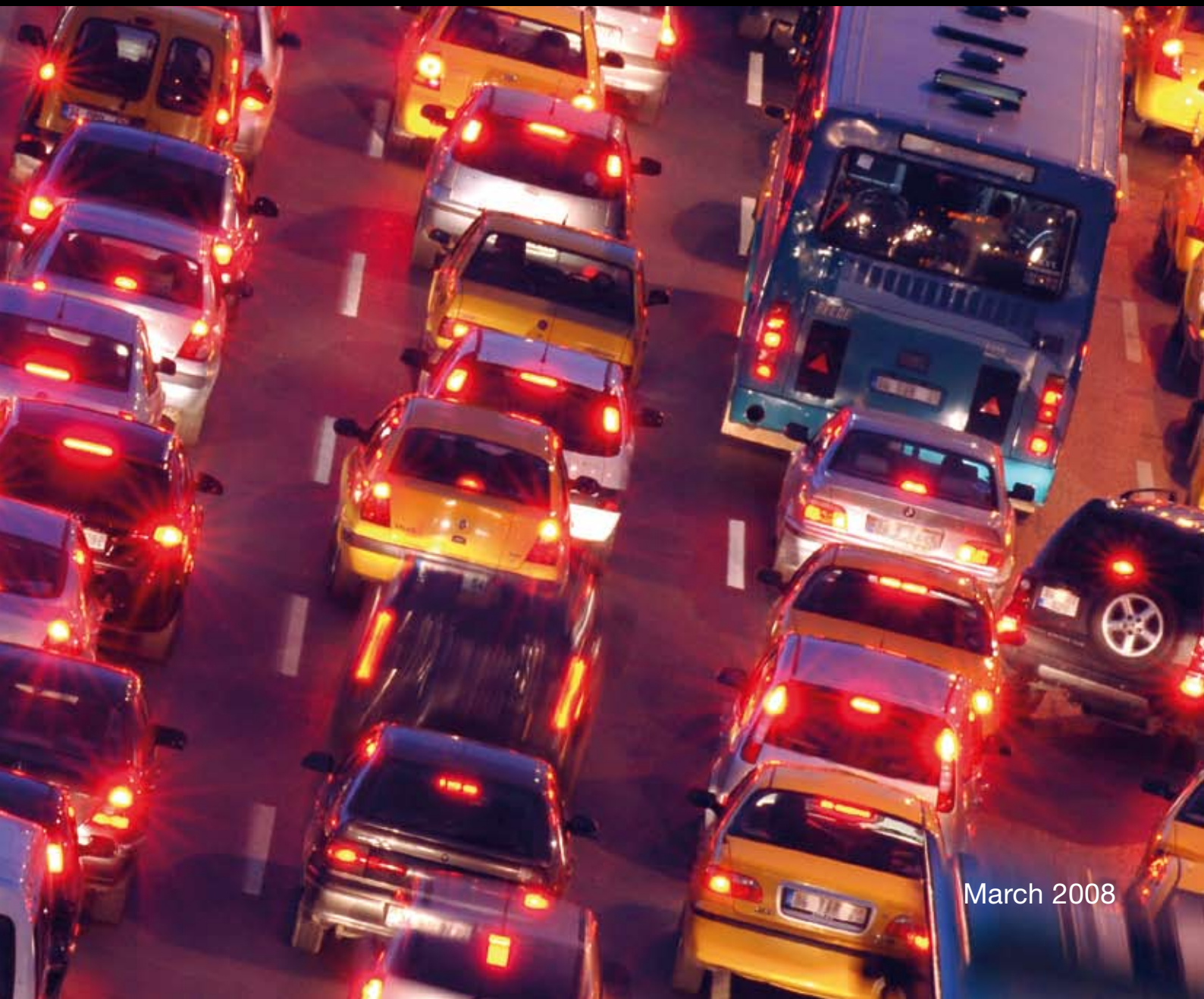
WWF

for a living planet®

PLUGGED IN

THE END OF THE OIL AGE

Summary Report

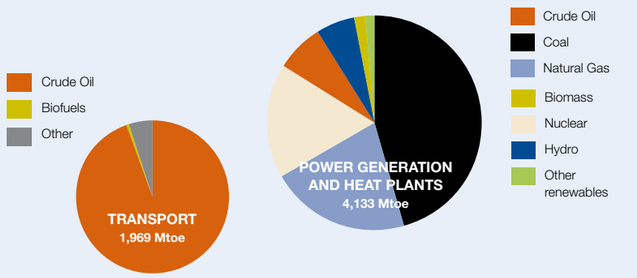


March 2008

TRANSPORT IS 95% DEPENDENT ON OIL

A century of economic and social development has been made possible by a transport sector – enabling the movement of goods, services and people – which is ninety-five percent dependent on liquid hydrocarbon fuels derived from crude oil. No other sector is so utterly reliant on a single source of primary energy.

GLOBAL PRIMARY ENERGY MIX (2004): TRANSPORT VERSUS HEAT AND POWER



Data source: IEA World Energy Outlook 2006

Comparison of the global primary energy demand mixes of the tranport sector and heat and power plants, highlighting the unique fuel specificity of transport. This oil dependency is highly problematic as it represents an enormous barrier to achieving energy security through diversification.

The circumstances in which this transport sector evolved have changed beyond recognition. While one hundred years ago crude oil was abundant, cheap, and most areas of society were unaware of the negative consequences of its use, today anthropogenic climate change, deteriorating urban air quality, destruction of essential ecosystems, and escalating political squabbles over diminishing and increasingly expensive crude oil resources are the backdrop to the global energy system.

Today, around half of every barrel of crude oil is converted into transportation fuels, and the share continues to grow. The automotive sector accounts for roughly three-quarters of the total transport sector demand for primary energy, with the remainder shared equally between aviation and shipping. It is no exaggeration to say that the oil and transport sectors are inextricably linked.

If we are to stand any chance of reversing the negative trends, this link must end by transitioning to a transport paradigm which is both highly efficient and compatible with a sustainable renewable energy future. WWF's book *"Plugged In: The End of the Oil Age"* focuses on solutions to break this link.

