Submitted by the representatives of India and USA

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Task Force Group on Environmentally Friendly Vehicles

Environmentally Friendly Vehicles and the World Forum For the Harmonization of Vehicle Regulations (WP. 29)

2003 – 2012

Ten Years of Progress and Future Trends

Preface

The first production automobiles were introduced just over 120 years ago in Europe and followed just a few years later with introduction in the United States.[1] Since then, automobiles and heavy-duty vehicles have been an important part of economic growth and have answered the growing desire for mobility. There continues to be an increasing demand for automobiles all over the world. With this increasing vehicular population around the world, there is also growing concern of the public health, welfare and climate change impacts vehicle emissions have globally. Regulatory activities to mitigate the impact of vehicle pollution have been advancing over the last 40 years. Since around 2000, those activities have been accelerated as both policy makers and automakers acted to advance the development and introduction of vehicles that were increasingly being noticed for being environmentally friendly by reducing vehicles' impacts on the environment and public health and becoming increasingly more efficient to preserve energy. It was well recognized that a more Environmentally Friendly Vehicle (EFV) fleet was a necessity for the future to mitigate the effects of transportation pollution.

The Ministerial Conference on Transport was held in 2002 in Tokyo, during which a Ministerial Statement on Comprehensive Strategy for Environmentally Friendly Vehicles was announced. Ministers noted that it was important to hold an international meeting on EFVs to discuss possible solutions based on the knowledge of existing and future vehicle technologies and the availability of different type of fuels, and to explore the possibility of international coordination of policy to facilitate the development and dissemination of EFVs. In this context, the EFV conference was organized in Tokyo in 2003. The objective of the first "EFV International Conference" was to identify solutions to mitigate the impacts of air pollution, climate change and other environmental problems for which the transport sector is considered to be a significant contributor. The belief then and now was that international collaboration would be aided through timely exchange of information and views among participating countries concerning the concept of EFVs and policies for promoting the development and dissemination of EFVs. Three additional conferences have been held since 2003.

The conferences have been an important forum for the exchange of information and sharing of best practices to advance the development and introduction of EFVs. The need to have a continuing form of cooperation between EFV conferences and the World Forum for the Harmonization of Vehicles Regulations (WP.29) was identified at the first EFV conference[2]. As interest grew WP.29 established the Informal Working Group on Environmentally Friendly

[1] From Steam Carriages to Automobiles: The History of the Car; http://www.randomhistory.com/1-50/013car.html

[2] WP.29 is a working party under the United Nations Economic Commission for Europe's Inland Transport Committee. It has now become the World Forum for the Harmonization of Vehicle Regulations (WP.29). Its role and that of its subsidiary Working Parties is to develop new regulations, harmonize existing regulations and amend and update current vehicle regulations that address the areas of concern covered by the Agreements administered byWP.29. For more information please see: WORLD FORUM FOR HARMONIZATION OF VEHICLE REGULATIONS(WP.29)-HOW IT WORKS; HOW TO JOIN IT http://www.unece.org//fileadmin/DAM/trans/main/wp29/wp29wgs/wp29gen/wp29pub/wp29pub2002e.pdf

Vehicles under the Working Party on Pollution and Energy (GRPE). Also, the G8 2007 Summit decided to organize regular EFV conferences every second year, and, to have a regular status report on these issues to the G8 leaders. This has enabled the International EFV conferences to maintain a global perspective through the involvement of WP.29.

These activities were part of a dynamic and important set of policy developments and technology innovations due to the cooperative efforts of governments, automotive manufacturers, engineers, scientists and the public. The advancement in engine and vehicle technologies has been far beyond the expectations from just ten years ago at the first EFV conference. Innovation, investment and opportunity continue to be keys to the introduction of a new fleet of vehicles that will protect public health, address climate change and reduce energy impacts.

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1. Environmentally Friendly Vehicles: The Conferences and the Concept

Since the inaugural ministerial meeting on Environmentally Friendly Vehicles, it was clear that the intent was to provide a forum for open discussion and sharing of different viewpoints to facilitate solutions for air pollution, climate change and other environmental problems for which the transport sector is a significant contributor. The goal of the conferences was to create an international platform to promote the need for cleaner and more efficient vehicles. "This will be achieved with as much international collaboration as possible through the exchange of information and views among participating countries, concerning the concept of environmentally friendly vehicles (EFV) and policies for promoting the development and dissemination of the EFV."[3]

1.1 International Environmentally Friendly Vehicle Conferences

Japan organized the first conference in 2003 with a unique focus on the concept of environmentally friendly vehicles (EFV). The effort was to gather officials from around the world to discuss the potential role of government in advancing vehicle technologies to address the public health, environmental and energy impacts of transportation. The dialogue was initiated and there was an increased effort to share research on developing technologies and activities. The need to have cooperation between EFV conferences and WP.29 was identified at the very first EFV conference and is mentioned in the chair's statement delivered as the outcome of the Tokyo meeting[4].

