive.

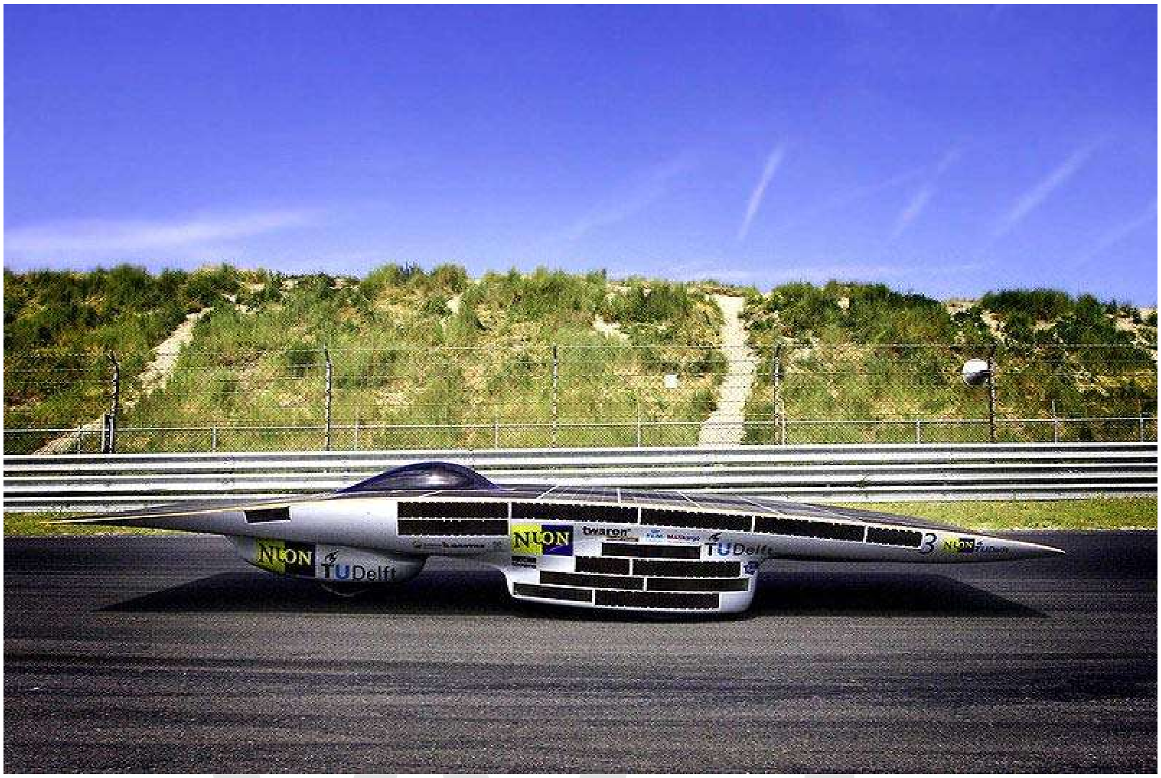
The 2011 Nissan Leaf, introduced in Japan and the U.S. in December 2010, is the world's first mass production 100% electric car for sale from a major manufacturer.

As of December 2010, several neighborhood electric vehicles, city electric cars and highway-capable electric cars are available in several countries, including the Tesla Roadster, REVAi, Buddy, Th!nk City, Mitsubishi i MiEV, and Nissan Leaf. Due to the premium price of electric cars because of the high cost of the battery pack, several countries and local governments have established tax credits and other incentives for early buyers of electric vehicles.

Other models expected to reach the market between 2011 and 2012 include the Wheego Whip LiFe, CODA Sedan, REVA NXR, Renault Fluence Z.E., Ford Focus BEV, Hyundai BlueOn, Tesla Model S, and BMW Active E. There are also several pre-production models and plug-in conversions of existing models that are currently undergoing field trials or are part of demonstration programs including the Mini E, Smart ED, BYD e6, Audi A1 e-tron andVolvo C30 DRIVe Electric.

Solar

Nuna team at a racecourse.



Nuna solar powered car, which has travelled up to 140km/h (84mph).

A solar car is an electric vehicle powered by solar energy obtained from solar panels on the car. Solar panels cannot currently be used to directly supply a car with a suitable amount of power at this time, but they can be used to extend the range of electric vehicles. They are raced in competitions such as the World Solar Challenge and the North American Solar Challenge. These events are often sponsored by Government agencies such as the United States Department of Energy keen to promote the development of alternative energy technology such as solar cells and electric vehicles. Such challenges are often entered by universities to develop their students engineering and technological skills as well as motor vehicle manufacturers such as GM and Honda.

Trev's battery lasts over 250,000 kilometres.

The North American Solar Challenge is a solar car race across North America. Originally called Sunrayce, organized and sponsored by General Motors in 1990, it was renamed American Solar Challenge in 2001, sponsored by the United States Department of Energy and the National Renewable Energy Laboratory. Teams from universities in the United States and Canada compete in a long distance test of endurance as well as efficiency, driving thousands of miles on regular highways.

Nuna is the name of a series of manned solar powered vehicles that won the World solar challenge in Australia three times in a row, in 2001 (Nuna 1 or just Nuna), 2003 (Nuna 2) and 2005 (Nuna 3). The Nunas are built by students of the Delft University of Technology.

The World solar challenge is a solar powered car race over 3,021 kilometres (1,877 mi) through central Australia from Darwin to Adelaide. The race attracts teams from around the world, most of which are fielded by universities or corporations although some are fielded by high schools.

Trev (two-seater renewable energy vehicle) was designed by the staff and students at the University of South Australia. Trev was first displayed at the 2005 World Solar Challenge as the concept of a low-mass, efficient commuter car. With 3 wheels and a mass of about 300 kg, the prototype car had maximum speed of 120 km/h and acceleration of 0–100 km/h in about 10 seconds. The running cost of Trev is projected to be less than 1/10 of the running cost of a small petrol car.

Ammonia fuelled vehicles

Ammonia GreenNH3 is being used with success by developers in Canada , since it can run in spark ignited or diesel engines with minor modifications,also the only green fuel to power jet engines,, and despite its toxicity is reckoned to be no more dangerous than petrol or LPG. It can be made from renewable electricity, and having half the density of petrol or diesel can be readily carried in sufficient quantities in vehicles. On combustion it has no emissions other than nitrogen and water vapour.The Canadian group GreenGas dot cc have developed a machine to make the GreenNH3 from zero carbon energy sources so as not to have any link to carbon. That would be as opposed to brownNH3 which can be made from carbon things like coal or natural gas.

Biofuels

Bioalcohol / Ethanol

The Ford Model T was the first commercial flex-fuel vehicle. The engine was capable of running on gasoline or ethanol, or a mix of both.

The 1996 Ford Taurus was the first flexible-fuel vehicle produced with versions capable of running with either ethanol (E85) or methanol (M85) blended with gasoline.

The 2003 VW Gol 1.6 Total Flex was the first commercial flexible-fuel vehicle in the Brazilian market, capable of running on any mixture of gasoline (E20 to E25 blend) and ethanol (E100).

The first commercial vehicle that used ethanol as a fuel was the Ford Model T, produced from 1908 through 1927. It was fitted with a carburetor with adjustable jetting, allowing use of gasoline or ethanol, or a combination of both. Other car manufactures also provided engines for ethanol fuel use. In the United States, alcohol fuel was produced in corn-alcohol stills until Prohibition criminalized the production of alcohol in 1919. The use of alcohol as a fuel for internal combustion engines, either alone or in combination with other fuels, lapsed until the oil price shocks of the 1970s. Furthermore, additional attention was gained because of its possible environmental and long-term economical advantages over fossil fuel.

Both ethanol and methanol have been use as an automotive fuel. While both can be obtained from petroleum or natural gas, ethanol has attracted more attention because it is considered a renewable resource, easily obtained from sugar or starch in crops and other agricultural produce such as grain, sugarcane, sugar beets or even lactose. Since ethanol occurs in nature whenever yeast happens to find a sugar solution such as overripe fruit, most organisms have evolved some tolerance to ethanol, whereas methanol is toxic.

Other experiments involve butanol, which can also be produced by fermentation of plants. Support for ethanol comes from the fact that it is a biomass fuel, which addresses climate change and greenhouse gas emissions, though these benefits are now highly debated, including the heated 2008 food vs fuel debate.

Ethanol has the property of slowly decomposing certain rubber compounds such as are found in the fuel lines and seals used in vehicles produced before the mid 1980s. Also, because gasoline is more volatile than ethanol, it can be harder to start some engines using higher ethanol percentages than they were designed to use, especially when the engine is cold during the winter. Ethanol is also electrically conductive (gasoline is an effective insulator) which can cause problems with some early electric fuel pump designs and fuel tank sensors. Corrosion of magnesium and aluminium parts is also a concern at higher ethanol percentages. Most modern cars are designed to run on gasoline are capable of running with a blend from 10% up to 15% ethanol mixed into gasoline (E10-E15). With a small amount of redesign, gasoline-powered vehicles can run on ethanol concentrations as high as 85% (E85), the maximum set in the United States and Europe due to cold weather during the winter, or up to 100% (E100) in Brazil, with a warmer climate. Ethanol has close to 34% less energy per volume than gasoline, consequently fuel economy ratings with ethanol blends are significantly lower than with pure gasoline, but this lower energy content does not translate directly into a 34% reduction in mileage, because there are many other variables that affect the performance of a particular fuel in a particular engine, and also because ethanol has a higher octane rating which is beneficial to high compression ratio engines.

For this reason, for pure or high ethanol blends to be attractive for users, its price must be lower than gasoline to offset the lower fuel economy. As a rule of thumb, Brazilian consumers are frequently advised by the local media to use more alcohol than gasoline in their mix only when ethanol prices are 30% lower or more than gasoline, as ethanol price fluctuates heavily depending on the results and seasonal harvests of sugar cane and by region. In the US, and based on EPA tests for all 2006 E85 models, the average fuel economy for E85 vehicles was found 25.56% lower than unleaded gasoline. The EPA-rated mileage of current American flex-fuel vehicles could be considered when making price comparisons, though E85 has octane rating of about 104 and could be used as a substitute for premium gasoline. Regional retail E85 prices vary widely across the US, with more favorable prices in the Midwest region, where most corn is grown and ethanol produced. In August 2008 the US average spread between the price of E85 and gasoline was 16.9%, while in Indiana was 35%, 30% in Minnesota and Wisconsin, 19% in Maryland, 12 to 15% in California, and just 3% in Utah. Depending of the vehicle capabilities, the break even price of E85 usually has to be between 25 to 30% lower than gasoline.

E85 fuel sold at a regular gasoline station in Washington, D.C..

Reacting to the high price of oil and its growing dependence on imports, in 1975 Brazil launched the Pro-alcool program, a huge government-subsidized effort to manufacture ethanol fuel (from its sugar cane crop) and ethanol-powered automobiles. These ethanol-only vehicles were very popular in the 1980s, but became economically impractical when oil prices fell - and sugar prices rose - late in that decade. In May 2003 Volkswagen built for the first time a commercial ethanol flexible fuel car, the Gol 1.6 Total Flex. These vehicles were a commercial success and by early 2009 other nine Brazilian manufacturers are producing flexible fuel vehicles: Chevrolet, Fiat, Ford, Peugeot, Renault, Honda, Mitsubishi, Toyota, Citroën, and Nissan. The adoption of the flex technology was so rapid, that flexible fuel cars reached 87.6% of new car sales in July 2008. As of August 2008, the fleet of "flex" automobiles and light commercial vehicles had reached 6 million new vehicles sold, representing almost 19% of all registered light vehicles. The rapid success of "flex" vehicles, as they are popularly known, was made possible by the existence of 33,000 filling stations with at least one ethanol pump available by 2006, a heritage of the *Pro-alcool* program.