"[S]ince the marriage of fossil fuels and the internal combustion engine some hundred years ago, the fortunes of our industries have been tied together."
Rob Routs, Royal Dutch Shell, speech delivered at "Fuelling the Automotive Future", Amsterdam, 28/05/06.

"[A]n attempt by any outside force to gain control of the Persian Gulf region will be regarded as an assault on the vital interests of the United States of America, and such an assault will be repelled by any means necessary, including military force."
US President Jimmy Carter, 1980 State of the Union Address.

Security comes through diversification

Energy security frequently dominates the political debate, particularly among the most powerful and fast developing economies in the world. Throughout the 20th Century, and in the early years of this millennium, access to crude oil has provided the backdrop for many of the world's titanic military struggles.

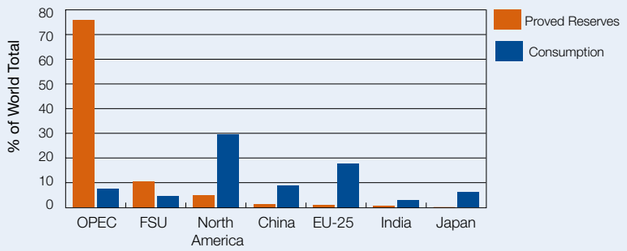
One of the keys to security of supply comes through diversification of supply. However, remaining oil reserves are concentrating in relatively few countries, and this erects a significant barrier to diversification. More than three-quarters of all remaining reserves are located in the eleven OPEC member states. With the exception of Russia, all the major oil consumers – US, EU, China, Japan, and India – are significant net importers today. This geological fact of life makes crude oil a potent source of political and military conflict.

International Oil Companies (IOCs) face similar pressures. Six of the ten most powerful corporations in the world – as measured by revenues – operate in the oil sector. But since financial markets value oil companies by their ability to replace reserves – which they can no longer access freely – the concentration of reserves in the hands of the few, coupled with a recent spate of resource nationalism, represents a direct threat to their ongoing prosperity.