The meeting allowed for an exchange of information regarding environmental issues such as air pollution, climate change, traffic noise pollution, traffic congestion, and the efforts in countries and regions to address them. Delegates discussed what the overall prospects would be for the technical development and dissemination of EFVs including fuel cell motor vehicles, how to define the concept of next-generation EFVs for their promotion, and the importance of clean fuels to the successful introduction of EFVs. It also included a discussion of efforts that could be taken to facilitate the development and introduction of EFVs, such as financial and/or tax incentives, accelerated and coordinated research programs, and consumer awareness programs. It was noted that by influencing better driving habits, drivers could significantly reduce their fuel consumption. In this context it was recognized that in-car devices such as displays for actual fuel consumption, as well as gear selection and cruise control could be important.

Delegates recognized that it would be vital to continue the discussion and information sharing and therefore establish ongoing cooperation between future EFV conferences and World Forum for Harmonization of Vehicle Regulations (WP.29). It was established that the goal of organizing biannual International EFV Conferences would be to share ideas and experiences with regard to

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[3] Informal document No. 12;(127th WP.29, 25-28 June 2002; Submitted by Japan)
[4] Informal Document No.10(129th WP.29, 11-14 March 2003, agenda item 2.2.); http://www.unece.org/trans/main/wp29/wp29wgs/wp29gen/geninf129.html

ongoing measures for promoting and introducing environmentally friendly vehicles, developing the legal and economic framework for the introduction of such vehicles and advances in technology innovation to address future directions for both energy security and a cleaner environment to protect public health.

The second conference held in Birmingham, United Kingdom in 2005 looked to expand the discussion and involve all stakeholders in an event that would host and exchange best practices from around the world on how to encourage consumers to buy clean and efficient vehicles. In particular the conference looked at two questions:

- Why the development of Environmentally Friendly Vehicles is so important worldwide? ; and,

- How Industry and Governments can work to develop and encourage the uptake of Environmentally Friendly Vehicles?

There was a robust discussion from many stakeholders that addressed a range of subjects such as:

- Lessons learned from EFV policies worldwide
- Fiscal measures to encourage the uptake of EFVs
- Non-fiscal measures to encourage the uptake of EFVs
- How emerging economies are seeking to mitigate the environmental impact of the forecast rapid growth in vehicle ownership and use
- Technical Standards for EFVs, and whether more needs to be done to harmonize them worldwide
- Marketing and perceptions of EFVs
- Barriers to incentivizing EFVs

The German government, organizer of the third EFV conference, consistently involved WP.29 in the preparation of the conference. In addition, the German government fostered the G8 decision to regularly organize EFV conferences and to have a regular status report on these issues to the G8 leaders. This agreement meant that the biannual conferences would be part of the on-going dialogue at the World Forum. The official framework for the cooperation between EFV conferences and WP.29 was initiated by a proposal[5] in 2007 to establish an informal group within GRPE in order to explore the development of an environmentally friendly vehicle concept. The participating countries at WP.29 unanimously agreed to this proposal at the same session in November, 2007.

[5] Reports of the World Forum for Harmonization of Vehicle Regulations on its one-hundred-and-forty-third session (13-16 November 2007); page 15; paragraph 66. http://www.unece.org/fileadmin/DAM/trans/doc/2008/wp29/ECE-TRANS-WP29-1064e.doc

During the 4th EFV conference held in New-Delhi India in 2009, the discussions found that the technology was advancing rapidly and that many new vehicles were emerging in the market place with advanced technologies that addressed both air pollution and climate change. In addition, advancements in alternative powertrains were seeing as the advent of a new generation preparing for mass marketing such as electric vehicles. One of the identified areas for future work was to continue to explore the possible development of a methodology to define EFV from a technical and scientific point of view. This has proved difficult mainly because there are differences and multiple specifications, weightings, factors subject to regional or temporal circumstances and data availability concerning environmental aspects.