In the United States, initial support to develop alternative fuels by the government was a also response to the 1973 oil crisis, and later on, as a goal to improve air quality. Also, liquid fuels were preferred over gaseous fuels not only because they have a better volumetric energy density but also because they were the most compatible fuels with existing distribution systems and engines, thus avoiding a big departure from the existing technologies and taking advantage of the vehicle and the refueling infrastructure. California led the search of sustainable alternatives with interest in methanol. In 1996, a new FFV Ford Taurus was developed, with models fully capable of running either methanol or ethanol blended with gasoline. This ethanol version of the Taurus was the first commercial production of a E85 FFV. The momentum of the FFV production programs at the American car companies continued, although by the end of the 90's, the emphasis was on the FFV E85 version, as it is today. Ethanol was preferred over methanol because there is a large support in the farming community and thanks to government's incentive programs and corn-based ethanol subsidies. Sweden also tested both the M85 and the E85 flexifuel vehicles, but due to agriculture policy, in the end emphasis was given to the ethanol flexifuel vehicles.

Biodiesel

Bus running on soybean biodiesel

Biodiesel (B20) pump in the U.S.

The main benefit of Diesel combustion engines is that they have a 44% fuel burn efficiency; compared with just 25-30% in the best gasoline engines. In addition diesel fuel has slightly higher Energy Density by volume than gasoline. This makes Diesel engines capable of achieving much better fuel economy than gasoline vehicles.

Biodiesel (Fatty acid methyl ester), is commercially available in most oilseed-producing states in the United States. As of 2005, it is somewhat more expensive than fossil diesel, though it is still commonly produced in relatively small quantities (in comparison to petroleum products and ethanol). Many farmers who raise oilseeds use a biodiesel blend in tractors and equipment as a matter of policy, to foster production of biodiesel and raise public awareness. It is sometimes easier to find biodiesel in rural areas than in cities.

Biodiesel has lower Energy Density than fossil diesel fuel, so biodiesel vehicles are not quite able to keep up with the fuel economy of a fossil fuelled diesel vehicle, if the diesel injection system is not reset for the new fuel. If the injection timing is changed to take account of the higher Cetane value of biodiesel, the difference in economy is negligible. Because biodiesel contains more oxygen than diesel or vegetable oil fuel, it produces the lowest emissions from diesel engines, and is lower in most emissions than gasoline engines. Biodiesel has a higher lubricity than mineral diesel and is an additive in European pump diesel for lubricity and emissions reduction.

Some Diesel-powered cars can run with minor modifications on 100% pure vegetable oils. Vegetable oils tend to thicken (or solidify if it is waste cooking oil), in cold weather conditions so vehicle modifications (a two tank system with diesel start/stop tank), are essential in order to heat the fuel prior to use under most circumstances. Heating to the temperature of engine coolant reduces fuel viscosity, to the range cited by injection system manufacturers, for systems prior to 'common rail' or 'unit injection (VW PD)' systems. Waste vegetable oil, especially if it has been used for a long time, may become hydrogenated and have increased acidity. This can cause the thickening of fuel, gumming in the engine and acid damage of the fuel system. Biodiesel does not have this problem, because it is chemically processed to be PH neutral and lower viscosity. Modern low emission diesels (most often Euro -3 and -4 compliant), typical of the current production in the European industry, would require extensive modification of injector system, pumps and seals etc. due to the higher operating pressures, that are designed thinner (heated) mineral diesel than ever before, for atomisation, if they were to use pure vegetable oil as fuel. Vegetable oil fuel is not suitable for these vehicles as they are currently produced. This reduces the market as increasing numbers of new vehicles are not able to use it. However, the German Elsbett company has successfully produced single tank vegetable oil fuel systems for several decades, and has worked with Volkswagen on their TDI engines. This shows that it is technologically possible to use vegetable oil as a fuel in high efficiency / low emission diesel engines.

Greasestock is an event held yearly in Yorktown Heights, New York, and is one of the largest showcases of vehicles using waste oil as a biofuel in the United States.

Biogas

Compressed Biogas may be used for Internal Combustion Engines after purification of the raw gas. The removal of H2O, H2S and particles can be seen as standard producing a gas which has the same quality as Compressed Natural Gas. The use of biogas is particularly interesting for climates where the waste heat of a biogas powered power plant cannot be used during the summer.

Charcoal

In the 1930s Tang Zhongming made an invetion of using abundant Charcoal resources for Chinese auto market.The Charcoal-fuelled car was later used intensively in China,serving the army and conveyancer after the breakout of WWII.

CNG Compressed Natural Gas

The Brazilian Fiat Siena Tetrafuel 1.4, the first multifuel car that runs as a flexible-fuel on pure gasoline, or E25, or E100; or runs as a bi-fuel with natural gas (CNG).

High pressure compressed natural gas, mainly composed of methane, that is used to fuel normal combustion engines instead of gasoline. Combustion of methane produces the least amount of CO_2 of all fossil fuels. Gasoline cars can be retrofitted to CNG and become bifuel NGV Natural gas vehicles as the gasoline tank stays. You can switch between CNG and gasoline during operation. Natural gas vehicles (NGVs) are popular in regions or countries where natural gas is abundant. Widespread use began in the Po River Valley of Italy, and later became very popular in New Zealand by the eighties, though its use has declined.

Buses powered with CNG are common in the United States.

As of 2009 there were 11,2 million natural gas vehicles by 2009, led by Pakistan with 2.4 million, Argentina (1.8 million), Iran (1.7 million), Brazil (1.6 million), and India (725 thousand). with South America leading the global market with a share of 39%. In Europe they are popular in Italy (580,000), Ukraine (200,000), Russia (100,000) and Germany (85,000), and they are becoming more so as various manufacturers produce factory made cars, buses, vans and heavy vehicles. In the United States CNG powered buses are the favorite choice of several public transit agencies, with an estimated CNG bus fleet of some 130,000. Other countries where CNG-powered buses are popular include India, Australia, Argentina, and Germany.

CNG vehicles are common in South America, where these vehicles are mainly used as taxicabs in main cities of Argentina and Brazil. Normally, standard gasoline vehicles are retrofitted in specialized shops, which involve installing the gas cylinder in the trunk and the CNG injection system and electronics. The Brazilian GNV fleet is concentrated in the cities of Rio de Janeiro and São Paulo.

In 2006 the Brazilian subsidiary of FIAT introduced the Fiat Siena Tetra fuel, a four-fuel car developed under Magneti Marelli of Fiat Brazil. This automobile can run on 100% ethanol (E100), E25 (Brazil's normal ethanol gasoline blend), pure gasoline (not available in Brazil), and natural gas, and switches from the gasoline-ethanol blend to CNG automatically, depending on the power required by road conditions. Other existing option is to retrofit an ethanol flexible-fuel vehicle to add a natural gas tank and the corresponding injection system. Some taxicabs in São Paulo and Rio de Janeiro, Brazil, run on this option, allowing the user to choose among three fuels (E25, E100 and CNG) according to current market prices at the pump. Vehicles with this adaptation are known in Brazil as "tri-fuel" cars.

Hydrogen

The 2009 Honda FCX Clarity is an hydrogen fuel cell automobile launched to the market in 2008.

Hydrogen fueling station in California.

Sequel, a hydrogen fuel cell-powered vehicle from General Motors.

A hydrogen car is an automobile which uses hydrogen as its primary source of power for locomotion. These cars generally use the hydrogen in one of two methods: combustion or fuel-cell conversion. In combustion, the hydrogen is "burned" in engines in fundamentally the same method as traditional gasoline cars. In fuel-cell conversion, the hydrogen is turned into electricity through fuel cells which then powers electric motors. With either method, the only byproduct from the spent hydrogen is water.

Honda introduced its fuel cell vehicle in 1999 called the FCX and have since then introduced the second generation FCX Clarity. Limited marketing of the FCX Clarity, based on the 2007 concept model, began in June 2008 in the United States, and it was introduced in Japan in November 2008. The FCX Clarity is available in the U.S. only in Los Angeles Area, where 16 hydrogen filling stations are available, and until July 2009, only 10 drivers have leased the Clarity for US$600 a month. Honda stated that it could start mass producing vehicles based on the FCX concept by the year 2020.

A small number of prototype hydrogen cars currently exist, and a significant amount of research is underway to make the technology more viable. The common internal combustion engine, usually fueled with gasoline (petrol) or diesel liquids, can be converted to run on gaseous hydrogen. However, the most efficient use of hydrogen involves the use of fuel cells and electric motors instead of a traditional engine. Hydrogen reacts with oxygen inside the fuel cells, which produces electricity to power the motors. One primary area of research is hydrogen storage, to try to increase the range of hydrogen vehicles while reducing the weight, energy consumption, and complexity of the storage systems. Two primary methods of storage are metal hydrides and compression. Some believe that hydrogen cars will never be economically viable and that the emphasis on this technology is a diversion from the development and popularization of more efficient hybrid cars and other alternative technologies.

High speed cars, buses, motorcycles, bicycles, submarines, and space rockets already run on hydrogen, in various forms. There is even a working toy model car that runs on solar power, using a reversible fuel cell to store energy in the form of hydrogen and oxygen gas. It can then convert the fuel back into water to release the solar energy.

BMW's Clean Energy internal combustion hydrogen car has more power and is faster than hydrogen fuel cell electric cars. A limited series production of the 7 Series Saloon was announced as commencing at the end of 2006. A BMW hydrogen prototype (H2R) using the driveline of this model broke the speed record for hydrogen cars at 300 km/h (186 mi/h), making automotive history. Mazda has developed Wankel engines to burn hydrogen. The Wankel uses a rotary principle of operation, so the hydrogen burns in a different part of the engine from the intake. This reduces pre-detonation, a problem with hydrogen fueled piston engines.

The other major car companies like Daimler, Chrysler, Honda, Toyota, Ford and General Motors, are investing in hydrogen fuel cells instead. VW, Nissan, and Hyundai/Kia also have fuel cell vehicle prototypes on the road. In addition, transit agencies across the globe are running prototype fuel cell buses. Fuel cell vehicles, such as the new Honda Clarity, can get up to 70 miles (110 km) on a kilogram of hydrogen (roughly equivalent to a gallon of gasoline.)

Oxyhydrogen

Oxyhydrogen is another fuel that can be used in existing internal combustion engines (originally developed for using gasoline). This allows the engine to eliminate emissions, although fuel efficiency is reduced rather than improved (since the energy required to split water exceeds the energy recouped by burning it).

Liquid nitrogen car

Liquid nitrogen (LN2) is a method of storing energy. Energy is used to liquify air, and then LN2 is produced by evaporation, and distributed. LN2 is exposed to ambient heat in the car and the resulting nitrogen gas can be used to power a piston or turbine engine. The maximum amount of energy that can be extracted from 1 kg of LN2 is 213 W-hr or 173 W-hr per liter, in which a maximum of 70 W-hr can be utilized with an isothermal expansion process. Such a vehicle can achieve ranges similar to that of gasoline with a 350 liter (90 gallon) tank. Theoretical future engines, using cascading topping cycles, can improve this to around 110 W-hr/kg with a quasi-isothermal expansion process. The advantages are zero harmful emissions and superior energy densities than compressed air, and a car powered by LN2 can be refilled in a matter of minutes.

LPG or Autogas

A propane-fueled school bus in the United States.

LPG or liquified petroleum gas is a low pressure liquified gas mixture composed mainly of propane and butane which burns in conventional gasoline combustion engines with less CO_2 than gasoline. Gasoline cars can be retrofitted to LPG aka Autogas and become bifuel vehicles as the gasoline tank stays. You can switch between LPG and gasoline during operation. Estimated 10 million vehicles running worldwide.

In the U.S., 190,000 on-road vehicles use propane, and 450,000 forklifts use it for power. It is the third most popular vehicle fuel in America, behind gasoline and diesel.

