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Hybrid Electric Vehicle

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ABSTRACT

Have you pulled your car up to the gas pump lately and been shocked by the high price of gasoline? As the pump clicked past $20 or $30, maybe you thought about trading in that SUV for something that gets better mileage. Or maybe you are worried that your car is contributing to the greenhouse effect. Or maybe you just want to have the coolest car on the block.Currently, there is a solution for all this problems; it's the hybrid electric vehicle. The vehicle is lighter and roomier than a purely electric vehicle, because there is less need to carry as many heavy batteries. The internal combustion engine in hybrid-electric is much smaller and lighter and more efficient than the engine in a conventional vehicle. In fact, most automobile manufacturers have announced plans to manufacture their own hybrid versions.How does a hybrid car work? What goes on under the hood to give you 20 or 30 more miles per gallon than the standard automobile? And does it pollute less just because it gets better gas mileage. In this seminar we will study how this amazing technology works and also discuss about TOYOTA & HONDA hybrid cars.

I.INTRODUCTION

The traditional internal combustion engine made economic sense when oil was cheap and plentiful and the effects of burning fossil fuels and pollution were not understood. Although electric vehicles were popular at the start of the 20th century, they declined given their low top speed, and the discovery of large oil reserves [1-2]. One hundred years later, oil now accounts for about 95 per cent of the global transportation sector fuel and 13 percent of global greenhouse gas emissions.

The environmental damage from the internal combustion engine is further compounded by the problem of air pollution [3]. As well as carbon dioxide emissions, cars also produce dangerous chemicals such as nitrogen oxides (NOx), Sulphur oxide (SOX) and carbon monoxide emissio ns [4]. While the industry has been able to produce technologies to try to limit these dangerous chemicals, transport using fossil fuels cannot completely eliminate these emissions.

The problem of lost energy, as well as the need to reduce carbon emissions and reduce dangerous pollutants, has spawned the industry to attempt to meet these challenges, whilst sticking to the traditional petrol and diesel run engine [5-7]. Indeed a lot of these technologies, whether it be turbo chargers to improve fuel efficiency, catalytic converters that can remove dangerous gases or drivetrain technologies that address problems of wasted energy. These technologies have directly contributed to huge improvements being made in the last 20 years, however, over the next 5 to 10 years the industry needs to accelerate this improvement [8].

The key issues for widespread EV adoption are the lack of range and the lack of refueling infrastructure. Most EVs have a range of about 100 miles, with some as low as 48 before they need recharging [9-10]. When you do recharge, they inevitably take much longer to charge than it does to fill your car with fuel. This presents an important impediment to the widespread adoption of

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electric vehicles, if consumers have to sacrifice convenience. Until widespread adoption occurs, companies are unwilling to invest in infrastructure to ensure it's easier to recharge your car, and until you can conveniently refuel, consumers are unlikely to adopt EVs on a wide scale [11-12].

1.1 Vehicle Fuel Efficiency and the Role of Hybrid Technology

Given its importance in current and future emission scenarios and its near-complete dependency on fossil fuels, innovations in road transport - and particularly vehicle technology - are receiving a lot of attention from decision makers and consumers searching for more efficient mobility. This is true in both developed and developing countries.

Hybrid electric vehicle (HEV) technology and its various applications, the subject of this paper, have made significant market gains in recent years and form an important part of the fuel economy equation. Initially only introduced in North American, European and Japanese markets in the mid 1990's, HEVs are now starting to gain markets in developing and transitional countries, including China and Brazil. The export and import of second-hand vehicles also ensures that new markets are gaining exposure to hybrids. Hybrid electric vehicle technology is already mature enough for large scale deployment worldwide today; however, cost, limited production capacity, and various market barriers hinder their wide scale use.

UNEP has developed this overview of the basics of hybrid technology to guide users on the spectrum of hybrids currently available, the rapid pace of innovation in vehicle manufacturing, and the emergence of plug-in hybrids and fully electric vehicles. The subsequent chapters cover HEV technology applications, potential savings in terms of fuel and lower emissions, and its feasibility in developing and transitional country settings where policy environments for vehicles and fuel efficiency, fuel quality and maintenance facilities for advanced vehicle technology vary considerably.