1.2 Informal Working Group on Environmentally Friendly Vehicles

It was recommended that the EFV conferences ~~to~~ have close cooperation with the World Forum for Harmonization of Vehicle Regulations (WP.29) of the United Nations in Geneva (UN-ECE). The pursuit of the EFV concept within WP.29 required the involvement of the two environmental working parties (GRs) of WP.29: GRPE (pollutant emissions, fuel consumption/CO2) and GRB (noise). The work of the GRs would be part of the on-going dialogue for future EFV Conferences and enhance the exchange of experiences with regard to ongoing measures for promoting and introducing EFVs.

The Informal Group (IG) on Environmentally Friendly Vehicles in GRPE, once established in 2008, developed a terms of reference[6] approved by WP.29 and initiated a series of meetings exploring the possible approaches for defining the EFV concept. Open exchange of information and experiences were extended from automakers to regulators to energy specialists and consumer groups. The IG initiated an effort to develop the scope and parameters for EFV-concepts to be evaluated and then began the initiation of item (1) of EFV feasibility phase (screening and analysis of available literature and concepts including regulations and standards).

The premise has always been that activities should be open to any efforts to reduce CO2 emissions, pollutants and other environmental impacts from vehicles and that such an assessment should be done in a technology neutral manner. As GRPE took up the task of reviewing the potential to define EFVs it was duly noted that this should be based on a holistic approach and any globally harmonized method would need to consider the regional and national differences. The GRPE Informal working group on EFVs led by Germany identified the key inputs to evaluate in examining a vehicle in the document, "Background document regarding the Feasibility Statement for the development of a methodology to evaluate Environmentally Friendly Vehicles "[7] ("Feasibility Statement"), as the base for further discussion.

[6] Working paper No. EFV-01-03 (GRPE Informal Group on EFV,1st meeting, 6 June 2008) http://www.unece.org/fileadmin/DAM/trans/doc/2008/wp29grpe/EFV-01-03e.doc

[7] Informal document No. **GRPE-58-02**(58th GRPE, 9-12 June 2009, agenda item 8.) http://www.unece.org/fileadmin/DAM/trans/doc/2009/wp29grpe/ECE-TRANS-WP29-GRPE-58-inf02e.pdf

The "Feasibility Statement", described, "…options to define and evaluate vehicles. However it needs to be assessed whether these approaches can be used for the development of a holistic evaluation concept. This assessment (chapter 4. of the background document) needs to first anticipate the foreseen target groups and the purpose(s) for applying an EFV concept. In a next step of this assessment, it was analyzed and listed what environmental aspects are relevant for an EFV concept. Additionally, tool evaluation criteria had been specified to describe the dimensions and applicability of regulations, concepts and tools. A table was developed with an evaluation of the main existing different regulations, concepts and tools against the environmental criteria and the tool evaluation criteria.
Based on this overview of tools versus criteria, an analysis of potential approaches of an EFV concept was possible. The conceptual idea rests upon the so-called SWOT analysis. The idea of this concept depends on the assessment based on four issues: **S**trength, **W**eakness, **O**pportunity and **T**hreat. These were then taken into consideration when various approaches with regard to the assessment of the environmental friendliness of vehicles were analyzed"[8]

While the work deemed it possible to assess vehicles on some level for their environmentally friendliness it was left for the discussion at the 4th IEFV conference in New Delhi and future IG meetings to review the potential to determine the exact parameters and appropriate application of an evaluation method to meet the needs of various nations and regions. A central consideration would be the target audience for such information, such as policy makers, regulators and consumers.

During the 4th EFV conference held in New-Delhi India in 2009, the discussions led to the conclusion that developing the entire holistic approach for defining EFV from a technical and scientific point of view was not feasible. This is mainly because there are differences in testing procedures, multiple specifications, weightings, factors subject to regional or temporal circumstances and data availability concerning environmental aspects and impacts of vehicles.

In view of all the above aspects, it was suggested that to avoid a single score assessment, but, as a next step, to consider the following parameters in more detail.[9]

1. CO_2 emission: The factor has a direct impact on the target groups. Also substantial regional, worldwide, good quality data is available. Data is also regularly updated.
2. Noise: It has a direct impact on consumers and other road users. Good quality data is available. It is the topic which has a high relevance at present.
3. Regulated pollutants: Has a high relevance. Good quality regional data is available and data is updated regularly. Has a high local environmental impact.
4. Recyclability: Relevant to environment. Regional good quality data is available.
5. Type of fuel: Relevant to environment. Has high quality of good data available.