Hyundai Motor Company began sales of the Elantra LPI Hybrid in the South Korean domestic market in July 2009. The Elantra LPI (Liquefied Petroleum Injected) is the world's first hybrid electric vehicle to be powered by an internal combustion engine built to run onliquefied petroleum gas (LPG) as a fuel.

Steam

The Stanley Steam Car

A steam car is a car that has a steam engine. Wood, coal, ethanol, or others can be used as fuel. The fuel is burned in a boiler and the heat converts water into steam. When the water turns to steam, it expands. The expansion creates pressure. The pressure pushes the pistons back and forth. This turns the driveshaft to spin the wheels forward. It works like a coal-fueled steam train, or steam boat. The steam car was the next logical step in independent transport.

Steam cars take a long time to start, but some can reach speeds over 100 mph (161 km/h) eventually. the late model doble could be brought to operational condition in less than 30 seconds, and were fast, with high acceleration, but they were ridiculously expensive.

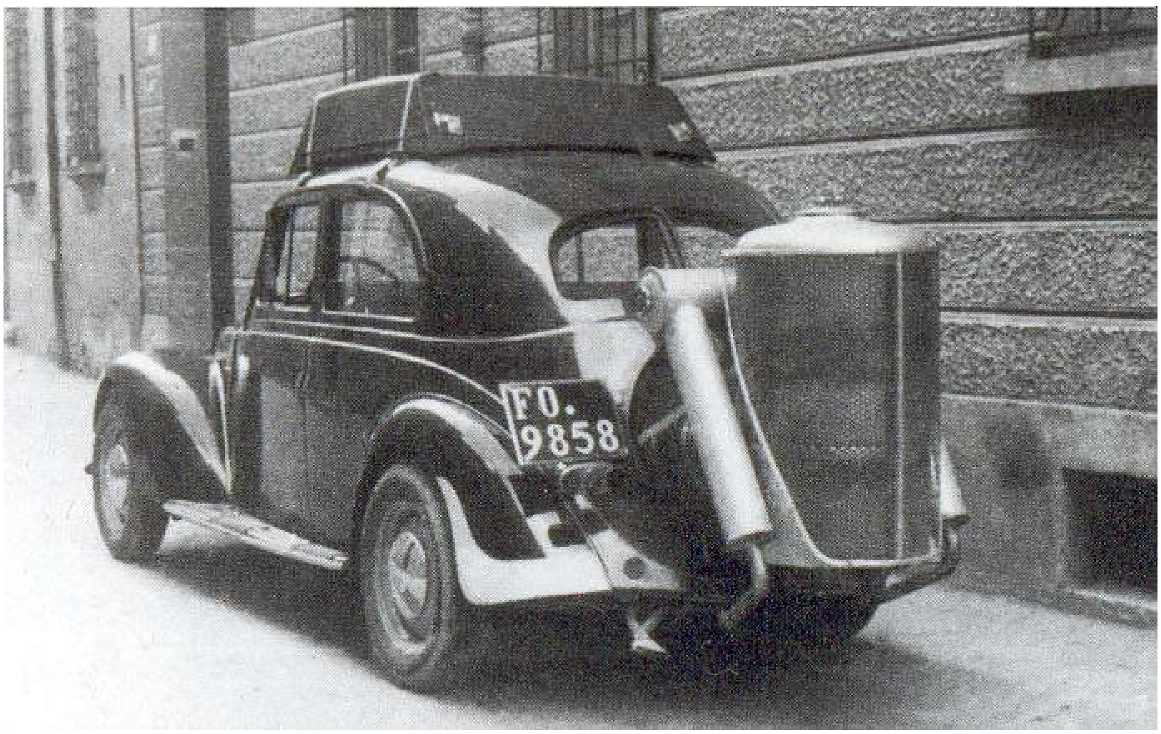
A steam engine uses external combustion, as opposed to internal combustion. Gasoline-powered cars are more efficient at about 25-28% efficiency. In theory, a combined cycle steam engine in which the burning material is first used to drive a gas turbine can produce 50% to 60% efficiency. However, practical examples of steam engined cars work at only around 5-8% efficiency.

The best known and best selling steam-powered car was the Stanley Steamer. It used a compact fire-tube boiler under the hood to power a simple two-piston engine which was connected directly to the rear axle. Before Henry Ford introduced monthly payment financing with great success, cars were typically purchased outright. This is why the Stanley was kept simple; to keep the purchase price affordable.

Steam produced in refrigeration also can be use by a turbine in other vehicle types to produce electricity, that can be employed in electric motors or stored in a battery.

Steam power can be combined with a standard oil-based engine to create a hybrid. Water is injected into the cylinder after the fuel is burned, when the piston is still superheated, often at temperatures of 1500 degrees or more. The water will instantly be vaporized into steam, taking advantage of the heat that would otherwise be wasted.

Wood gas



Vehicle with a gasifier

Wood gas can be used to power cars with ordinary internal combustion engines if a wood gasifier is attached. This was quite popular during World War II in several European and Asian countries because the war prevented easy and cost-effective access to oil.

Multiple fuel source

Flexible fuel

Six typical Brazilian full flex-fuel models from several carmakers, popularly known as "flex" cars, that run on any blend of ethanol and gasoline(actually between E20-E25 to E100).

A flexible-fuel vehicle (FFV) or dual-fuel vehicle is an alternative fuel automobile or light duty truck with a multifuel engine that can use more than one fuel, usually mixed in the same tank, and the blend is burned in the combustion chamber together. These vehicles are colloquially called flex-fuel, or flexifuel in Europe, or just flex in Brazil. FFVs are distinguished from bi-fuel vehicles, where two fuels are stored in separate tanks. The most common commercially available FFV in the world market is the ethanol flexible-fuel vehicle, with the major markets concentrated in the United States, Brazil, Sweden, and some other European countries. In addition to flex-fuel vehicles running with ethanol, in the US and Europe there were successful test programs with methanol flex-fuel vehicles, known as M85 FFVs, and more recently there have been also successful tests using p-series fuels with E85 flex fuel vehicles, but as of June 2008, this fuel is not yet available to the general public.

Ethanol flexible-fuel vehicles have standard gasoline engines that are capable of running with ethanol and gasoline mixed in the same tank. These mixtures have "E" numbers which describe the percentage of ethanol in the mixture, for example, E85 is 85% ethanol and 15% gasoline. Though technology exists to allow ethanol FFVs to run on any mixture up to E100, in the U.S. and Europe, flex-fuel vehicles are optimized to run on E85. This limit is set to avoid cold starting problems during very cold weather. The alcohol content might be reduced during the winter, to E70 in the U.S. or to E75 in Sweden. Brazil, with a warmer climate, developed vehicles that can run on any mix up to E100, though E20-E25 is the mandatory minimum blend, and no pure gasoline is sold in the country.

By mid 2010 cumulative global sales of flexible-fuel vehicles have reached around 21 million units, led by Brazil with 10.6 million, followed by the United States with 9.3 million, Canada (600,000), and Europe, led by Sweden (199,004). In addition, 183,375 flexible-fuel motorcycles were sold in Brazil in 2009. In Brazil, 65% of flex-fuel owners use ethanol fuel regularly in 2009, while, the actual number of American FFVs being run on E85 is much lower; surveys conducted in the U.S. have found that 68% of American flex-fuel car owners were not aware they owned an E85 flex. This is thought to be due to a number of factors, including:

Typical labeling used in the US to identify E85 vehicles. Top left: a small sticker in the back of the fuel filler door. Bottom left: the bright yellow gas cap used in newer models. E85 Flexfuel badging used in newer models from Chrysler (top right), Ford (middle right) and GM (bottom right).

- The appearance of flex-fuel and non-flex-fuel vehicles is identical;
- There is no price difference between a pure-gasoline vehicle and its flex-fuel variant;
- The lack of consumer awareness of flex-fuel vehicles;
- The lack of promotion of flex-fuel vehicles by American automakers, who often do not label the cars or market them in the same way they do to hybrid cars

By contrast, automakers selling FFVs in Brazil commonly affix badges advertising the car as a flex-fuel vehicle. As of 2007, new FFV models sold in the U.S. were required to feature a yellow gas cap emblazoned with the label "E85/gasoline", in order to remind drivers of the cars' flex-fuel capabilities. Use of E85 in the U.S. is also affected by the relatively low number of E85 filling stations in operation across the country, with just over 1,750 in August 2008, most of which are concentrated in the Corn Belt states, led by Minnesota with 353 stations, followed by Illinois with 181, and Wisconsin with 114. By comparison, there are some 120,000 stations providing regular non-ethanol gasoline in the United States alone.

US E85FlexFuel Chevrolet Impala LT 2009.

There have been claims that American automakers are motivated to produce flex-fuel vehicles due to a loophole in the Corporate Average Fuel Economy (CAFE) requirements, which gives the automaker a "fuel economy credit" for every flex-fuel vehicle sold, whether or not the vehicle is actually fueled with E85 in regular use. This loophole allegedly allows the U.S. auto industry to meet CAFE fuel economy targets not by developing more, more fuel-efficient models, but by spending between $100 and $200 extra per vehicle to produce a certain number of flex-fuel models, enabling them to continue selling less fuel-efficient vehicles such as SUVs, which netted higher profit margins than smaller, more fuel-efficient cars.

In the United States, E85 FFVs are equipped with sensor that automatically detect the fuel mixture, signaling the ECU to tune spark timing and fuel injection so that fuel will burn cleanly in the vehicle's internal combustion engine. Originally, the sensors were mounted in the fuel line and exhaust system; more recent models do away with the fuel line sensor. Another feature of older flex-fuel cars is a small separate gasoline storage tank that was used for starting the car on cold days, when the ethanol mixture made ignition more difficult.

The Honda CG 150 Titan Mix was the first flex-fuel motorcycle launched to the market in the world.

Modern Brazilian flex-fuel technology enables FFVs to run an any blend between E20-E25 gasohol and E100 ethanol fuel, using a lambda probe to measure the quality of combustion, which informs the engine control unit as to the exact composition of the gasoline-alcohol mixture. This technology, developed by the Brazilian subsidiary of Bosch in 1994, and further improved and commercially implemented in 2003 by the Italian subsidiary of Magneti Marelli, is known as "Software Fuel Sensor". The Brazilian subsidiary of Delphi Automotive Systems developed a similar technology, known as

"Multifuel", based on research conducted at its facility in Piracicaba, São Paulo. This technology allows the controller to regulate the amount of fuel injected and spark time, as fuel flow needs to be decreased to avoid detonation due to the high compression ratio (around 12:1) used by flex-fuel engines.

The latest innovation within the Brazilian flexible-fuel technology, is the development of flex-fuel motorcycles. In 2007 Magneti Marelli presented the first motorcycle with flex technology, adapted on a Kasinski Seta 125. Delphi Automotive Systems also presented in 2007 its multifuel injection technology for motorcycles. The first flex motorcycle was launched by Honda in March 2009. Produced by its Brazilian subsidiary Moto Honda da Amazônia, the CG 150 Titan Mix is sold for around US$2,700. Because the motorcycle does not have a secondary gas tank for a cold start like the Brazilian flex cars do, the tank must have at least 20% of gasoline to avoid start up problems at temperatures below 15°C (59°F). The motorcycle's panel includes a gauge to warn the driver about the actual ethanol-gasoline mix in the storage tank.

Hybrid

The Toyota Prius Plug-in Hybrid has a larger all-electric range than the conventional Prius.

The Chevrolet Volt is a plug-in hybrid able to run in all-electric mode up to 35 miles (56 km) (EPA rating).

A hybrid vehicle uses multiple propulsion systems to provide motive power. The most common type of hybrid vehicle is the gasoline-electric hybrid vehicles, which use gasoline (petrol) and electric batteries for the energy used to power internal-combustion engines (ICEs) and electric motors. These motors are usually relatively small and would be considered "underpowered" by themselves, but they can provide a normal driving experience when used in combination during acceleration and other maneuvers that require greater power.