Fuels and vehicles work together as a system; the vehicle- fuel system determines the quality and amount of both conventional and greenhouse gas emissions and the extent to which emissio n control technologies will be able to reduce these emissions. The type of fuel used, the quality of the fuel, vehicle maintenance, and driving conditions all play a role. This paper also explains the required complementary conditions for the use of advanced vehicle technology – from enabling policies and incentives to aid introduction and create consumer demand, to ensuring that fuel quality is sufficient to maintain proper vehicle function.

In addition, hybrid technology is compared to other cleaner vehicle technology options. New generation diesel vehicles with advanced engine technology and emission controls can offer comparable efficiency when used with low and ultra-low Sulphur fuels (500 ppm or less, 15 ppm or less respectively). Low carbon fuels and fuel switching are also options; introducing compressed natural gas (CNG) vehicles or low-level blending with bio-ethanol or biodiesel from sustainab le sources are other options to consider and compare. Biofuel blends are already in use worldwide, but given that in-depth information is already available in a number of other publications, an analysis is not provided in this paper.

1.2 Comparison of Current Technologies– HEV, CNG, Clean Diesel

In this paper three cleaner vehicle options will be compared - HEV, CNG and clean diesel vehicles for emission reductions, fuel efficiency and overall CO2 reductions, and life cycle costs. The Cleaner vehicle options considered in this report can meet future stricter regulations on emissions such as hydrocarbons, nitrogen oxides, Sulphur oxides, and particulate matter using available, 'off The shelf' emission control technologies. The main difference between the technologies considered is in fuel consumption and the resulting emissions of CO2.

Although petrol is widely used for passenger vehicles, the diesel engine is inherently more efficient than a

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conventional petrol engine. For the average passenger car fuel savings are around 20%. Advanced cleaner diesel vehicles now include emission control technologies to lower tailpipe emissions, including harmful particulate matter (PM).

Changing to Liquefied Petroleum Gas (LPG) or CNG are additional options that are still fossil-based. The advantages are that they are inherently low Sulphur and the combustion process is cleaner, resulting in lower harmful particulate matter and hydrocarbon emissions. CNG vehicles also typically have lower emissions of NOx compared to standard petrol vehicles. CNG or LPG fuelled petrol engines can also use a 3-way catalyst to reduce emissions even further.

1.3 Hybrid Electric Vehicles

HEVs are powered with a combination of a combustion engine and an electric motor. This design, which is described in more detail in the next section, makes the HEV more energy efficient, potentially achieving almost twice the fuel-mileage compared to conventional vehicles and reducing tailpipe emissions substantially. Another driver for the high interest in hybrid technology is that HEVs can act as a stepping-stone for future zero-emitting fuel cell and electric vehicles, which will be described in section 2.3. Fuel cell vehicles and HEVs share several critical components such as the electric motor, power controls, and high power density batteries. By driving the cost reduction and increased performance of these components, the continued development of HEVs will also help the development of the low and zero emission vehicles of the future.

1.4 Clean diesel vehicles

Clean diesel vehicles are equipped with advanced after treatment technologies, such gains are inherently more efficient than petrol engines, but have historically had problems with high emission, especially nitrogen oxides (NOx) and PM. However, diesel emission control technologies have made great progress over the past decade, resulting in low emitting diesel vehicles with high efficiency. Today, diesel vehicles fueled with ultralow Sulphur diesel and equipped with emission control technologies such as catalyzed particulate filters, selective catalytic converters, and NOx are an energy efficient and cleaner vehicle option. Particulate filters are already installed in many diesel vehicles sold in the EU and the U.S. today and with the coming stricter emission regulations SCRs or NOx will be mandatory.

1.5 Compressed Natural Gas vehicles (CNG)

Natural gas vehicles have adjusted engines that run on natural gas (95% methane) stored in a fuel tank in the car under high pressure (around 200 to 240 bars). Petrol engines need some adjustments to run on CNG. Diesel engines can also be adjusted to run on CNG; however, in this case the CNG needs an “igniter”, usually in the form of a small amount of diesel. CNG as an automotive fuel has been developed since the 1970s in the aftermath of the oil crisis in countries that have ample supplies of natural gas. Argentina, New Zealand, United States, Brazil, Eastern European countries, and China all have major fleets of CNG vehicles. CNG buses have also replaced diesel buses in places like India and the U.S. in an effort to reduce air pollution.