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[8] Informal document No. WP.29-148-11 (148th WP.29, 23-26 june 2009).
[9] Working Paper No. EFV-07-07-Rev1(GRPE Informal Group on EFV, 7th Meeting, 11th June 2010); Minutes of the 7th meeting of the GRPE Informal Group on Environmentally Friendly Vehicles (EFV) held at Geneva on 11th June 2010; http://www.unece.org/fileadmin/DAM/trans/doc/2010/wp29grpe/EFV-07-07r1e.doc

The IG had many in-depth discussions but met with some of important obstacles when determining the likelihood of success in identifying a single matrix to rate the "environmentally friendliness" of vehicles.

After much discussion and with the growing national and regional tools being developed to rate vehicles on the national and regional scale it was agreed that a global assessment tool may not be possible or warranted. However, during the exercise it was observed and understood that development of EFV evaluation criteria is very complex and difficult mainly because of:

- Differing market situations and consumer needs;
- Varying environmental needs (nationally or region-wise); with different priorities in different area;
- Complexity of environmental parameters that cannot be aggregated into a single score in an internationally and scientifically appropriate way ; and
- Technology choices (e.g. alternative fuels / propulsions) depend on different regions and segment conditions and a technology neutral approach is generally preferred.

Finally the IG referred the EFV working group activities to a newly formed Task Force Group on Environmentally Friendly Vehicles in June 2011.

This was suggested, proposed to and further agreed by WP.29[10]. The Task Force Group (TFG) has been established to take-up the work of EFV Informal Group and an effort has been made to prepare a progress report to show the promising advancements that have been made in technology innovation and EFV implementation since the first EFV conference in 2003.

The fifth EFV Conference was held in Baltimore, Maryland, USA on September 10-12, 2012. Prior to the conference, the EFV Task Force determined that due to significant progress made in EFV development since 2002, the fifth EFV Conference would be an appropriate time to both reflect on this progress and set the state for the next developments in this area. It was also decided that a sixth EFV Conference was not needed at this time.

Accordingly, the fifth EFV Conference focused on three main ideas which supported the overall conference theme of "Driving our Future Today". Specifically, the conference addressed the need for continual technical innovation in the transport area, identified areas to facilitate on-going investment in new technologies, and identified ways to take advantage of every opportunity to meet transportation needs in a responsible way for future generations.

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[10] Page 19; paragraph 73.Reports of the World Forum for Harmonization of Vehicle Regulations on its 154th session; http://www.unece.org/fileadmin/DAM/trans/doc/2011/wp29/ECE-TRANS-WP29-1091e.doc

On the conference's first day, participants heard from distinguished speakers as part of the plenary sessions and the Executive Panel, on which high-level experts explored the three main themes of the conference though discussions of several hypothetical scenarios. On the final day, twelve different breakout sessions covered topics from the development of EFV technology through green racing to Latin America's approach to the EFV to consumer acceptance of EFVs. Materials from the conference can be found at www.efv2012.org.

The fifth EFV conference clearly showed that significant progress in both developing and bringing to market EFV technologies has been made since 2002. Working together, government, industry and NGO stakeholders are effectively providing consumers with a multitude of choices of sustainable transport. It is also clear that now is not the time to rest on these successes, as there are still many new vehicle, engine and fuel technologies that can help make transport even more sustainable. Given the projected growth in markets around the globe, this work is vitally important.

2. Environmentally Friendly Vehicles: Transforming the Fleet

Automotive technology is advancing at a rapid pace as governments are striving to decrease the environmental impact of transportation emissions and to increase energy security. The health and productivity consequences of emissions from the use of automobiles have long been known. The problem of climate change is one of the most serious consequences of the emission of large quantities of CO_2 and other greenhouse gases into the atmosphere. Transport in general and road transport in particular constitutes a major share of the CO_2 emissions around the world. With strained petroleum resources, the desire for alternative sources to fuel our transportation needs continues to grow. As nations around the world strive to reduce emissions from vehicles they have developed ever more stringent emission limits for new vehicles and have seen excellent results. Industry has allocated significant resources towards the development and introduction of new clean technologies. The International Environmentally Friendly Conferences and activities at WP.29 have highlighted the dynamic fleet changes that have occurred and are to come.