The Toyota Prius first went on sale in Japan in 1997 and it is sold worldwide since 2000. By 2010 the Prius is sold in more than 70 countries and regions, with Japan and the United States as its largest markets. In May 2008, global cumulative Prius sales reached the 1 million units, and by September 2010, the Prius reached worldwide cumulative sales of 2.0 million units. As the top seller market, there were 814 thousand Prius registered in the U.S. by December 2009.

The Honda Insight is a two-seater hatchback hybrid automobile manufactured by Honda. It was the first mass-produced hybrid automobile sold in the United States, introduced in 1999, and produced until 2006. Honda introduced the second-generation Insight in Japan in February 2009, and the new Insight went on sale in the U.S. on April 22, 2009. Honda also offers the Honda Civic Hybrid since 2002.

Among others, the following are popular gasoline-electric hybrid models available in the market by 2009: Ford Escape Hybrid, Chevrolet Silverado/GMC Sierra Hybrid, Lexus RX 400h, Toyota Highlander Hybrid, Mercury Mariner Hybrid, Toyota Camry Hybrid, Saturn Vue Green Line, Lexus LS600hL, Mazda Tribute Hybrid, Nissan Altima Hybrid, Ford Fusion/Mercury Milan Hybrid, and Mercedes S400 BlueHybrid.

Several major carmakers are currently developing plug-in hybrid electric vehicles (PHEVs). Chinese battery manufacturer and automaker BYD Auto released the F3DM PHEV-68 (PHEV109km) hatchback to the Chinese fleet market on December 15, 2008. The 2011 Chevrolet Volt is the first mass produced PHEV launched in the United States, and it was introduced in November 2010. Other PHEVs undergoing field testing as of December 2010 include the Toyota Prius Plug-in Hybrid, Ford Escape Plug-in Hybrid, Volvo V70 Plug-in Hybrid, and Suzuki Swift Plug-in.

The Sinclair C5 pedal-assisted battery vehicle.

The Elantra LPI Hybrid, launched in the South Korean domestic market in July 2009, is a hybrid vehicle powered by an internal combustion engine built to run onliquefied petroleum gas (LPG) as a fuel. The Elantra PLI is a mild hybrid and the first hybrid to adopt advanced lithium polymer (Li–Poly) batteries.

Pedal-assisted electric hybrid vehicle

In very small vehicles, the power demand decreases, so human power can be employed to make a significant improvement in battery life. Two such commercially made vehicles are the Sinclair C5 and the TWIKE.

Chapter- 5

Electric Bus

New (2004) Massachusetts Bay Transportation Authority Neoplan trolleybus

An **electric bus** is a bus powered by electricity.

There are two main electric bus categories:

- Non-autonomous electric buses:
    - The trolleybus is a type of electric bus powered by two overhead electric wires, with electricity being drawn from one wire and returned via the other wire, using two roof-mounted trolley poles.
    - The gapbus is a bus without rails or surface power lines, and it can share the road lane with other vehicles as well. Power is supplied over a gap of 12 cm (4.7 in) from a power line embedded in the ground.
- The onboard stored-electricity bus (autonomous electric buses):
    - Battery electric bus and *capabus*
    - Gyrobus

Capabus

The best ultracapacitors can only store about 5 percent of the energy that lithium-ion batteries hold, limiting them to a couple of miles per charge. This makes them ineffective as an energy storage medium for passenger vehicles. But what ultracapacitors lack in range they make up in their ability to rapidly charge and discharge. So in vehicles that have to stop frequently and predictably as part of normal operation, energy storage based exclusively on ultracapacitors begins to make sense.

China is experimenting with a new form of electric bus, known as *Capabus*, which runs without continuous overhead lines by using power stored in large onboard electric double-layer capacitors, which are quickly recharged whenever the vehicle stops at any bus stop (under so-called **electric umbrellas**), and fully charged in the terminus.

A few prototypes were being tested in Shanghai in early 2005. In 2006, two commercial bus routes began to use electric double-layer capacitor buses; one of them is route 11 in Shanghai. In 2009, Sinautec Automobile Technologies, based in Arlington, VA, and its Chinese partner, Shanghai Aowei Technology Development Company are testing with 17 forty-one seat Ultracap Buses serving the Greater Shanghai area since 2006 without any major technical problems. Buses in the Shanghai pilot are made by Germantown, TN-based Foton America Bus Co. Another 60 buses will be delivered early next year with ultracapacitors that supply 10 watt-hours per kilogram.

Foton America Bus Co is in talks with New York City, Chicago, and some towns in Florida about trialing the buses.

The buses have very predictable routes and need to stop regularly, every 3 miles (4.8 km), allowing opportunities for quick recharging. The trick is to turn some bus stops along the route into charging stations. At these stations, a collector on the top of the bus rises a few feet and touches an overhead charging line. Within a couple of minutes, the ultracapacitor banks stored under the bus seats are fully charged. The buses can also capture energy from braking, and the company says that recharging stations can be equipped with solar panels. A third generation of the product, which will give 20 miles (32 km) of range per charge or better.

Sinautec estimates that one of its buses has one-tenth the energy cost of a diesel bus and can achieve lifetime fuel savings of $200,000. Also, the buses use 40 percent less electricity compared to an electric trolley bus, mainly because they are lighter and have the regenerative braking benefits. The ultracapacitors are made of activated carbon, and have an energy density of six watt-hours per kilogram (for comparison, a high-performance lithium-ion battery can achieve 200 watt-hours per kilogram), but the ultracapacitor bus is also cheaper than lithium-ion battery buses, about 40 percent less expensive, with a far superior reliability rating.

There is also a plug-in hybrid version, which also uses ultracaps.

Future developments

Sinautec is in discussions with MIT's Schindall about developing ultracapacitors of higher energy density using vertically aligned carbon nanotube structures that give the devices more surface area for holding a charge. So far, they are able to get twice the energy density of an existing ultracapacitor, but they are trying to get about five times.

This would create an ultracapacitor with one-quarter of the energy density of a lithium-ion battery.

Future developments includes the use of inductive charging under the street, to avoid overhead wiring. A pad under each bus stop and at each stop light along the way would be used.

Solar-charged

Tindo is an experimental battery electric bus being tested in Adelaide, Australia. The word "Tindo" comes from the aboriginal word for sun. The bus will get its electricity from a photovoltaic system on Adelaide's central bus station. Rides are free as part of Adelaide's public transport system.

Zinc

There is a 40-foot (12 m) pure electric bus being developed, using a pre-commercial battery technology. Electric Fuel Corporation is developing and demonstrating a 40-foot (12 m) electric bus powered by a zinc air cell, along with an ultracapacitor. The zinc-air energy device, often described as a battery, converts zinc to zinc oxide in a process that provides energy to the bus. The bus is not recharged; instead, the zinc oxide cartridges are swapped out for new zinc ones. This bus has shown a range of over 100 miles (160 km) in testing and has been demonstrated in Las Vegas, Nevada. However, this technology is in the development phase, and several major hurdles must be overcome before it can be adopted for transit fleet use, including available refueling infrastructure or use in bus stations.

Onboard solar panels

Air conditioning

Solar panels and supercapacitors are used in some electric buses to power the specific air conditioning circuit.

Makers and models

A fleet of 8 Tecnobus Gulliver is used by the Réseau de transport de la Capitale, in Quebec City since 2008.

Bus with trailer (trailer can be used to store batteries and/or generator - this last to hybridize-)

There are currently more than 25 manufacturers of trolleybuses.

Makers of other types of all-electric buses (mostly battery buses):

- APS Systems, Oxnard, CA, shuttle buses in partnership with Enova Systems and Saft
- Astonbus, Marina del Rey, CA: E-city midi and full-size models, with a range between 250 and 500 km. Astonbus is the Zonda Electric bus sole distributor in all EU states.
- BredaMenarinibus in Bologna, Italy. Zeus M-200 E model, with Ansaldo Electric Drive motor and 288V - 200 Ah lithium-ion batteries.
- Designline International, in New Zealand: The Tindo solar-electric bus (prototype only).
- Ebus, in Downey, California, minibuses : 22 feet (6.7 m) buses .
- Iveco, in Turin, Italy: EuroPolis model.
- Jiangsu Alfa Bus company, Jiangsu, China, delivered in Italy by Rama Company.
- Lujo EV, in Weihai City, Shandong Prov., China.: Lujo YX Bus69 LHD (9 m, maximum speed 80 km/h, maximum range 220 km).

- Mitsubishi Heavy Industries is developing electric buses that are capable of battery swapping.
- Optare: Solo EV.
- Proterra in Golden, CO: 35 feet (11 m) full-size bus FCBE 35.
- Smith Electric Vehicles, Kansas City, Missouri, Speedster and Edison electric minibuses.
- Solaris Bus & Coach in the European Union (Poland).
- Specialty Vehicle Manufacturing Corp. (SVMC) in Downey, CA.
- Tecnobus, in Frosinone, Italy. The Gulliver model is currently used in several cities in Canada, England, France, Germany, Italy, Portugal and Spain.
- Thomas Built Buses Inc in High Point, NC.
- Thunder Sky Energy Group of Shenzhen, China (near Hong Kong) builds lithium-ion batteries and has four models of electric buses, the ten passenger EV-6700 with a range of 260 km (160 mi), the TS-6100EV and TS-6110EV city buses (top speed 80 km/h), and the 43 passenger Thunder-Sky-EV-2008 highway bus (top speed 100 km/h), which has a range of 300 km (190 mi). The batteries can be recharged in 1 hour or replaced in 5 minutes. The buses are also to be built in the United States and Finland.
- U.S. Electricar in Santa Rosa, California.
- Zonda Bus, in Jiangsu, China: YCK6128HEC (12 m), YCK6118HEC (11 m) and the Zonda Bus New Energy (with a 500 km only-electric range and a battery lifespan of above 500,000 km).

Transit use

Transit authorities that use battery buses or other types of all-electric buses, other than trolleybuses:

Canada

Québec

- Réseau de transport de la Capitale, Quebec City's public transit authority has integrated 8 electric buses to its fleet in 2008 to serve the Old City. The Tecnobus Gulliver buses can carry up to 20 passengers and runs on $3.25 worth of electricity per day.
- Montreal, bus fleet going all-electric by 2025.

China

- Shanghai (capabuses).
- YanCheng.

Europe

There is an European Union directive that mandates the purchase of electric buses for public services.

- Gruppo Torinese Trasporti — Turin, Italy

Spain

- Empresa Malagueña de Transportes (EMT), S.A.M
- Empresa Municipal de Transportes de Madrid (20 all-electric and 20 hybrid diesel-electric buses)
- Councillor for the Environment, Figueres
- León: Minibus Tecnobus Gulliver
- Seville

United States

Federal Transit Administration Clean Air Program

- Anaheim, CA
- Atlanta, GA (at Emory University)
- Chattanooga, TN
- Colorado Springs, CO
- Hampton, VA
- Los Angeles, CA
- Miami Beach
- Mobile, AL
- New Haven, CT
- Santa Barbara, CA
- San Francisco, where electric trolleybuses are already commonplace on most SF Muni routes.

California

There is a Californian mandate (Zero Emission Bus, in short, ZBus) that 15% of new buses after 2011 be electric. The ZBus Regulation is part of the Fleet Rule for Transit Agencies, which is also referred to as the Public Transit Agencies Regulation.

Chapter- 6

Battery Electric Vehicle

Citroën Berlingo Electrique vans of the ELCIDIS goods distribution service in La Rochelle, France

A **battery electric vehicle**, or **BEV**, is a type of electric vehicle (EV) that uses chemical energy stored in rechargeable battery packs.

As with other electric vehicles, BEVs use electric motors and motor controllers instead of internal combustion engines (ICEs) for propulsion.