Together with the major world economies of today and tomorrow, IOCs find themselves collectively facing a liquid fuels crisis. This crisis is reflected in the high price of crude oil – reaching a record US$ 100/bbl in 2007 – as diminishing conventional supplies and infrastructural bottlenecks are unable to satisfy rising demand for transportation services. In response, governments and IOCs are forced to develop substitutes for crude oil, which belong to a family loosely referred to as 'alternative fuels'.

But many of the oil substitutes which are currently being pursued have environmental impacts significantly worse than conventional crude oil. Their development is driven by the unchallenged dominance of the internal combustion engine (ICE) in automotive transport. This is the root cause of the problem that we must tackle.

CRUDE OIL GEOGRAPHY IN 2006: RESERVES VS CONSUMPTION



Data source: BP Statistical Review 2007

The geographical distribution of conventional crude oil resources bears no relationship to the areas of high consumption. Remaining proved reserves are gradually concentrating in relatively few countries: OPEC member states and the nations which comprise the former Soviet Union (FSU).

THE CLIMATE CHANGE IMPERATIVE

Excessive concentrations of greenhouse gases (GHGs) in the atmosphere are largely caused by the global economy's dependence on fossil fuels.

Climate change is one of the biggest challenges facing the world today. In 2005, the average global temperature was 0.74 degrees Celsius (°C) higher than a century earlier. Scientists attribute the planet's increasing temperature to excessive concentrations of greenhouse gases (GHGs) in the atmosphere, which are largely caused by the global economy's dependence on fossil fuels. It is increasingly accepted that the average increase in global surface temperatures must stay below 2°C compared with the pre-industrial era. This threshold has been chosen because of the extreme risks to human populations posed by an increase beyond 2°C, in particular the combined threats of disease, coastal flooding, and food and water shortages.

In order to avert the worst impacts of climate change, the global economy must as soon as possible reduce emissions of carbon dioxide (CO_2), the main greenhouse gas, and move towards sustainability. Within the power sector – the number one source of CO_2 emissions today – a broad range of sustainable options exist, many of which are becoming increasingly competitive as climate change policies penalise emissions. Meanwhile, the transport sector – currently responsible for one-quarter of energy-related GHG emissions worldwide – looks set to increase its carbon intensity as unconventional oils are exploited to satisfy the steadily growing demand for liquid hydrocarbon fuels.

The environmental impacts of unconventional oils are extreme

Greenhouse gas emissions from oil sands processing are up to three times higher than from conventional petroleum production.

Oil sands, coal-to-liquids (CTL), and gas-to-liquids (GTL) technologies are touted by IOCs as the answer to the liquid fuels crisis. Such technologies allow development of liquid hydrocarbon fuels from oil sands, coal and natural gas respectively. Their greatest strength is compatibility with existing infrastructure and engine systems – but this is also their fundamental limitation, as they sustain our dependency on liquid hydrocarbon fuels and internal combustion engines.

All of the major oil companies are converging on the oil sands of Alberta, seen as a new 'gold rush' because Canada offers such a stable investment climate. However, the oil sands developments are devastating to the local environment, as well as being extremely energy-intensive to extract and process. Greenhouse gas emissions from oil sands processing are up to three times higher than from conventional petroleum production.

The life-cycle CO_2 impact of CTL fuels is at least twice that of conventional petroleum.

The only sustainable approach to the crisis is to tackle its root cause: the prevalence of the internal combustion engine.

Gas-to-liquids technology delivers fuels which are clean burning, in terms of air pollutants like sulphur dioxide (SO_2), nitrogen oxides (NOx), and particulate matter. But the energy-intensity of the process represents an unjustifiable waste. GTL fuels are no better than conventional petroleum on a life-cycle basis. Natural gas is also likely to show supply constraints similar to oil. Challenged to decarbonise our energy system, natural gas must be deployed in heat and power generation, displacing dirty coal and thereby realising its greatest carbon abatement potential.

Coal-to-liquids programmes are strong indicators of a 'state of emergency'. CTL has only prospered in two notable episodes during the 20th Century: Nazi Germany and Apartheid South Africa. Nations with limited access to crude oil and large domestic coal reserves may see CTL as a way to reduce expensive oil imports. However, the life-cycle CO_2 impact of CTL fuels is at least twice that of conventional petroleum. In addition, the process is incredibly water-intensive. China, the US, India, Australia and South Africa are all currently pursuing CTL programmes.