Since 2003 to present, the technology in the vehicle design, powertrain, emission control devices, fuels and transmission has been significantly upgraded. Vehicles complying with current emission regulations are equipped with advanced emission control technologies like three-way catalytic converters, diesel particulate filters, and selective catalytic reduction, as well as sophisticated electronic systems to control engine operations. Emissions reductions have been significant while efficiencies have increased. Newly developed fuels have been added as an automotive fuel with conventional gasoline and diesel. DME, biodiesel, ethanol have proven their applicability and effectiveness as an alternatives to gasoline or diesel. Gaseous fuels are utilized in automobiles. CNG and LPG vehicles are becoming more significant where national Green Initiatives have advanced these fuels, thus reducing the need for gasoline and diesel.

The focus today is on developing a new generation engines and vehicles and bringing them to market. The regulatory framework around the world has targeted significant reductions for both traditional air pollutants and greenhouse gases. In addition, investments in advanced technologies and fuels have paved the way for a fleet of vehicles that will be far less polluting and will save energy.

These advancements include development of advanced fuel efficient, light weight and compact engines with optimized fuel injection and alternative fuel technologies. Vehicle development will focus on improved vehicles with electrified power trains such as electric, hybrid electric and fuel cell technology. Development of long life, high energy density and cost-effective batteries for electric drive (including hybrids, electric, and fuel cell) vehicles is high on the agenda of automobile researchers. The focus of advancement can be characterized in three areas of developments:

- Engine technology
- Vehicle technology
- Fuel technology

The fleet has become less polluting over the last thirty years and now is on the brink of a transformation due to the dedicated commitment to innovation and investments that a new generation of vehicles will require.

2.1 Regulatory Drivers to Environmentally Friendly Vehicles

Nations worldwide have been_increasingly_concerned about the need to reduce air pollution, reduce greenhouse gas emissions and preserve energy security through reduction in transportation emissions. The need to protect public health, the environment and energy security are important objectives in the mandating of more stringent vehicle emission limits over the last 30 or more years. This has resulted in significant reductions of criteria pollutants (including, particulate matter (PM), nitrogen oxides (NOx), volatile organic compounds (VOCs) and air toxics) resulting in meaningful reductions in premature deaths, reductions in hospitalizations, and lost work days[11]. More recently, the concerns for climate change impacts of emissions from mobile sources combined with the need to conserve energy have been vital considerations in programs to reduce greenhouse gases emissions, primarily carbon dioxide.

2.1.1 Regulation of Vehicle Emissions

Cars driven today in nations that have the most stringent emission limits are more than 90% cleaner than vehicles that were on the road in the 1970s. Advances in technology development and the recognition of the systems approach, establishing fuel quality standards[12] for lead and sulfur to enable advanced emission control technologies, have been instrumental in bringing new technologies to market in a manner that has maintained the other vehicle attributes while introducing a cleaner fleet of vehicles.

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[11] For example , see U.S. EPA Tier 2 program,, http://www.unece.org/fileadmin/DAM/trans/doc/wp29compendium/US_EPA_Tier2.pdf

[12] Annex 4: Key parameters for market fuel quality; Proposal for a new annex to the Consolidated Resolution on the Construction of Vehicles (R.E.3);Submitted by the Working Party on Pollution and Energy; ECE/TRANS/WP.29/2011/127; November 2011

There is a level of complexity and difficulty in comparing emissions limits around the world. Regulations for criteria emissions control vary widely from country to country, not only in absolute levels, but in how they are applied. Comparison of criteria emissions legislation is particularly difficult due, in part, to the following differences:

- Differences in test cycles and changes in test cycles
- Differences in vehicle categorization
- Phase-ins of limit values, by year, and/or region
- Differences in standards by fuel type
- Fleet averaging, credits, debits, production average vs. max limits, etc
- Differences in definition of full-life durability
- Differences in type of regulatory pollutants.

In the EU, criteria emission legislation is currently the EURO 5 standard. Other nations, such as India, China, Australia and Russia are phasing in versions of the EURO levels with schedules for phase in differing in time and/or region. These nations have made some other changes to these regulations such as modifying vehicle classification to better fit their market.