1.6 Comparison of CO2 and non-CO2 emission reductions for various vehicles

Pure CNG vehicles emit less air pollutants than standard petrol and diesel vehicles due to natural gas being a cleaner burning fuel. CNG vehicles are usually also equipped with a catalyst, thus lowering emissions even further. Clean diesel vehicles need advanced emission control technologies and ultralow Sulphur diesel (15 ppm or less) for optimal emission reductions. However, with the use of advanced emission control technologies and ultralow Sulphur diesel, clean diesel vehicles can meet stringent emission standards and are in some cases comparable to both CNG and HEV technology in terms of emission standards.

In a HEV, the combustion engine is less exposed to accelerations (transient loads) and burns fuel under more stable conditions, thus emitting less pollution and CO_2 than an engine in a conventional vehicle. However, all

HEVs today require emission control technologies (e.g. catalysts) in order to meet emission standards.

1.7 Emerging Technologies

The rapid growth and development of HEVs has also spurred the development of other emerging technologies that share critical components (e.g. electric motors, batteries) with HEVs, i.e. plug - in hybrid electric vehicles and fuel cell electric vehicles. Both plug-in hybrids and fuel cell vehicles require technologies for electric propulsion. However, as these emerging technologies are still expensive and require a reliable supply of electricity or hydrogen, these technologies are not expected to play an important role in developing countries soon. Ultra cheap cars are more likely to enter these markets in the interim due to their fuel efficiency and low cost.

1.8 Uptake and Fleet Turnover in Developing and Transitional Countries

Incomes, emission standards, and policy incentives affect the rate of vehicle renewal on a given market, and thus the uptake and introduction of cleaner vehicle technologies. Rates of change are crucial to the development of policies and programs designed to encourage emerging technologies.

2.1 Ageing vehicle fleets

Vehicles in developing countries are generally older compared to OECD countries. The average age of the vehicle fleet can be up to 15 - 20 years, with some vehicles (e.g. old heavy duty diesels) sometimes operating for more than 40 years; these vehicles can act as super emitters responsible for a high percentage of air pollution despite their low fleet numbers.17 The main reasons for the persistence of old technology include the high cost of new vehicles, the relatively low maintenance and support cost for older technology, and a lack of government fleet renewal incentives (including inspection and maintenance regimes).

2.2 Fleet uptake of second-hand and new vehicles

Apart from Brazil, China and India, the majority of developing and transitional countries do not produce vehicles, but rather rely on imports. Most vehicles are imported second hand; this is an important mechanism for the introduction of cleaner vehicles in new and developing markets. Import technology and age restrictions and incentives can be introduced to improve the quality of vehicles entering a country and promote fleet renewal. In Kenya, for example, only models newer than seven years old can be imported. In Belarus import taxes are relatively high for older cars to discourage their import. Vehicle scrap page programs are also part of the fleet renewal process.

2.3 HEV Technical Considerations

In general, HEVs outperform conventional vehicles in terms of fuel consumption and pollutant emissions. However, the degree of HEV performance and cost savings achieved largely depend on its application (including the types of trips), the level of available technical service and maintenance, fuel price, and the availability of optimal fuel quality.

2.3.1 Basics of HEV technology

A conventional vehicle has a mechanical drive train that includes the fuel tank, the combustion engine, the gear box, and the transmission to the wheels. A HEV has two drive trains - one mechanical and one electric. The electric drive train includes a battery, an electric motor, and power electronics for control. In principle, these two drive trains can be connected with each other, sharing some components such as the transmission and gear box. The 'hybrid' denotation refers to the fact that both electricity and conventional fuel can be used. Current hybrid models all use gear boxes, but in the future a single one-gear transmission might be a reality for series hybrid configurations as the electric drive train can handle a wide variety of speeds and loads without losing efficiency. This is already used in Brazilian HEV buses.

2.3.2 Degrees of Hybridization

A petrol engine in a conventional car has an average engine efficiency 20 of 17%-20% under normal driving conditions. Most of the energy in the fuel is lost as heat and a smaller part as engine friction. However, of the remaining energy out from the engine approximately 10%-12% is lost during idling and another 20%-30% is 'lost' when braking. In conclusion, only 12%-14% of the energy supplied as fuel is actually used to move the car forward.