TIME FOR CHANGE

The only sustainable approach to the crisis is to tackle its root cause: the prevalence of the internal combustion engine coupled to a mechanical drivetrain, an outdated combination which is inherently inefficient in converting stored chemical energy into kilometres.

Unnecessary journeys can be eliminated through smarter urban planning, encouraging behavioural change, and switching from private to public transport modes. Doubling the effective fuel economy of a private car is as easy as carrying a passenger. Vehicle downsizing, lightweighting, aerodynamic improvements, efficient auxiliary components, lower maximum speed limits, reducing the rolling resistance of tyres and simple hybridising are worthwhile in that all will increase the efficiency of the automotive fleet. Yet none of these measures will do anything to reduce the transport sector's dependency on liquid hydrocarbon fuels.

Automotive transport is ripe for transformational change. We need to accelerate the commercialisation of vehicles with diversified primary energy sources, high efficiency and compatibility with a sustainable, renewable energy future. The electrification of automotive transport offers a promising way to achieve this objective.

Electric vehicles are highly energy efficient

Grid-connected vehicle technology – enabling all or part of every journey to be powered by electricity taken from the grid – is available based on existing infrastructure and current technology. Battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) – which may be supplemented by sustainable biofuels for range extension – can dramatically reduce the crude oil dependency of automotive transport in a highly efficient and sustainable manner.

Even based on today's fossil-rich energy mix, electric vehicles can deliver an overall reduction of greenhouse gas emissions.

Electric vehicles still need energy, and that energy today comes mostly from fossil fuels. However, the electric powertrain is up to four times more efficient than its conventional mechanical counterpart. This means electric vehicles consume far less primary energy per kilometre travelled, so that even based on today's fossil-rich energy mix, electric vehicles can deliver an overall reduction of greenhouse gas emissions. In addition, electric vehicles can contribute to improving urban air quality and reduce noise levels.

For any given resource, electricity beats liquid fuels

Whether the starting point is crude oil, natural gas, coal, or biomass, electric vehicles will emit fewer GHG emissions per kilometre travelled than their conventional mechanical rivals. For example, the latest coal-fired power plants can deliver three times as many automotive kilometres as CTL plants, for the same life-cycle CO_2 emissions. Thus there can be no rational argument for CTL programmes on the grounds of energy security, nor climate security.

Electric vehicles get cleaner over time

The power sector is set to decarbonise over time as climate change policies penalise CO_2 emissions from large stationary sources such as power plants. Physical renewable energy technologies – wind, solar-thermal, solar-PV, geothermal, hydro, wave, tidal – will become increasingly competitive and will hopefully form the major share of our electricity mix within a few decades. From these techniques it is impossible to refine liquid hydrocarbon fuels such as diesel or gasoline. Only vehicles which are capable of receiving electricity from the grid will benefit from the future decarbonisation of the power sector.

Why electric vehicles will succeed in the future

Electric vehicles are not new. In 1900, electric vehicle sales outstripped their gasoline-powered competitors. However, the decision criteria in those days were very different: oil was cheap and abundant, and the external costs of using it were largely invisible or unknown. Thus the internal combustion engined vehicle (ICEV) emerged as the dominant technology, since it was less expensive and not limited by battery capacity or recharging times. A century of infrastructural development based around the ICEV has created 'lock in', which has enabled the incumbent suppliers to hold disruptive technologies at bay. It is no coincidence that nine of the ten largest corporations on Earth are either oil companies or automotive manufacturers.

It is no coincidence that nine of the ten largest corporations on Earth are either oil companies or automotive manufacturers.

Today, however, crude oil reserves are diminishing and concentrating in relatively few states and climate change impacts are knocking on the door. The grave risks posed by climate change demand that we decarbonise our economy as quickly as possible, therefore we can find no answers in energy-intensive unconventional oils.