Sometimes, all-electric vehicles are referred as BEVs (although a plug-in hybrid is also a battery electric vehicle).

All-electric and hybrid electric vehicles

Vehicles using both electric motors and internal combustion engines are examples of hybrid electric vehicles, and are not considered pure (or all) EVs because they operate in a charge-sustaining mode.

- Regular hybrid electric vehicles cannot be externally charged.
- Hybrid vehicles with batteries that can be charged externally to displace some or all of their internal combustion engine power and gasoline fuel are called plug-in hybrid electric vehicles (PHEV), and are BEVs during their charge-depleting mode.

All-electric and plug-in hybrids are off-vehicle charge capable ("OVCC" or pluginable), which means their batteries can be charged from an off-vehicle electric energy source that cannot be connected or coupled to the vehicle while the vehicle is being driven (so, it is autonomous).

Vehicles

The concept of battery electric vehicles is to charge batteries on board vehicles for propulsion using the electric grid.

Battery electric cars are becoming more and more attractive with the advancement of new battery technology (Lithium Ion) that have higher power and energy density (i.e. greater possible acceleration and more range with less batteries) and higher oil prices.

BEVs include automobiles, light trucks, and neighborhood electric vehicles.

Electric bus

A battery-electric minibus in St Helens, England

Chattanooga, Tennessee operates nine zero-fare electric buses, which have been in operation since 1992 and have carried 11.3 million passengers and covered a distance of 3,100,000 kilometres (1,930,000 mi), They were made locally by Advanced Vehicle Systems. Two of these buses were used for the 1996 Atlanta Olympics.

Wrightbus has a new a hybrid-electric driveline for the StreetCar RTV which has been developed in conjunction with the ISE Corporation of California and incorporates Siemens ELFA traction components and a Cummins ISL engine. The chassis is built to Wright Group specifications by Swiss trolleybus specialists Carosserie Hess and is powered by Valence Technology lithium phosphate batteries .

Beginning in the summer of 2000, Hong Kong Airport began operating a 16-passenger Mitsubishi Rosa electric shuttle bus, and in the fall of 2000, New York City began testing a 66-passenger battery-powered school bus, an all electric version of the Blue Bird TC/2000. A similar bus was operated in Napa Valley, California for 14 months ending in April, 2004.

The 2008 Beijing Olympics used a fleet of 50 electric buses, which have a range of 130 km (81 mi) with the air conditioning on. They use Lithium-ion batteries, and consume about 1 kW·h/mi (0.62 kW·h/km; 2.2 MJ/km). The buses were designed by the Beijing Institute of Technology and built by the Jinghua Coach Co. Ltd. The batteries are replaced with fully charged ones at the recharging station to allow 24 hour operation of the buses.

Thunder Sky

Thunder Sky (based in Hong Kong) builds lithium-ion batteries used in submarines and has three models of electric buses, the 10/21 passenger EV-6700 with a range of 280 km (170 mi) under 20 mins quick-charge, the EV-2009 city buses, and the 43 passenger EV-2008 highway bus, which has a range of 300 km (190 mi) under quick-charge (20 mins to 80%), and 350 km (220 mi) under full charge (25 mins). The buses will also be built in the United States and Finland.

Valence

Valence Technology has entered into a contract with The Tanfield Group Plc to manufacture and supply Lithium Phosphate energy storage systems to power Tanfield's all-electric commercial delivery vehicles. The Valence battery systems will be installed in vans and trucks produced by Tanfield's UK-based trading division, Smith Electric Vehicles, the world's largest manufacturer of electric vans and trucks.

Free Tindo

Tindo is an all-electric bus from Adelaide, Australia. The Tindo (aboriginal word for sun) is made by Designline International in New Zealand and gets its electricity from a solar PV system on Adelaide's central bus station. Rides are zero-fare as part of Adelaide's public transport system.

Trucks

Drive Star is a CalCars plan to cut our oil use in half by 2020. U.S. 100 million trucks, vans, and buses now gulp down one third of the oil. About half stay on the road a surprisingly long time: 15 to 35 years. That is long enough for CalCars to merit a makeover. Retrofitting these gas guzzlers will pay off. Mass conversions will cost under $10–$15,000. Retrofitters can partner with energy service companies to finance these costs, backed by federal loan guarantees. Since an electric mile is up to five times cheaper than a petroleum mile, retrofits will cost less to drive right away, benefitting vehicle fleets and individual drivers.

Semi-trailer trucks

The Port of Los Angeles and South Coast Air Quality Management District have demonstrated a short-range heavy-duty all electric truck capable of hauling a fully loaded

40-foot (12 m) cargo container. The current design is capable of pulling a 60,000 lb (27 t) cargo container at speeds up to 40 mph (64 km/h) and has a range of between 30 and 60 miles (48 and 97 km). It uses 2 kilowatt-hours per mile (1.2 kW·h/km; 4.5 MJ/km), compared to 5 miles per US gallon (47 L/100 km; 6.0 mpg_{-imp}) for the hostler semi tractors it replaces.

Electric tractors

Electric tractors have been built since the 1990s.

Milk float

A Dairy Crest Smith's Elizabethan milk float

A common example of the battery electric trucks is the milk float. Since it makes many stops in delivering milk it is more practical to use an electric vehicle than a combustion truck, which would be idling much of the time; it also reduces noise in residential areas. For most of the 20th century, the majority of the world's battery electric road vehicles were British milk floats.

Garbage truck

With a similar driving pattern of a delivery vehicle like the milk float above, garbage trucks are excellent candidates for electric drive. Most of their time is spent stopping, starting or idling. These activities are where internal combustion engines are their least efficient. In preparation for the 2008 Olympic Games, 3,000 of the internal combustion engine garbage trucks in Beijing were replaced with lithium ion polymer battery pack electric drive trucks. The batteries were procured for about $3,300 each.

Pickup trucks

In early 2009, Phoenix Motorcars will be shipping a test fleet of their all-electric SUT (Sports Utility Truck) to Maui. One of the surviving electric vehicles from the late 1990s is the Chevy S-10 electric pickup truck. Many other vehicles from this era, such as the General Motors EV1 were recalled and destroyed. A newcomer is the Miles Electric Vehicles ZX40ST electric truck now available in the United States. Miles Electric Vehicles is based in Santa Monica, California.

The Big Bike Company Limited, in Gloucestershire, England, is now offering fully electric pick up trucks for sale. Powered by an impressive bank of batteries, these small utility vehicles are able to deliver a payload of approximately 500 kg, and have a range of up to 80 miles. Using a 3 wheel configuration, the rolling and aerodynamic drag is reduced. As a tricycle it can also be driven on a motorcycle licence.

Electric cars

An **electric car** is a plug-in battery powered automobile which is propelled by electric motor(s).

Although electric cars often give good acceleration and have generally acceptable top speed, the lower specific energy of production batteries available in 2010 compared with Carbon-based fuels means that electric cars need batteries that are fairly large fraction of the vehicle mass but still often give relatively low range between charges. Recharging can also take significant lengths of time. For shorter range commuter type journeys, rather than long journeys, electric cars are practical forms of transportation and can be inexpensively recharged overnight. Longer range journey options are currently being pursued by installing battery swapping station infrastructure throughout several pilot cities such as Tokyo.

Electric cars have the potential of significantly reducing city pollution by having zero tail pipe emissions. Vehicle greenhouse gas savings depend on how the electricity is generated. With the current U.S. energy mix, using an electric car would result in a 30% reduction in carbon dioxide emissions. Given the current energy mixes in other countries, it has been predicted that such emissions would decrease by 40% in the UK, 19% in China, and as little as 1% in Germany.

Electric cars are expected to have a major impact in the auto industry given advantages in city pollution, less dependence on oil, and expected rise in gasoline prices. World governments are pledging billions to fund development of electric vehicles and their components. The U.S. has pledged US$2.4 billion in federal grants for electric cars and batteries. China has announced it will provide US$15 billion to initiate an electric car industry. Nissan CEO Carlos Ghosn has predicted that one in 10 cars globally will run on battery power alone by 2020. Additionally a recent report claims that by 2020 electric cars and other "green" cars will take a third of the total of global car sales.

Technology

Fuel use in vehicle designs

Vehicle type	Fuel used
All-petroleum vehicle	Most use of petroleum
Regular hybrid electric vehicle	Less use of petroleum, but non-pluginable
Plug-in hybrid vehicle	Residual use of petroleum. More use of electricity
All-electric vehicle	Most use of electricity

Motors

Electric cars have traditionally used series wound DC motors, a form of brushed DC electric motor. More recent electric vehicles have made use of a variety of AC motor types, as these are simpler to build and have no brushes that can wear out. These are usually induction motors or brushless AC electric motors which use permanent magnets. There are several variations of the permanent magnet motor which offer simpler drive schemes and/or lower cost including the brushless DC electric motor.

Motor controllers

The motor controller regulates the power to the motor, supplying either variable pulse width DC or variable frequency variable amplitude AC, depending on the motor type, DC or AC.

Chapter- 7

Compressed Air Car

Tata/MDI OneCAT

A **compressed air car** is a car that uses a motor powered by compressed air. The car can be powered solely by air, or combined (as in a hybrid electric vehicle) with gasoline, diesel, ethanol, or an electric plant with regenerative braking.

History

Technology

Engines

Compressed air cars are powered by motors fueled with compressed air, which is stored in a tank at high pressure such as 30 MPa (4500 psi or 300 bar). Rather than driving engine pistons with an ignited fuel-air mixture, *compressed air cars* use the expansion of compressed air, in a similar manner to the expansion of steam in a steam engine.

Storage tanks are often made of carbon-fiber for weight reduction while maintaining strength; if penetrated carbon fiber will crack but not produce shrapnel.

There have been prototype cars since the 1920s, and compressed air has been used in torpedo propulsion as well.

Storage tanks

The major manufacturers that are developing air cars have designed safety features into their containers. In contrast to hydrogen's issues of damage and danger involved in high-impact crashes, air, on its own, is non-flammable. It was reported on Seven Network's *Beyond Tomorrow* that on its own, carbon-fiber is brittle and can split under sufficient stress, but creates no shrapnel when it does so. Carbon-fiber tanks safely hold air at a pressure somewhere around 4500 psi, making them comparable to steel tanks. The cars are designed to be filled up at a high-pressure pump.

Compressed air is also relatively space inefficient way of storing energy when compared to conventional gasoline. Air at 30 MPa (4,500 psi) contains about 50 Wh of energy per liter. Gasoline contains about 9411 Wh per liter.

Emissions

Compressed air cars are emission-free at the exhaust. Since a compressed air car's source of energy is usually electricity, its total environmental impact depends on how clean the source of this electricity is. Different regions can have very different sources of power, ranging from high-emission power sources such as coal to zero-emission power sources such as wind. A given region can also update its electrical power sources over time, thereby improving or worsening total emissions.

However a study showed that even with very optimistic assumptions, air storage of energy is less efficient than chemical (battery) storage.

Advantages

The principal advantages of an air powered vehicle are:

- Refueling can be done at home using an air compressor or at service stations. The energy required for compressing air is produced at large centralized plants, making it less costly and more effective to manage carbon emissions than from individual vehicles.
- Compressed air engines reduce the cost of vehicle production, because there is no need to build a cooling system, spark plugs, starter motor, or mufflers.
- The rate of self-discharge is very low opposed to batteries that deplete their charge slowly over time. Therefore, the vehicle may be left unused for longer periods of time than electric cars.
- Expansion of the compressed air lowers its temperature; this may be exploited for use as air conditioning.
- Reduction or elimination of hazardous chemicals such as gasoline or battery acids/metals
- Some mechanical configurations may allow energy recovery during braking by compressing and storing air.