Table 1: Simplified Euro levels for Gasoline and Diesel Vehicles

Standard	Fuel	Date (EU)	Standard (g/km)					
			CO	HC	HC+NOx	NOx	PM	PN
Euro 3	Gasoline	2000	2.30	0.20	--	0.15	--	--
Euro 3	Diesel	2000	0.64	--	0.56	0.50	0.05	--
Euro 4	Gasoline	2005	1.0	0.10	--	0.08	--	--
Euro 4	Diesel	2005	0.05	--	0.30	0.25	0.025	--
Euro 5	Gasoline	2011	1.0	0.10	--	0.06	0.005	--
Euro 5	Diesel	2011	0.50	--	0.23	0.18	0.005	6×10^{11}
Euro 6	Gasoline	2014	1.0	0.10	--	0.06	0.005	6×10^{11} (for GDI)
Euro 6	Diesel	2014	0.50	--	0.17	0.08	0.005	6×10^{11}

Source: www.dieselnet.com/standards/eu/ld.php

Japan and Brazil have established their own emission regulations, with their own phase-in schedules and compliance mechanisms. Japan uses a system of mean and max standards where mean standards act as a production average and max standards are an individual vehicle limit, or a limit for low volume production. Brazil's levels are based on EU regulations, but use a drive cycle based on the U.S. FTP-75 drive cycle.

In the U.S., Federal standards apply to all vehicles, except vehicles sold in California or states that have not adopted the California standards. California standards, promulgated by the California Air Resources Board (CARB) are applied to all vehicles sold in California and in states that have chosen to adopt the California standards in lieu of Federal standards. There are currently 13 states that have adopted California standards.

Table 2: Selected U.S. Federal and California Light Duty Vehicle Emission Standards (simplified)
Full Useful Life

		Standards (g/mi)					
Federal		THC	NMHC/NMOG	CO	NOx	PM	HCHO
Tier 1 (gasoline)	Car, LDT1	--	0.31	4.2	0.6	0.10	--
	LDT2	0.80	0.80	5.5	0.97	0.10	--
Tier 2, bin 5	All	--	0.090	4.2	0.07	0.01	0.018
California							
LEV 1	Car, LDT	--	0.090	4.2	0.3	0.08	0.018
	LDT2	--	0.130	5.5	0.5	0.10	0.023
LEV 2	All	--	0.090	4.2	0.07	0.01	0.018
ULEV2	All	--	0.055	2.1	0.07	0.01	0.011
SULEV	All	--	0.010	1.0	0.02	0.01	0.004

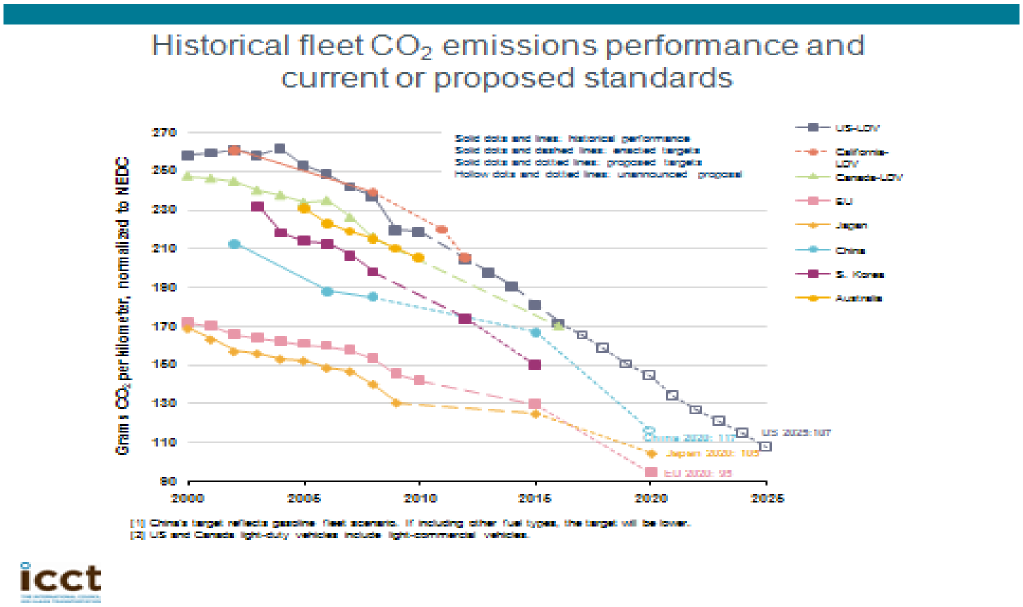
Source: dieselnet.com/standards/us
LDT1 are trucks ≤ 3750 lbs, LDT2 are trucks >3750
Full useful life is generally 100K or 120K miles

U.S. Federal Tier 2 standards contain a number of emission level bins. Manufacturers can certify a mix of vehicles in various bins in order to attain a fleet average NOx standard. The fleet average NOx standard is equivalent to that in bin 5. Also, U.S. Federal standards include three Supplemental Federal Test Procedures (SFTP) with standards that apply to high-speed, high-load driving, and operation in hot ambient with air conditioning. This is in addition to cold temperature standards and standards for evaporative emissions. California standards generally have a similar structure to Federal standards, but with different levels, often more stringent. California has an additional requirement that each manufacturer certify a portion of their fleet to a zero emission standard, referred to as the ZEV mandate.