In recent years, the cost and performance of advanced batteries have improved dramatically. And plug-in hybrid electric vehicles (PHEVs) – electric vehicles with an onboard generator – can overcome the perceived range limitations which hamper the market acceptance of battery-electric vehicles (BEVs). The technology is proven, and requires no significant new infrastructure. BEVs and PHEVs supplemented with sustainably produced biofuels are compatible with a future in which all of our energy services derive from sustainable renewable resources. And because electric vehicles are so much more efficient than conventional mechanical vehicles at converting stored energy into kilometres, the overall system demand for energy – and CO_2 emissions – will be reduced, helping us fight climate change.

The hype about hydrogen

Oil companies continue to promote a vision of an automotive future based around hydrogen and fuel cells. It is easy to understand why: oil companies are expert in the production, distribution, and retail of flammable fluids via a firmly established network of roadside filling stations. However, based on the information available to us today, the hydrogen pathway makes little sense either energetically or economically.

As a carrier of sustainable renewable energy, electricity can be three times more efficient than hydrogen.

Assuming that in the future all of our energy services will be derived from sustainable renewable sources, the hydrogen / fuel cell solution suffers bi-directional efficiency losses as hydrogen must first be manufactured *from* electricity and then recombined to *create* electricity within the fuel cell. As a carrier of sustainable renewable energy, electricity can be three times more efficient than hydrogen. Furthermore, an entirely new parallel infrastructure will need to be developed before hydrogen-powered vehicles can make any impression on the automotive market.

POLICY INTERVENTIONS

By definition, transformational changes of this type require disruption to the status quo. We cannot depend upon today's dominant transport solution providers to drive – or even support – a shift away from liquid hydrocarbon fuels. Strong policies will be required to dismantle market barriers to superior technologies, and to remove hidden and overt subsidies which perpetuate the liquids paradigm. It is essential that policies accounting for all externalities assign the correct responsibility to each of the actors involved.

Strong policies will be required to dismantle market barriers to superior technologies, and to remove hidden and overt subsidies which perpetuate the liquids paradigm.

- Vehicle manufacturers should improve the efficiency of their products

  As with all energy consuming appliances, vehicle manufacturers should be responsible for improving the efficiency of their products. Existing metrics which refer to liquids consumption (in gallons or litres) or CO_2 emissions presuppose that vehicles must consume hydrocarbon fuels onboard. In order to avoid erecting barriers to superior technologies, vehicle efficiency standards should therefore be expressed in units of energy consumed as a function of distance travelled, e.g. kilowatt-hours per kilometre (kWh/km), and successively tightened.

- Energy suppliers should decarbonise their energy supplies

  Suppliers of energy, whether in the form of liquids, gases, or electricity, must be held responsible for reducing the carbon content of that energy (expressed for example as gCO_2/kWh). For liquid and gaseous fuel suppliers, this may be achieved through Low Carbon Fuels Standards which encourage the introduction of sustainably produced biofuels. For electricity suppliers, a wide range of policies and carbon abatement technologies are available, including a variety of renewable resources, fuel switching from coal to natural gas and potentially carbon capture and storage (CCS).

- Incentives for consumers to make the right choices

  Customers can then be encouraged through financial incentives to choose the cleanest and most efficient solution. National and local governments should take the lead in fostering a market demand for grid-connected vehicles, through public procurement programmes and fiscal policy. Supporting infrastructural measures such as installing public charging facilities, providing access to priority traffic lanes, or offering exemptions from road tolls may play an important part in promoting the use of vehicles which are demonstrably less damaging to human health and the environment.

New business opportunities abound

In the private sector, companies will likely emerge which are today unknown to automotive transport. Innovative business models will come to the fore, which offer integrated mobility services as the sector moves away from the traditional product model. Electrical utilities and renewable energy suppliers will immediately identify the opportunities associated with transport electrification, and not only from the perspective of increasing sales. The grid management potential of electric vehicles will be explored in partnership with technology companies and vehicle manufacturers to further enhance the efficiency – and expedite the decarbonisation – of the power generation and distribution system.

Where electric vehicles make the most sense

In terms of geography, the electrification of automotive transport will appeal to any country or region which (i) is a net importer of crude oil; (ii) wishes to use indigenous energy resources as efficiently as possible; (iii) has a large, or fast growing, road transport sector; (iv) has a large, or fast growing, automotive industry; (v) possesses, or intends to invest in, widespread electricity infrastructure; and (vi) is committed to tackle rising greenhouse gas emissions. Prime candidates include North America, the EU, Japan, China, and India.