Disadvantages

The principal disadvantage is the indirect use of energy. Energy is used to compress air, which - in turn - provides the energy to run the motor. Any conversion of energy between forms results in loss. For conventional combustion motor cars, the energy is lost when chemical energy in fossil fuels is converted to heat energy, most of which goes to waste. For compressed-air cars, energy is lost when chemical energy is converted to electrical energy, and then when electrical energy is converted to compressed air.

- When air expands in the engine it cools dramatically (Charles's law) and must be heated to ambient temperature using a heat exchanger. The heating is necessary in order to obtain a significant fraction of the theoretical energy output. The heat exchanger can be problematic: while it performs a similar task to an intercooler for an internal combustion engine, the temperature difference between the incoming air and the working gas is smaller. In heating the stored air, the device gets very cold and may ice up in cool, moist climates.
- Conversely, when air is compressed to fill the tank it heats up: as the stored air cools, its pressure decreases and available energy decreases. It is difficult to cool the tank efficiently while charging and thus it would either take a long time to fill the tank, or less energy is stored.
- Refueling the compressed air container using a home or low-end conventional air compressor may take as long as 4 hours, though specialized equipment at service stations may fill the tanks in only 3 minutes. To store 14.3 kWh @300 bar in 300 l (90 m3 @ 1 bar) reservoirs, you need at least 93 kWh on the compressor side (with an optimum single stage compressor working on the ideal adiabatic limit), or rather less with a multistage unit. That means, a compressor power of over 1 Megawatt (1000 kW) is needed to fill the reservoirs in 5 minutes from a single stage unit, or several hundred horsepower for a multistage one.

- The overall efficiency of a vehicle using compressed air energy storage, using the above refueling figures, cannot exceed 14%, even with a 100% efficient engine—and practical engines are closer to 10-20%. For comparison, well to wheel efficiency using a modern internal-combustion drivetrain is about 20%, Therefore, if powered air compressed using a compressor driven by an engine using fossil fuels technology, a compressed air car would have a larger carbon footprint than a car powered directly by an engine using fossil fuels technology.
- Early tests have demonstrated the limited storage capacity of the tanks; the only published test of a vehicle running on compressed air alone was limited to a range of 7.22 km.
- A 2005 study demonstrated that cars running on lithium-ion batteries out-perform both compressed air and fuel cell vehicles more than threefold at the same speeds. MDI has recently claimed that an air car will be able to travel 140 km in urban driving, and have a range of 80 km with a top speed of 110 km/h (68 mph) on highways, when operating on compressed air alone, but in as late as mid 2009, MDI has still not produced any proof to that effect.
- A 2009 University of Berkeley Research Letter found that "Even under highly optimistic assumptions the compressed-air car is significantly less efficient than a battery electric vehicle and produces more greenhouse gas emissions than a conventional gas-powered car with a coal intensive power mix."

Crash safety

Safety claims for light weight vehicle air tanks in severe collisions have not been verified. North American crash testing has not yet been conducted, and skeptics question the ability of an ultralight vehicle assembled with adhesives to produce acceptable crash safety results. Shiva Vencat, vice president of MDI and CEO of Zero Pollution Motors, claims the vehicle would pass crash testing and meet U.S. safety standards. He insists that the millions of dollars invested in the AirCar would not be in vain. To date, there has never been a lightweight, 100-plus mpg car which passed North American crash testing. Technological advances may soon make this possible, but the AirCar has yet to prove itself, and collision safety questions remain.

The key to achieving an acceptable range with an air car is reducing the power required to drive the car, so far as is practical. This pushes the design towards minimizing weight. In a collision the occupants of a heavy vehicle will, on average, suffer fewer and less serious injuries than the occupants of a lighter vehicle. An accident in a 2000 lb (900 kg) vehicle will on average cause about 50% more injuries to its occupants than a 3000 lb (1350 kg) vehicle. Air cars may use low rolling resistance tires, which typically offer less grip than normal tires. In addition, the weight (and price) of safety systems such as airbags, ABS and ESC may discourage manufacturers from including them.

Developers and manufacturers

Various companies are investing in the research, development and deployment of *Compressed air cars*. Overoptimistic reports of impending production date back to at least May 1999. For instance, the MDI Air Car made its public debut in South Africa in 2002, and was predicted to be in production "within six months" in January 2004. As of January 2009, the air car never went into production in South Africa. Most of the cars under development also rely on using similar technology to Low-energy vehicles in order to increase the range and performance of their cars.

MDI

MDI has proposed a range of vehicles made up of AirPod, OneFlowAir, CityFlowAir, MiniFlowAir and MultiFlowAir. One of the main innovations of this company is its implementation of its "active chamber", which is a compartment which heats the air (through the use of a fuel) in order to double the energy output. This 'innovation' was first used in torpedoes in 1904.

Tata Motors

As of January 2009 Tata Motors of India had planned to launch a car with an MDI compressed air engine in 2011. In December 2009 Tata's vice president of engineering systems confirmed that the limited range and low engine temperatures were causing problems.

Air Car Factories

Air Car Factories SA is proposing to develop and build a compressed air engine. This Spanish based company was founded by Miguel Celades. Currently there is a bitter dispute between Motor Development International, another firm called Luis which developed compressed-air vehicles, and Mr. Celades, who was once associated with that firm.

Energine

The Energine Corporation was a South Korean company that claimed to deliver fully assembled cars running on a hybrid compressed air and electric engine. These cars are more precisely named pneumatic-hybrid electric vehicles. Engineers from this company made, starting from a Daewoo Matiz, a prototype of a hybrid electric/compressed-air engine (Pne-PHEV, pneumatic plug-in hybrid electric vehicle). The compressed-air engine is used to activate an alternator, which extends the autonomous operating capacity of the car.

The CEO is the first compressed air car promoter to be arrested for fraud.

A similar (but only for braking energy recovery) concept using a pneumatic accumulator in a largely hydraulic system has been developed by U.S. government research laboratories and industry, and is now being introduced for certain heavy vehicle applications such as refuse trucks.

K'Airmobiles

K'Airmobiles vehicles were intended to be commercialized from a project developed in France in 2006-2007 by a small group of researchers. However, the project has not been able to gather the necessary funds.

People should note that, meantime, the team has recognized the physical impossibility to use on-board stored compressed air due to its poor energy capacity and the thermal losses resulting from the expansion of the gas.

These days, using the patent pending 'K'Air Fluid Generator', converted to work as a compressed-gas motor, the project should be launched in 2010, thanks to a North American group of investors, but for the purpose of developing first a green energy power system.

Engineair

Engineair is an Australian company which manufactures small industrial vehicles using an air engine of its own design.

Chapter- 8

Solar Vehicle

The University of Michigan's Infinium during testing on the Stuart Highway.

A **solar vehicle** is an electric vehicle powered by solar electricity. This is obtained from solar panels on the surface (generally, the top or window) of the vehicle or using a solar jacket in electric bicycles. Photovoltaic (PV) cells convert the sun's energy directly into electrical energy.

Solar vehicles are not sold as practical day-to-day transportation devices at present, but are primarily demonstration vehicles and engineering exercises, often sponsored by government agencies. However indirectly solar-charged vehicles are widespread and solar boats are available commercially.

By type

Solar Cars

Ned, constructed in 1999 by the South Australian Solar Car Consortium, can speed up to 120km/h.

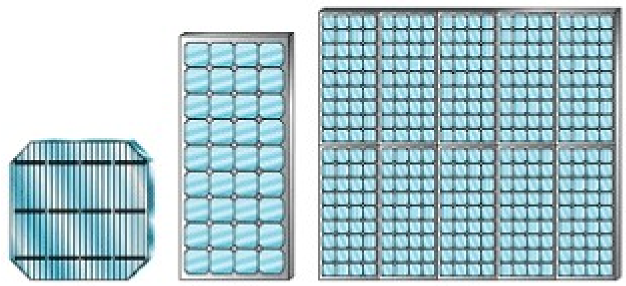
Solar cars combine technology typically used in the aerospace, bicycle, alternative energy and automotive industries. The design of a solar vehicle is severely limited by the amount of energy input into the car. Most solar cars have been built for the purpose of solar car races. Exceptions include solar-powered cars and utility vehicles.

Solar cars are often fitted with gauges as seen in conventional cars. In order to keep the car running smoothly, the driver must keep an eye on these gauges to spot possible problems. Cars without gauges almost always feature wireless telemetry, which allows the driver's team to monitor the car's energy consumption, solar energy capture and other parameters and free the driver to concentrate on driving.

Solar cars depend on PV cells to convert sunlight into electricity. In fact, 51% of sunlight actually enters the Earth's atmosphere. Unlike solar thermal energy which converts solar energy to heat for either household purposes, industrial purposes or to be converted to electricity, PV cells directly convert sunlight into electricity. When sunlight (photons) strike PV cells, they excite electrons and allow them to flow, creating an electrical current. PV cells are made of semiconductor materials such as silicon and alloys of indium, gallium and nitrogen. Silicon is the most common material used and has an efficiency rate of 15-20%. Of late, several consulting companies, such as Phoenix Snider Power, have started offering technical and financial services to institutes and teams developing solar cars worldwide.

Solar array

The solar array consists of hundreds of photovoltaic solar cells converting sunlight into electricity. In order to construct an array, PV cells are placed together to form modules which are placed together to form an array. The larger arrays in use can produce over 2 kilowatts (2.6 hp).



Cells,Modules,Arrays

The solar array can be mounted in several ways:

- **horizontal**. This most common arrangement gives most overall power during most of the day in low latitudes or higher latitude summers and offers little interaction with the wind. Horizontal arrays can be integrated or be in the form of a free canopy.
- **vertical**. This arrangement is sometimes found in free standing or integrated sails to harness wind energy. Useful solar power is limited to mornings, evenings, or winters and when the vehicle is pointing in the right direction.
- **adjustable**. Free solar arrays can often be tilted around the axis of travel in order to increase power when the sun is low and well to the side. An alternative is to tilt the whole vehicle when parked. Two-axis adjustment is only found on marine vehicles, where the aerodynamic resistance is of less importance than with road vehicles.
- **integrated**. Some vehicles cover every available surface with solar cells. Some of the cells will be at an optimal angle whereas others will be shaded.
- **trailer**. Solar trailers are especially useful for retrofitting existing vehicles with little stability, e.g. bicycles. Some trailers also include the batteries and others also the drive motor.
- **remote**. By mounting the solar array at a stationary location instead of the vehicle, power can be maximised and resistance minimized. The virtual grid-connection however involves more electrical losses than with true solar vehicles and the battery must be larger.

The choice of solar array geometry involves an optimization between power output, aerodynamic resistance and vehicle mass, as well as practical considerations. For example, a free horizontal canopy gives 2-3 times the surface area of a vehicle with integrated cells but offers better cooling of the cells and shading of the riders. There are also thin flexible solar arrays in development.

Solar arrays on solar cars are mounted and encapsulated very differently from stationary solar arrays. Solar arrays on solar cars are usually mounted using industrial grade doublesided adhesive tape right onto the car's body. The arrays are encapsulated using thin layers of Tedlar and

Some solar cars use gallium arsenide solar cells,, with efficiencies around thirty percent. Other solar cars use silicon solar cells, with efficiencies around twenty percent.

Races

Solar cars from University of Michigan and University of Minnesota heading west toward the finish line in the 2005 North American Solar Challenge.

The two most notable solar car races are the World Solar Challenge and the North American Solar Challenge, overland road rally-style competitions contested by a variety of university and corporate teams.

The World Solar Challenge features a field of competitors from around the world who race to cross the Australian continent, over a distance of 3000 km. Speeds of the vehicles have steadily increased. So, for example, the high speeds of 2005 race participants led to the rules being changed for solar cars starting in the 2007 race.

The North American Solar Challenge, previously known as the 'American Solar Challenge' and 'Sunrayce USA', features mostly collegiate teams racing in timed intervals in the United States and Canada. This race also changed rules for the most recent race due to teams reaching the regulated speed limits. The most recent North American Solar Challenge ran from June 20-26, 2010, from Broken Arrow, Oklahoma to Naperville, Illinois. The next race is expected to be run in the summer of 2012.