2.1.2 Regulation of CO_2 equivalent and Fuel Economy

The impressive targets which have been set for lowering CO_2eq emissions and increasing fuel economy over the next 15 years is a continuation of aggressive efforts by regulating parties to pave the way for solutions to come to the market to protect public health and increase energy security. The targets reflect a growing acceptance of these advanced technologies and alternative fuel sources. The chart below illustrates the fact that more environmentally friendly vehicles are entering the market everyday and the promise is there for the transformation to continue.

Figure 1: Fleet CO2 Emissions and Standards 2000-2025[13]



The next section the document reflects the current suite of technologies that are making their way to the market place to ensure that the progress continues.

2.2.1 Engine Technologies

Typical internal combustion engines (ICE) in use today in transportation vehicles are two-stroke or four-stroke designs fueled by gasoline, diesel, ethanol, and compressed natural gas (CNG). Gasoline, ethanol and CNG engines are spark-ignited (SI) and most often port-fuel injected with compression ratios around 10:1. They use Oxygen feedback and three-way catalyst systems to reduce criteria pollutants. Diesel engines are usually turbocharged and direct-injected with compression ratios around 17:1.

Two-stroke engines were very popular throughout the 20th century in motorcycles and small-engined devices and were also used in some large trucks, cars, a few tractors and many ships. This popularity was mainly because of its simple design, light weight, high specific power output, and ease of maintenance. The majority of the current stock of three wheelers and two wheelers in India and other Asian countries are powered by two-stroke gasoline engines. The major disadvantage of the 2-stroke engine is its high level of emissions, especially particulate matter and HC resulting from un-burnt lubricant and gasoline, as well as relatively high fuel consumption. To control pollution from two stroke engines, several measures were taken which include reduction in fuel sulphur, improvements in fuel injection systems, use of gaseous fuels (LPG / CNG) and improved after treatment systems. However, due to the introduction of

[13] The ICCT, Global Comparison of Light-Duty Vehicle Fuel Economy/GHG Emissions Standards; http://theicct.org/global-passenger-vehicle-standards-update

stringent emission norms over the years, two stroke engines are being replaced by four-stroke engines, which emit fewer pollutants.

Exhaust aftertreatment for diesel engines varies from no aftertreatment to complex arrangements of catalysts, particulate filters and/or selective catalytic reduction (SCR) injection systems with injected reductants such as urea. In the most recent public document on this issue, the U.S. EPA and the U.S. Department of Transportation thoroughly reviewed technologies in developing a proposed rulemaking for reducing greenhouse gases while preserving stringent reductions of other pollutants. The list below is not meant to be exhaustive but to provide a representative list of the most cost effective technologies that can be employed to continue to reduce pollutants and greenhouse gases from vehicles.

2.2.1.1 Advanced spark-ignited engine technologies

There are several advanced SI engine technologies that have been offered in various products for a number of years and are beginning to enter the market in significant numbers.
Turbocharging has been employed for many years to increase the power of an engine by increasing the airflow. When accompanied with engine downsizing to maintain the same power level and vehicle performance, the engine becomes more efficient because of reduced pumping losses at lighter loads. The benefit varies with boost level and with the application of other technologies like EGR and direct injection. Engineering consultant Ricardo estimates that advanced engines in the 2020-2025 timeframe can be expected to have advanced boosting systems that increase the pressure of the intake charge by up to 3 bar which could allow for engine downsizing of greater than 50%[14]

Direct injection is a technology that injects fuel directly into the combustion chamber of an engine at very high pressure. This technology improves the cooling of the air/fuel charge in the combustion chamber which allows for higher compression ratios and increased thermodynamic efficiency. When combined with high levels of turbocharging, it dramatically improves drivability and throttle response, making the engine feel more responsive and eliminating "turbo lag."

Exhaust gas recirculation boost increases the amount of exhaust gas recirculated (EGR) in the engine which improves thermal efficiency and reduces pumping losses. EGR has been used in engines for many years to improve fuel economy, but high levels of EGR can be used to improve efficiency in highly-boosted engines.