2.3.3 Plug-in hybrid electric vehicles

By enabling, enlarging the battery pack and recharging it with energy from a conventional wall plug, vehicle fuel consumption will be reduced dramatically as it is partly exchanged with the consumption of electricity. As a result, the fuel reduction depends strongly on the distance driven after every recharge and on the capacity of the batteries installed. At the time of writing, PHEVs are still in the testing phase. The announced PHEV prototypes will have a battery-only range between30-60 km. For many users this will be sufficient for a large share of the daily distance traveled.

2.3.4 Technical Constraints

In order to drive HEVs in developing countries, some basic technical and service requirements must be met, e.g. requirements for fuel and battery quality and technical support infrastructure.

2.3.5 Fuel quality requirements

As explained in section 2.2, both conventional vehicles and HEVs with catalytic converters can be used with high Sulphur petrol fuel as long as the fuel is unleaded. However, emission reduction technologies have a better efficiency with low and ultra-low Sulphur fuels. The only technical requirement is unleaded fuel in order to ensure proper function of the catalytic converter.

This is very promising for the introduction of HEVs to developing countries, as unleaded petrol fuel is available in most countries. Since fuel requirements set by car importers and car manufacturers can differ from region to region, one should check the requirements set by them to ensure the vehicle warrantee is maintained. If modern emissio n control technologies are used, e.g. NOx traps or Diesel Oxidation Catalyst, low Sulphur fuels (500 ppm or less) will be required.

2.4.1 Battery requirements

Since hybrid technology is relatively new, at least compared to the conventional drive train invented over 100 years ago, there have been reasonable concerns around technical failures when adopting this technology. The highest uncertainty remains around the battery lifetime, the cost of replacement, and the maintenance of advanced electronics.

In terms of HEV production and scrappage, including battery packs, a life cycle approach should be used. Battery power – Until the late 1990s battery development was driven by the need for battery powered electric vehicles and thus aimed for high energy density (low weight per energy storage capacity; kWh/kg). With the launch of the first HEVs the focus shifted toward developing batteries suitable for hybrid applications instead, i.e. focusing on high power density (low weight per power discharge ability; kW/kg). The first generation HEVs were sluggish since the battery development had not aimed for high specific power, i.e. they could not discharge energy quickly enough. This has been partly rectified by the development of improved battery types: nickel/metal hydride and lithium- ion batteries. Current HEV batteries provide the vehicle with ample power for driving but development is still on going, focusing on cost reduction and extending the lifetime.

2.4.2 Working of HEVs

Everyone loves cars, they're convenient, get you quickly from one place to another. Everyone hates pollution, it makes plants and animals and happy pristine environments unhappy. The H.E.V. is a compromise. Pure electric vehicles, while emission "free," can't go the distances or provide the power (for any extended length of time) of vehicles with internal combustion engines. Internal combustion engines pollute. H.E.V.'s combine both, so the vehicle can go as far and as long as most people would want and emit only a fraction of the harmful gases I.C.E.-powered vehicles do. The H.E.V. does this by balancing when and how each motor is used. On the highway, when internal combustion engines are at their most efficient, and where the battery

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would be depleted very quickly in an electric car, the I.C.E. is used. For shorter, city driving trips, the electric motor is either used exclusively, or in such a manner that the I.C.E. also runs, at its peak efficiency.

2.4.3 Classification of HEV

According to technical Committee 69 (electric road vehicles) of the International Electro technical Commission, an HEV is a vehicle in which propulsion energy is available from two or more kinds or types of energy sources or converters, and at least one of them can deliver electrical energy. Based on this definition, there are many kinds of HEVs, for example, battery and ICE, battery and capacitor, and battery and flywheel. However, the above definition is not accepted by ordinary people. Generally, they think that HEV is a vehicle having electric motor and ICE, thus this general definition is adopted in this paper. Traditionally, HEV can be classified into three types: series HEV, parallel HEV,and combination HEV.

2.4.4 Configuration of series HEV

We can see that the series HEV is composed of ICE, generator, power converter, motor, and battery. There is no mechanical connection between ICE and transmission, thus ICE can operate at maximum efficient point by regulating the output power of battery to satisfy the required power of vehicle.