The Dell-Winston School Solar Car Challenge is an annual solar-powered car race for high school students. The event attracts teams from around the world, but mostly from American high schools. The race was first held in 1995. Each event is the end product of a two-year education cycle launched by the Winston Solar Car Team. In odd-numbered years, the race is a road course that starts at the Dell Diamond in Round Rock, Texas; the end of the course varies from year to year. In even-numbered years, the race is a track race around the Texas Motor Speedway. Dell has sponsored the event since 2002.

The South African Solar Challenge is an epic, bi-annual, two-week race of solar-powered cars through the length and breadth of South Africa. Teams will have to build their own cars, design their own engineering systems and race those same machines through the most demanding terrain that solar cars have ever seen. The 2008 race proved that this event can attract the interest of the public, and that it has the necessary international backing from the FIA. Late in September, all entrants will take off from Pretoria and make their way to Cape Town via the N1, then drive along the coast to Durban, before climbing the escarpment on their way back to the finish line in Pretoria 10 days later. In 2008 the event was endorsed by International Solarcar Federation (ISF), Fédération Internationale de l'Automobile (FIA), World Wildlife Fund (WWF) making it the first Solar Race to receive endorsement from these 3 organizations.

There are other distance races, such as Suzuka, Phaethon, and the World Solar Rally. Suzuka is a yearly track race in Japan and Phaethon was part of the Cultural Olympiad in Greece right before the 2004 Olympics.

Solar bicycles and motorcycles

A solar bicycle or tricycle has the advantage of very low weight and can use the riders foot power to supplement the power generated by the solar panel roof. In this way, a comparatively simple and inexpensive vehicle can be driven without the use of any fossil fuels.

Solar photovoltaics helped power India's first Quadricycle developed since 1996 in Gujarat state's SURAT city.

The first solar "cars" were actually tricycles or quadricycles built with bicycle technology. These were called solarmobiles at the first solar race, the Tour de Sol in Switzerland in 1985 with 72 participants, half using exclusively solar power and half solar-human-powered hybrids. A few true solar bicycles were built, either with a large solar roof, a small rear panel, or a trailer with a solar panel. Later more practical solar bicycles were built with foldable panels to be set up only during parking. Even later the panels were left at home, feeding into the electric mains, and the bicycles charged from the mains. Today highly developed electric bicycles are available and these use so little power that it costs little to buy the equivalent amount of solar electricity. The "solar" has evolved from actual hardware to an indirect accounting system. The same system also works for electric motorcycles, which were also first developed for the Tour de Sol. This is rapidly becoming an era of solar production.. With today's high performance solar cells, a front and rear PV panel on this solar bike can give sufficient assistance, where the range is not limited by batteries.

Solar ships

Solar powered boats have mainly been limited to rivers and canals, but in 2007 an experimental 14m catamaran, the Sun21 sailed the Atlantic from Seville to Miami, and from there to New York.

Japan's biggest shipping line Nippon Yusen KK and Nippon Oil Corporation said solar panels capable of generating 40 kilowatts of electricity would be placed on top of a 60,213 ton car carrier ship to be used by Toyota Motor Corporation.

Tûranor PlanetSolar is the biggest solar ship. It is planned to be the first ship using only solar power to circumnavigate the globe.

Solar airplanes

A solar-powered aircraft in Switzerland completed a 26-hour test flight starting at 7 a.m. on 8 July 2010 which ended at 9 a.m. the next day. The plane was flown to a height of nearly 28,000 feet (8,500 meters) by Andre Borschberg. During the evening, the plane slowly descended to an altitude of 4,500 feet (1,500 meters), where it remained for the rest of the night using battery power. An hour before dawn, the plane still had six hours of flying time left in its solar-fueled batteries.

Solar propelled spacecraft

A few spacecraft that have been employed within the orbit of Mars have used solar power as an energy source for their propulsion system.

All current solar powered spacecraft use solar panels in conjunction with electric propulsion, typically ion drives as this gives a very high exhaust velocity, and reduces the propellant over that of a rocket by more than a factor of ten. Since propellant is usually the biggest mass on many spacecraft, this reduces launch costs.

Other proposals for solar spacecraft include solar thermal heating of propellant, typically hydrogen or sometimes water is proposed.

Another concept for solar propulsion in space is the light sail.

Practical applications

The Venturi Astrolab in 2006 was hailed as the world's first commercial electro-solar hybrid car, and it was originally due to be released in January 2008.

In May 2007 a partnership of Canadian companies lead by Hymotion altered a Toyota Prius to use solar cells to generate up to 240 watts of electrical power in full sunshine. This is reported as permitting up to 15 km extra range on a sunny summer day while using only the electric motors.

One practical application for solar powered vehicles is possibly golf carts, some of which are used relatively little but spend most of their time parked in the sun.

An inventor from Michigan, USA has built a street legal, licensed, insured, solar charged electric scooter. It has a top speed controlled at a bit over 30 mph, and uses fold-out solar panels to charge the batteries while parked.

Electric Vehicle with Solar Assist

A Swiss project, called "Solartaxi", has circumnavigated the world. The first time in history an electric vehicle (not self sufficient solar vehicle) has gone around the world, covering 50000 km in 18 months and crossing 40 countries. It is a road-worthy electric vehilce hauling a trailer with solar panels, carrying a 6 m² sized solar array. The Solartaxi has Zebra batteries, which permit a range of 400 km without recharging. The car can also run for 200 km without the trailer. Its maximum speed is 90 km/h. The car weighs 500 kg and the trailer weighs 200 kg. According to team leader Louis Palmer, the car in mass production could be produced for 16000 Euro. Solartaxi has toured the World from July 2007 till December 2008 to show that solutions to stop global warming are available and to encourage people in pursuing alternatives to fossil fuel. Palmer suggests the most economical location for solar panels for an electric car is on building rooftops though, likening it to putting money into a bank in one location and withdrawing it in another.

Louis Palmer standing in the Solartaxi.

Solar Electrical Vehicles is adding convex solar cells to the roof of hybrid electric vehicles.

Limitations and challenges

Fitting battery electric vehicles with solar cells would extend their range and allow recharging while parked anywhere in the sun. However, with present and near-term engineering considerations, it seems that the more likely place for solar cells will generally be on the roofs of buildings, where they are always exposed to the sky and weight is largely irrelevant, rather than on vehicle roofs, where size is limited. . However, solar cell technology is starting to be used successfully in the powering of electric golf cars and utility vehicles. In the case of both building and vehicles, energy from rooftop panels can be stored in batteries for future use. While some inconveniences might cause challenges, there are limitations to using PV cell:

- **Cost**. While sunlight can provide a free clean source of energy, the creation of PV cells to capture that sunlight is expensive. In 2003, it was found that energy would cost $.30/kWh which is more than double that of residential electricity. These costs have dropped recently with Solar Panel costs coming down further and the reliability of the cells have much improved with thinfilm technology. The cost of Energy will depend on the place of operation as solar radiation differs from place to place.
- **Lifetime**. Even though sunlight has no lifespan, PV cells do. The lifetime of a solar module is approximately 30 years. Standard photovoltaics often come with a warranty of 90 % (from nominal power) after 10 years and 80 % after 25 years. However, in automotive purposes they need to be sealed well if meant to operate efficiently for decades in all weather conditions.

Plug-in hybrid and solar vehicles

An interesting variant of the electric vehicle is the triple hybrid vehicle—the PHEV that has solar panels as well to assist.

The 2010 Toyota Prius model will have an option to mount solar panels on the roof. They will power a ventilation system while parked to help provide cooling. An unconfirmed report in January 2009 stated that Toyota is working on an all-solar vehicle.

Chapter- 9

Bicycle Sharing System

Vélo'v in Lyon

Bicycle sharing systems (also known as: community bicycle programs, yellow bicycle programs, white bicycle programs, public bikes, or free bikes) are increasingly popular and diverse. A number of bicycles are made available for shared use by individuals who do not own the bicycles. Public bicycles are a mobility service, mainly useful in urban environment for proximity travels. It is able to remove three difficulties of daily cycling use: home parking, theft and maintenance of your private bicycle.

The reasons for implementing bicycle sharing systems are as numerous as the forms the systems take. Recently and most notably, municipal governments have promoted systems as part of intermodal transportation, allowing people to shift easily from other forms of transport to bicycle and back again. However, for years community groups have promoted bicycle sharing as an easily accessible alternative to motorized travel, hoping to reduce the carbon footprint of commuting as well as enable residents to become healthier through exercise.

Bicycle sharing systems can be divided into two general categories: *Community Bike programs* organized mostly by local community groups or non-profit organizations; and *Smart Bike programs* implemented by municipalities or through public-private partnerships, as in the case of Paris' Vélib'. The central concept of many of the systems is free or affordable access to bicycles for short trips inside the city, as an alternative to motorised public transport or cars, thereby reducing traffic congestion, noise and air-pollution.

Bicycle sharing is part of a larger sharing movement known as Collaborative consumption.

Types

White bicycles for free use, in Hoge Veluwe national park, the Netherlands.

Bicing in Barcelona.

SmartBike DC rental site in downtown Washington, D.C..

Helsinki city bikes

Stockholm City Bikes, Sweden.

Bicisanvi, San Vicente del Raspeig, Spain.

Barclays Cycle Hire, London, UK started in 2010

A Vélib' station with bicycles, Paris

Bixi in Montreal, Canada

A Vélopop' station, Avignon, France

Vélivert, Saint-Étienne, France

Libélo, Valence, Drôme

Capital Bikeshare, Pentagon City, Arlington, Virginia.

Although users of such systems generally pay to use vehicles that they themselves do not own, sharing systems differ from traditional bike rental. Some are seen as a distinct break, having grown out of free community bicycle programs. Most require a user to become a member, and do not cater to tourists, shoppers, or other casual users. Most of the systems have bicycles available at unattended urban locations; and they operate in a manner that could be seen as "bicycle transit". Most bicycle sharing systems have been undertaken by community groups, public agencies or by public-private partnerships. In these regards they resemble carsharing.

There are many ways to provide community bicycles, but most programs are loosely based around one of the following designs:

Unregulated

In this type of program the bicycles are simply released into a city or given area. In some cases, such as a university campus, the bicycles are only designated for use within certain boundaries. Users are expected to leave the bike unlocked in a public area once they reach their destination.

Bicycle sharing programs without user electronic identification struggle against theft and vandalism. In one program tried in 1993 in Cambridge, United Kingdom, the overwhelming majority of the fleet of 300 bicycles were stolen, and the program was abandoned. Not-for-profit organization BiCyBa released White Bicycles into public use in Bratislava, Slovakia in 2001. During the next three months all the bikes were stolen or destroyed and the project was cancelled. A similar result occurred in Edmonton, Alberta, with 95% of the bikes in the People's Pedal program stolen in the 2008 season.

Deposit

A small cash deposit releases the bike from a locked terminal and can only be retrieved by returning it to another. Since the deposit (usually one or more coins) is a fraction of the bike's cost, this does little to deter theft.

Membership

In this version of the program, bicycles are kept either at volunteer-run hubs or at self-service terminals throughout the city. Individuals registered with the program identify themselves with their membership card (or a smart card, via cell phone, etc.) at any of the hubs to check out a bicycle for a short period of time, usually less than two hours. In many schemes the first half hour is free. The individual is responsible for the bike until it is returned to another hub.