Unintended negative consequences

Despite the obvious benefits of automotive electrification, we must remain wary of unintended negative consequences. Advanced battery systems will demand the extraction and processing of raw materials, associated energy consumption, the development of a 'second life' industry for used batteries and a scaling up of existing waste management programmes. Electricity consumption will necessarily rise as liquid fuel demand falls, so technologies to mitigate large static emissions should be implemented; strategies which drive the power sector towards efficient sustainability will go hand-in-hand with the transformation of transport.

Another potential risk is that energy efficient devices may be used more often and in greater numbers than their inefficient predecessors, resulting in a net increase in energy consumption. Expanded mass transit and smart growth community planning efforts are the necessary corollary strategies.




CONCLUSIONS

With eight hundred million vehicles in the world today, potentially doubling by 2030, the longer we ignore the fundamental dependency of the transport sector on liquid hydrocarbon fuels, the more we will be forced to confront additional challenges: pressure on governments to open up protected areas for oil exploration, widespread support for destructive unconventional 'solutions' like oil sands and coal-to-liquids, increasing geopolitical conflicts and human rights abuses, and rapidly growing CO_2 emissions from tailpipes.

Battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) can dramatically reduce the oil dependency of automotive transport in an efficient and sustainable manner.

Grid-connected vehicles – enabling all or part of every journey to be powered by electricity taken from the grid – are a ready-to-use solution to such challenges based on existing infrastructure and current technology. Battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) can dramatically reduce the oil dependency of automotive transport in an efficient and sustainable manner. The inherent efficiency of the electric powertrain means that the electron pathway can be more efficient than the liquid pathway for any given resource. There can be no justification for the wasteful and carbon-intensive 'alternative fuels' from coal, natural gas or oil sands.

An environmentally and economically sustainable transport sector will not be achieved through electrification alone. Additional measures to reduce overall demand through smarter urban planning, modal shift to mass transit, from road to rail, increased use of telecommunications technologies, and car sharing will make necessary and significant contributions. Nevertheless, road-based transport will likely continue to play a vital role in the delivery of essential mobility services which underpin economic and social development. Automotive electrification can ease the necessary transition towards *a transport paradigm which is both highly efficient and compatible with a sustainable renewable energy future.*

The WWF book "Plugged In – The End of the Oil Age" can be downloaded from www.panda.org/climate or www.panda.org/eu

Requests for a written copy should be addressed to:
Florence Danthine
Tel: +32 2 743 88 01
Email: FDanthine@wwfepo.org

Published March 2008 by WWF-World Wide Fund for Nature (formerly World Wildlife Fund).

Cover: © Ezequiel Scagnetti
Inside: © CC vision, Ezequiel Scagnetti, WWF/Nigel DICKINSON, CC vision, WWF/Fritz PÖLKING, WWF-Canon/Michel GUNTHER, Jiri Rezac/WWF-UK, Calcars, Adam Vaughan - www.thegreenguy.co.uk, WWF-Canon/Adam OSWELL, WWF-Canon/Tanya PETERSEN, WWF-Canon/Andrew KERR, WWF-Canon/Chris Martin BAHR, Th!nk City, Segway Inc., Wallorail, WWF/Bruno Arnold, CC vision.

Design: Imprimerie Les Editions Européennes, Yesmine Lawton.
Printed by Imprimerie Les Editions Européennes on FSC paper.

The oil and transport sectors are inextricably linked.
If we are to stand any chance of reversing climate change, destruction of essential ecosystems and geopolitical tensions, this link must be broken by transitioning to a transport paradigm which is both highly efficient and compatible with a sustainable renewable energy future.

WWF

WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature, by:

- conserving the world's biological diversity
- ensuring that the use of renewable natural resources is sustainable
- promoting the reduction of pollution and wasteful consumption

for a living planet®

WWF European Policy Office
168 avenue de Tervurenlaan Box 20
B-1150 Brussels

Tel: +32 2 743 88 00
Fax: +32 2 743 88 19
E-mail: wwf-epo@wwfepo.org

www.panda.org/climate
www.panda.org/eu