2.4.5 Configuration of parallel HEV

From Figure we can see that the parallel HEV allows both the electric motor and ICE to deliver power in parallel to drive the vehicle, that is, ICE and motor can drive, respectively, or together. Different from the series HEV, there is mechanical connection between ICE and transmission, and thus the ICE's rotational speed depends on the driving cycle, so the ICE can operate based on optimal operating line by regulating the output power of battery.

2.5.1 MODELING OF REGENERATIVE BRAKING SYSTEM

The regenerative braking system with two wheel drive series-parallel drivetrain configuration is modeled using PSAT. The RBS model from PSAT is then segregated into multiple ECUs and hardware components. The ensuing model consists of a driver model, a component (physical system) model and six ECUs, namely battery control unit, engine ECU, motor1control unit, motor2 control unit, mechanical brake control unit, and powertrain controller. These individual models in MATLAB/Simulink are converted into using MATLAB Real Time Workshop and then uploaded into the Vector environment. The simulation setup of ECUs and communication network of RBS is shown in Communication between the ECUs is carried out via signals on the accelerator and brake pedal positions to achieve the desired vehicle speed. A simple proportional and integral (PI) controller is designed to control the vehicle speed, and a suit-able torque demand is requested that is proportional to the error between the desired and actual vehicle speed subsequently, the torque demand is used to request the torque from different powertrain components via the supervisory.

2.5.2 Working of HEV

The on-board batteries in hybrid cars are recharged by capturing the kinetic energy created when using the brakes (commonly referred to as "regenerative braking"), and some hybrids use the combustion engine to generate electricity by spinning an electrical generator to either recharge the battery or directly feed power to an electric motor that drives the vehicle.

3.1 DOMINANT PHYSICS

The flow of power through the hybrid system and the efficiencies and mechanics of the components and connections therein comprise the most important physics in the H.E.V. For the components used, the object of the H.E.V. designer is to connect and control each part so that maximum efficiency is achieved.

An internal combustion engine runs most efficiently at highway speeds, and so it is used alone in highway driving. It is very inefficient in stop and go traffic, however. An electric motor would soon deplete its battery on a long highway drive, but can drive the

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vehicle efficiently through city traffic with no emissions to release into the city atmosphere. Of course, there are driving modes in between these, when both I.C.E. and electric motors work in tandem, as when the vehicle is accelerating.

Power flow through the drive mechanism depends on the arrangement of the system and several clutches which engage and disengage components from the assembly. In the following diagrams (follow the links):
solenoid clutch #1 controls the connection between the I.C.E. and the generator.
solenoid clutch #2 controls the connection between the I.C.E. and the transmission.
overrunning clutch #3 controls the connection between the I.C.E. and the system.
overrunning clutches control the connections between the electric motors and the **#4&5** system.

3.1.1 Advantages of HEV

Here are few of the top advantages of having a hybrid car:-
Environmentally Friendly: One of the biggest advantage of hybrid car over gasolinepowered car is that it runs cleaner and has better gas mileage which makes it environmentallyfriendly. A hybrid vehicle runs on twin powered engine (gasoline engine and electric motor) that cuts fuel consumption and conserves energy.
Financial Benefits: Hybrid cars are supported by many credits and incentives that help tomake them affordable. Lower annual tax bills and exemption from congestion charges comes in the form of less amount of money spent on the fuel.

Less Dependence on Fossil Fuels: A Hybrid car is much cleaner and requires less fuel to runwhich means less emissions and less dependence on fossil fuels. This in turn also helps to reduce the price of oil in domestic market.

Regenerative Braking System: Each time you apply brake while driving a hybrid vehiclehelps you to recharge your battery a little. An internal mechanism kicks in that captures the energy released and uses it to charge the battery which in turn eliminates the amount of time and need for stopping to recharge the battery periodically.

Built from Light Materials: Hybrid vehicles are made up of lighter materials whichmeans less energy is required to run. The engine is also smaller and lighter which also savesmuch energy.

Higher Resale Value: With continuous increase in price of gasoline, more and more peopleare turning towards hybrid cars. The result is that these green vehicles have started commanding higher than average resale values. So, in case you are not satisfied with your vehicle, you can always sell it at a premium price to buyers looking for it.

3.2 Policy Measures

The four key policy-relevant and consumer choice advantages of HEVs over conventional and comparably clean and efficient technology (clean diesel, CNG) can be summarized as follows:
Emissions –Available HEV technology will decrease emissions of conventional airpollutants substantially as compared to a standard vehicle on the roads today. While similar emission reductions can be achieved with, e.g. CNG and clean diesel vehicles with advanced emission control technologies, the HEV combines both non-CO2 and CO2 reductions.