Public-private partnership

Many of the membership programs are being operated through public-private partnerships. Several European cities, including the French cities of Lyon and Paris as well as London, Barcelona, Stockholm and Oslo, have signed contracts with private advertising agencies (JCDecaux in Brussels, Lyon, Paris, Seville and Dublin; Clear Channel in Stockholm, Oslo, Barcelona, Perpignan and Zaragoza) that supply the city with thousands of bicycles free of charge (or for a minor fee). In return, the agencies are allowed to advertise both on the bikes themselves and in other select locations in the city. These programs also prevent theft by requiring users to purchase subscriptions with a credit card or debit card (this option requiring a large, temporary deposit) and by equipping the bike with complex anti-theft and bike maintenance sensors. If the bike is not returned within the subscription period, or returned with significant damage, the bike sharing operator withdraws money from the user's credit card account. Some other programs are not linked to an advertising deal, for example Smoove with Vélomagg' in Montpellier, Vélopop' in Avignon, Libélo in Valence and Vélivert in Saint-Étienne, but can be financed by public support.

Long-term checkout

Sometimes known as Bike Library models, these bicycles may be given free of charge, for a refundable deposit, or sold at a reduced price. They are assigned to one person who will typically keep the bike for months or years and lock it between uses. A disadvantage of this model is the much lower using frequency, around three uses per day as compared to between 10 to 15 uses per day with other bike sharing models.

Advantages of long term use include a familiarity the rider gets with their bicycle and a mode of travel that is always ready for use. The bicycle can be checked out like a library book, a liability waiver can be collected at check out, and the bike can be returned any time. A Library Bike in a person's possession can be chosen for some trips instead of a car, thus lowering car usage. This model requires less repair as users tend to care for the bikes as their own. The LibraryBikes.org program of the City of Arcata, California has loaned over 4000 bicycles with this system.

Partnership with railway sector

In a national-level programme which combines a typical rental system with several of the above system types, a passenger railway operator or infrastructure manager partners with a national cycling organization and others to create a system closely connected with public transport. These programs usually allow for a longer rental time of up to 24 or 48 hours, as well as tourists and round trips. In some German cities the national rail company offers a bike rental service called Call a Bike.

Partnership with car park operators

Some car park operators such as Vinci Park in France lend bikes to their customers who park a car.

Operations

Many of the community-run bicycle programs paint their bicycles in a strong solid colour, such as yellow or white. The reasons are, firstly, that as the fleet of coloured bicycles begin to appear around the city, it helps to advertise the program. And secondly, many programs paint over the brand name and other distinguishing features of the bicycle, some even going so far as to paint every component such as the pedals, shifters, and wheels. This is helpful in deterring theft since the painted bicycle has little resale value.

Large scale bike sharing programs, however, have designed their own bike with singular designs of frame and other parts to prevent disassembly and resale of stolen parts.

Another advantage of bike sharing systems is that the smart cards allow the bikes to be returned to any station in the system, which facilitates one-way rides to work, education or shopping centres. Thus, one bike may take 10-15 rides a day with different users and can be ridden up to 10,000 km (6,200 mi) a year (citing Lyon, France). The distance between stations is only 300–400 metres (980–1,300 ft) in inner city areas.

It was found—in cities like Paris and Copenhagen—that to have a major impact there had to be a high density of available bikes. Copenhagen has 2500 bikes which cannot be used outside the 9 km^2 (3.5 sq mi) zone of the city centre (a fine of DKr 1000 applies to any user taking bikes across the canal bridges around the periphery). Since Paris' Velib program operates with an increasing fee past the free first half hour, users have a strong disincentive to take the bicycles out of the city centre.

History

The earliest community bicycle program, or at least the most legendary, was started in the 1960s by Luud Schimmelpenninck in association with the radical group Provo in Amsterdam, the Netherlands. This so-called **White Bicycle** Plan provided free bicycles that were supposed to be used for one trip and then left for someone else. Within a month, most of the bikes had been stolen and the rest were found in nearby canals. The program is still active in some parts of the Netherlands (the Hoge Veluwe National Park; bikes have to stay inside the park). It originally existed as one in a series of White Plans proposed in the street magazine produced by the anarchist group PROVO.

In 2000 Schimmelpenninck admitted that "the Sixties experiment never existed in the way people believe", that "no more than about ten bikes" had been put out on the street "as a suggestion of the bigger idea", but the police confiscated the bicycles within a day.

In 1974 the French city of La Rochelle launched a free bike program featuring yellow bicycles that were free to take and use. It is regarded as one of the first successful bike sharing programs.

Other bike sharing systems were evolving to reduce the operating overhead as well as find other sources of funding. The first system of this 'generation' was Copenhagen's ByCyklen **- City Bikes**, launched 1995. This was the first large-scale urban bike share program featuring specially-designed bikes with parts that could not be used on other bikes. Riders pay a refundable deposit at one of 100 special bike stands and have unlimited use of a bike within a specified area. The scheme is funded by commercial sponsors. In return, the bikes carry advertisements, which appear on the bike frame and the solid-disk type wheels. Helsinki had a similar scheme, using bicycles available at over 26 stands for a €2 deposit, which is refundable at any other stand. This model of community bike has spread to many other cities. Lack of funding forestalled Helsinki city bikes in 2010.

The next innovation was to use smart cards. **Bikeabout**, launched in 1996 by Portsmouth, UK, included cards with magnetic stripes that the students would swipe to sign out a bike. A similar system was set up in Rotterdam. They were not particularly successful, as the number of stations and operating times were seriously limited.

The launch of Velo'v in Lyon, France turned out to be a watershed. A bike unfriendly city prior to the launch of Velo'v in 2005, Lyon saw an increase of 500% in bicycle trips, a quarter of which were due to the bike sharing system. Velo'v introduced a number of innovations that were later copied by Velib and most other systems, including electronic locks, smart cards, telecommunication systems and on board computers.

One of the first community bicycle projects in the United States was started in Portland, Oregon in 1994 by civic and environmental activists Tom O'Keefe, Joe Keating and Steve Gunther. It took the approach of simply releasing a number of bicycles to the streets for unrestricted use. Portland's **Yellow Bike Project** was an amazing publicity success, but proved unsustainable initially due to theft and vandalism of the bicycles. The program was later revised to operate under a more restrictive system. Since then many community projects around the country have attempted similar models and met with varying degrees of success.

Madison, Wisconsin, for instance, had a program where specific bicycles, always painted red, were available for the use of anyone coming across them on the street (especially used on State Street between the UW campus and the capitol). The only rule regarding their use was that they were always to remain outside and unlocked for any passerby to use. This program (called **Red Bikes**) has since been modified to include deposits for the bicycle and a lock and is only available from spring (when all snow has melted) to November 30.

A similar program, **BikeShare**, operated by the Community Bicycle Network (CBN) in Toronto from 2001 to 2006, was North America's most successful *community* bicycle system, but has paled in comparison with the launches of the large-scale systems such as Washington, D.C.'s Capital Bikeshare and Montreal's Bixi. BikeShare was designed to attempt to overcome some of the theft issues by requiring yearly memberships to sign out any of the 150 refurbished bikes locked up at 16 hubs throughout central Toronto. At its height over 400 members could sign out a bike from any hub for up to 3 days. The hubs were located at stores, cafes and community centres where the staff would volunteer their time to sign bikes out and in. The major failing of such more secure community bike programs was that it required a lot of administration, but could only charge users a portion of the overall costs. Over 80% of its operating costs had to be covered through grants as users were unlikely to spend more than $50 per year for a membership. By 2006 CBN was unable to secure enough private and government grants to continue operating BikeShare. BikeShare was very popular and did not have any major problems with theft or loss, but without a secure source of funding it was not possible to operate.

Current programs

Europe and North America

The current popularity of bike sharing is attributed by many to Paris' successful launching in 2007 of Vélib’, a network of 20,000 specially designed bicycles distributed among 1450 stations throughout Paris. Vélib’, in turn, followed Lyon's Vélo'v success and is now considered the largest system of its kind in the world. Bike sharing has spread to many other European cities and is currently enjoying surging popularity in North America. Two of more prominent launches have been a small program started in Washington D.C., and a much larger program, called Bixi, launched in Montreal in the spring of 2009.

Montreal's Bixi program became North America's largest bike sharing system in May 2009. Montreal began a limited pilot project of Bixi bike-sharing bicycles in fall 2008. Bixi is an effort to encourage locals and tourists to make use of the city's already well-established network of bike paths. The rental bicycles are available from depots located throughout the city, where bikes can be rented from automated stations using a credit card. The system was expanded twice during 2009, with 5000 bicycles available at 400 depots. The fee schedule is designed to discourage day-trippers. In 2008 the Bixi program was ranked by Time Magazine as the 19th best invention in their 50 Best Inventions of 2008; recent newspaper editorials have been equally positive, always pointing out that although the bike fleets aren't yet theft-proof the program hasn't yet won over big government support either.

Some of the systems use mobile phones to reserve or sign out bikes. In the UK, OYBike is currently delivering small-scale operations which may grow to this scale organically at 2 Universities, 3 Business Parks, and 3 London Boroughs (and a Hotel chain in London). Like Berlin's Call-a-Bike, OYBike uses mobile phone technology to log use and charge for hires and can set up hire points in as little as 10 minutes. Many of the business users can reclaim the cost of leasing bikes and hire points as part of a workplace cycling scheme or green travel plan. Research also reveals that for many major London rail stations an unknown number of the bikes parked are used only a couple of times per week, and the potential to replace these with hire bikes is widely ignored by UK rail operators.

London mayor Boris Johnson promised that an extensive bicycle sharing system modelled on the Paris Velib' system would be introduced in London during his first term in office. It is located mainly within the central zone, roughly bounded by the 'Zone 1' area of the Transport for London zoning system, and will comprise 400 docking stations when complete, at roughly 300 metre intervals. This program began operating on 30 June 2010, to great success. The scheme is sponsored by Barclays Bank and is known as Barclays Cycle Hire.

Zotwheels Bike Share at the University of California Irvine.

In the Fall of 2009, the University of California Irvine introduced its Zotwheels automated bike share program. Students and university employees may sign up for a Zotwheels membership card, which enables them to check out a bike from any bike station located throughout campus and drop it off at any other station. The program was developed as a collaboration between the UCI Parking and Transportation Services, The Collegiate Bicycle Company, CSL Ltd, and Miles Data Technologies.

Asia

Bike sharing has also become popular in China. Hangzhou's bike sharing system has 50,000 bikes, surpassing Paris' Velib program which offers over 20,000 bikes. Bike sharing stations can be found in Hangzhou every 100 meters compared to the 300 meters in Paris. The first hour is free to users in Hangzhou, followed by 1 yuan ($0.15) for the first hour, 2 yuan the second hour, and 3 yuan each additional hour. During their first year operation, no bikes were stolen and very few were damaged or vandalized compared to the half that were stolen or damaged in Paris. In preparation for the 2010 World Expo in Shanghai, China; Shanghai has launched a bike share program which are accessible by RFID cards. Users can purchase 100 ride credits for about $30. Short rides are rewarded credits and longer rides subtract credits once the bikes have been re-docked. Shanghai plans to expand to 3,500 Bicycle Hot Spots throughout the entire city by 2010.

Australia

Example of Melbourne Bike.

BikeShare.Tel, providing Melbourne cyclists with information about the bike stations.

The first municipal bicycle share system in Australia was launched in Melbourne in June 2010. The scheme is based on the Montreal BIXI system and was launched initially with only 10 stations, with the aim of having 50 stations by July 2010. During the first week of operation, the system was only used 253 times. The legal obligation to wear a bicycle helmet at all times may be contributing to the disappointing take-up of the Melbourne scheme so far. In contrast, the Dublin bike scheme, with 450 bikes available, racked up 1 million journeys in less than a year.

Grassroot efforts have begun promoting the system, often unintentionally such as when a cyclist using the system has been asked a number of questions by pedestrians. Mobile phone optimized websites have also been created, such as BikeShare.Tel, allowing users to locate stations and see bike availability.

Subscriptions for a Velib style community bike hire scheme by JCDecaux for Brisbane started on the 1st September 2010 with bikes available from 1st October 2010 at 150 stations from the University of Queensland to Tenerrife.