Summary of Results
Foresight Observatory for International Markets

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The Future of Green Car Technologies

Key ideas

1. Sustainable mobility will require the interplay of different drive systems and alternative fuels, including the use of renewable energy in the form of biofuel, electricity and hydrogen.

2. International energy policies will be the primary factor in determining how soon (renewable) electric energy and hydrogen become the main energy vectors.

Introduction

Vehicles in the future will be influenced by a wide range of different customer demands on design, the environment, dynamics, variability, comfort, safety, infotainment and cost effectiveness.

- **Reduction of fuel consumption:** The power train is the core component of an automobile. The market is still dominated by internal-combustion piston engines, in which petrol or diesel is combusted. The efficiency of internal combustion engines in converting the mechanical energy generated is about 30%. Electrification of the power train is increasing with the use of hybrid systems, but the success of electric drives depends to a large extent on technical advances in energy storage. As in the past, present-day vehicles are mainly made of cost-efficient sheet steel and high-strength steel. Light metals such as aluminium and magnesium as well as fibre-composite materials are, however, being increasingly used in order to reduce vehicle weight.

Brief Review of Key Applications

- **TSI engines:** The efficiency of spark-ignition engines has been steadily improved in recent years. The introduction of innovative supercharger systems in connection with petrol direct injection and modern downsizing concepts has improved vehicle dynamics and at the same time reduced fuel consumption. The reduction in torque and power is overcompensated by means of one- or two-stage charging using a mechanical supercharger and an exhaust turbocharger or two exhaust turbochargers of different sizes.

- **Dual-clutch gearbox:** The transmission systems in current automobiles continue to be dominated in Europe by the classic manual shift transmissions and in the United States and Japan by stepped automatic transmissions with hydrodynamic torque converter. Manual transmission offers the best efficiency, great robustness and low manufacturing costs. By contrast,

the stepped automatic transmission offers the driver a high degree of comfort and convenience; the car moves off smoothly from a stationary position and the jerk-free automatic gearshifts do not interrupt traction. In this context, it is logical to combine the advantages of both transmission systems in a new transmission generation: the dual-clutch gearbox. This transmission consists of two partial transmissions combined in one housing. The odd gears and the reverse gear are assigned to partial transmission 1, and the even gears are arranged in partial transmission 2. Each subgearbox has its own clutch. This enables the gears to be changed with no interruption of traction, as the two gears are synchronised and one clutch simultaneously closes while the other opens.

- **Innovative vehicle lighting:** The demand for automobiles that consume less fuel, combined with special design requirements, is driving the development of high energy consuming electrical components, especially car lights, in new directions. In many vehicles, functions such as parking, brake, indicator and day-driving lights are already being performed by LED modules. The maximum connected load of electrical consumers in the vehicle exterior lighting system can be reduced by up to 75% by replacing conventional lights with LED lamps.

- **Fuel cells:** The first fuel cell applications were used to supply power for space missions and used the hydrogen and oxygen on board the spacecraft as propellants for the rockets. They have been tested in public-transport bus systems.

- Direct **methanol fuel cell systems** in the power range of several tens of watts are in use on the military and leisure markets, and several companies manufacture hydrogen-fuelled polymer electrolyte membrane fuel cells for groundbreaking remote and uninterrupted power supply applications.

Some Key Trends

- **Electrification of the power train:** Hybrid drives are drives with at least two different energy converters (e.g. an internal-combustion engine and an electric motor). Hybrid drives are differentiated according to their drive-train topology (parallel hybrid, power-split hybrid and serial hybrid) and also according to their functional characteristics (micro-hybrid, mild hybrid, full hybrid and plug-in hybrid). Apart from minimising fuel consumption, the aim of these concepts is to travel as much of the journey as possible using electricity and as little as possible using fuel. The battery is charged preferably from the domestic power supply. Full hybrids and plug-in hybrids can be produced in any of the three basic structures presented here, whereby the dimensioning of the electrical and IC drive components allow total flexibility in the transition between power sources and extend all the way to an all-electric vehicle.

- **Automatic driving** can be regarded as a logical and consistent further development of driver-assistance systems. There are two major technical challenges to be overcome: the vehicle environment relevant for the driving task has to be reliably identified by suitable sensors and the correct decisions have to be made. To achieve complete environmental scanning, different detection methods have to work in harmony: laser scanners scan the stretch of road to be negotiated directly in front of the vehicle and identify any unevenness and dangerous sections up to a distance of about 22 m. Cameras observe road conditions up to a distance of about 50 m. Information about the road ahead and traffic over a longer distance is provided by radar systems. GPS location helps plan route to be taken.

- **Fuel Cells:**

  - Lifetime enhancement: All types of fuel cells still require significant lifetime enhancement and cost reductions if they are to compete with established technologies. Trends in fuel-cell development include reducing the content of expensive materials such as noble metal catalysts and adapting the cells for mass production.

  - Larger-scale stationary applications. In combined heat and power supply systems, the goal is flexibility and the type of fuel employed is also being investigated.

  - Small-scale fuel cells: The major goals for small-scale residential fuel-cell systems are to simplify the balance of plant and to improve lifetime and reliability.

  - Portable applications: Considerable effort has been made to develop miniature fuel cells for a

variety of portable applications such as laptop computers, mobile phones, and on-chip power supplies. The demands in terms of reliability and safety are very high, primarily due to the required passive operation in a consumer environment. Various concepts using either hydrogen or methanol as fuel are currently being pursued.

- The vehicle-to-grid concept: In future, the energy stored in the batteries of electrical vehicles could offer a new storage alternative. This "vehicle-to-grid" concept requires vehicles with combustion engines to be replaced with vehicles with electric motors. The automotive industry is pursuing this scenario on a global scale via the intermediate step of hybrid vehicles. The intelligent use of large numbers of such decentralised storage units represents an interesting approach. There are three different concepts:

· Intelligent charging: A major purpose of electric vehicles will be to drastically reduce connection time to the grid. An intelligent control system will be required for charging in order to avoid new peak loads in the grid and to adapt the fluctuating integration of renewable energies.

· Grid stabilisation: In addition to intelligent charging, automotive storage will be able to integrate currently unstable cases into the grid.

· Periodic load compensation for the grid: This concept is based on the idea that electrical vehicles are typically idle for more than 20 hours per day and could be connected to the grid during this time. In doing so, the batteries of the vehicles would serve as grid-integrated energy storage systems.

Prospects

- The desire for individual mobility will remain strong, but efforts to reduce the burden on the environment and resources will play a dominant role.

- Sustainable mobility will require the interplay of different drive systems and alternative fuels, including the use of renewable energy in the form of biofuel, electricity and hydrogen.

- New vehicle concepts will be geared more strongly to the individual needs of customers, such as small electric town cars for one or two people.

- Fuel cells:

  - Fuel cells are efficient energy-conversion devices and can help save energy in combined heat and power supply systems with natural gas in the near future.

  - The widespread use of fuel cells for electric traction depends on hydrogen supply and infrastructure, and thus on political decisions regarding how to cope with rising oil prices and limited resources. In the future, all hybrid electric systems are likely to be the propulsion method of choice.

  - In other applications, such as portable and micro-fuel cells, the advantages for the consumer are the main argument for investing R&D efforts in fuel-cell development.

  - The international energy policy will be the primary factor determining how soon (renewable) electric energy and hydrogen become the main energy vectors.