Energy - HEVs decrease fuel consumption substantially compared to conventionalvehicles used today and also compared to CNG and the new generation of cleaner diesel vehicles. Calculations have shown that over the average HEV useful life time savings can amount to 6,000 L of fuel.

Life Cycle Cost –While HEVs are more expensive initially, the fuel savings arerecouped based on mileage and driving conditions. Analysis has shown that the HEV life cycle cost, including the cost of purchase, fuel and maintenance costs, is, in most cases, less than

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owning a conventional vehicle. However, these calculations are strongly dependent on fuel prices, taxes and rebates.

Strategic Stepping Stone Technology - HEVs, plug-in hybrids, full electric vehicles, and fuelcell vehicles share basic technologies such as electric motors, batteries, and power electronics. Therefore, HEVs and plug-in hybrids function as stepping stone technologies to the large-scale electrification of fleets that is required for a long-term reduction of CO_2 emissions from road transport, and a low carbon transport sector.

4.0 Developing an Enabling Environment

4.1 Fuel economy policies

Putting in place fuel economy targets and policies that support more ambitious, mandatory fuel efficiency standards that are fuel and technology neutral is a first step to improving the performance of road transport and car fleets. Providing a clear, predictable policy and a simplified legislative framework that details both the fuel economy objectives, the means for reaching them (e.g. import standards, vehicle motor technology improvements in manufacturing countries, use of biofuels, minimum efficiency requirements for vehicle components such as air conditioners, among others), and a mutually agreed time frame for implementation is crucial for industry and the private sector. Such an approach would provide both importers and manufacturers with adequate lead time and will provide the regulatory certainty required in a sector where technology investment and development and production cycles are long. For vehicle importing countries, turnover of vehicle technology in fleets can be up to 20 years, so early policy and standard development and implementation is needed.

4.2 Leading by Example

In addition to direct financial support, tax incentives, and purchase subsidies that reduce the up-front cost of HEV ownership, governments can also encourage HEV adoption and wide-scale use through public procurement policies that favor low emission vehicles and contractors who use them. In young HEV markets, public measures to encourage technology adoption are extremely important for risk-averse consumers. Both government and major business fleet owners can help the development of hybrid vehicles by introducing them into their own fleets.

Government fleets are usually very visible and this gives a clear signal to consumers that this technology is viable. The initial market can act as a bridging market-pushing this technology to become more competitive. Hybrid vehicles are also good for fleets as fleet vehicles are usually driven more and the fuel economy benefit will be greater, making thus vehicle purchase and ownership even more cost-effective. Greener public procurement is a way of promoting cleaner vehicles, particularly in new markets.

4.3 Maintenance Training

Support is also required for repair and maintenance providers that specialize in HEV technology (e.g. training of maintenance personnel to handle high voltage systems, electric engines, procurement of spare parts), in addition to the developing technical standards for the safe recycling of used batteries. Standards can also ensure that new HEVs are sold with suitable warranties on technology, thus reducing the risk for presumptive buyers.

V. Conclusion

HEV technology for both light and heavy duty applications is commercially available today and demonstrates substantial reductions in tail-pipe emissions and fuel consumption, even when compared to other available low emission technologies. HEVs are particularly effective for urban travel, significantly lowering pollutant emissions and providing cost-effective CO_2 reductions in personal mobility. Encouraging hybridization of vehicle fleets through enabling policies and incentive structures can serve to lower both conventional and CO_2 emission, thus improving public health, energy security, and reducing fuel costs. Continuing innovation in hybrid technology

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and a growing demand for cleaner vehicles will mean that costs are likely to fall, particularly in second hand vehicle markets. While OECD countries need to be the avant-garde in doubling vehicle fuel efficiency in the next twenty years, the majority of vehicle growth will take place in non-OECD countries.

Today, most countries do not have fuel economy policies in place. In order to reach the global CO2 reductions required to stabilize greenhouse gas emissions and mitigate climate change, fuel economy policies and technology will need widespread use. This will only occur in the framework of efficiency-friendly economic and policy environments, and with the involvement of all sectors – from governments to manufacturers, importers and consumers.

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