Lean-burn gasoline engines can further reduce fuel consumption by reducing the fuel mixture under conditions of low load. However, this technology will increase NOx emissions, so appropriate measures should be taken to mitigate the increased NOx emissions.

[14] U.S. EPA, "Project Report: Computer Simulation of Light-Duty Vehicle Technologies for Greenhouse Gas Emission Reduction in the 2020-2025 Timeframe", Contract No. EP-C-11-007, Work Assignment 0-12,

Valve train technologies such as variable valve lift and variable valve timing have been used in mainstream engines for a number of years, but are expected to become even more prevalent in the future. Camless engine designs are also being developed. This technology would enable almost complete flexibility in valve actuation and may allow for the elimination of the engine's throttle valve. All these valve train technologies increase efficiency by optimizing engine airflow over a wider range of engine operation. Some engines will employ cylinder deactivation to reduce the effective size of the engine by disabling cylinders during light-load conditions.

Various friction-reducing technologies including advanced lubricants and engine design features that reduce frictional losses such as advanced bearings, coatings and thermal management techniques are also expected to play a role in engine efficiency improvements in the future.

These spark-ignited engine technologies can be used on engines fueled by gasoline, alcohols (ethanol, methanol), natural gas (compressed or liquefied), or propane. Often, manufacturers build engines that are capable of using more than one fuel. When the fuels can be mixed in the fuel tank, the vehicle is called flexible fueled vehicle (FFV). When the fuels are kept in separate tanks, the vehicle is called a bi-fuel (or tri-fuel, etc.). Typically FFVs are designed to run on a mix of gasoline and ethanol and bi-fuel vehicles are designed to run on CNG or propane and gasoline. While helpful from a fuel diversity perspective, some efficiency gains can be realized by dedicating a vehicle to operate on one of these alternative fuels. For example, alcohols have improved charge-cooling effects over gasoline, so compression ratios can be higher on dedicated alcohol engines and more efficiency can be realized. CNG has a high octane rating and so it too can allow for higher compression ratios.

2.2.1.2 Advanced compression-ignition engine technologies

Diesel engines incorporate many of the technologies and features discussed above. Diesel engines operate lean under most conditions and are typically turbocharged. They have low pumping losses due to a lack of a throttle (or reduced throttling) and they utilize a combustion cycle that operates at a higher compression ratio. They also utilize direct injection. However, because they operate lean, they have inherently higher NOx emissions than stoichiometric gasoline engines and they emit more particulate matter-especially at high power levels that require enough fuel to create smoke. Researchers continue to work to improve diesel engine technology while reducing emissions. Some of the technologies being considered include higher injection pressure with advanced controls and improved engine warm-up.

Homogeneous charge compression ignition (HCCI) is a technology being developed that seeks to take advantage of diesel's inherent efficiency benefits of higher compression ratio and low pumping losses while reducing NOx emissions and allowing for more fuels to be burned such as gasoline. However, it is difficult to sustain and control HCCI combustion over the entire engine operating range and requires sophisticated engine control strategies and sensors. It would most likely exist as a special operating mode within a more traditional combustion strategy for the rest of the engine's operating region.

2.2.1.3 Other engine technologies

Stop-start technology automatically turns off a vehicle's engine when the vehicle comes to a stop and restarts it when the driver releases the brake or presses on the accelerator which eliminates unnecessary idling. Stop-start systems can employ an upgraded version of the standard vehicle starter, or can utilize a specialized belt-driven starter-alternator that replaces the standard alternator.

Table 3: Summary of EPA estimates of selected engine technology effectiveness[15]

Technology Package	**Low**	**High**
Turbocharge and Downsize with Direct Injection and EGR boost	16%	26%
Advanced Valvetrain	2%	7%
Cylinder Deactivation	5%	6.5%
Friction Reduction	0.5%	5%
Advanced diesel (convert from gasoline or equivalent)	19%	22%
Stop Start	2%	2.5%

2.2.1.4 Exhaust After-treatment technologies

Stringency in vehicular emission norms resulted in fitment of various after treatment devices on vehicles. Various exhaust after treatment technologies available includes 2/3/4 way catalytic converters with and without closed loop control systems, diesel Particulate Filters (DPF), continuously regenerative trap (CRT), Lean NOx trap, Exhaust Gas Recirculation with hot or cold configuration, Selective Catalytic Reduction (SCR). These technologies are used in various combinations to meet highly stringent emission norms.

Exhaust Gas Recirculation (EGR) at different rates reduces Oxides of Nitrogen effectively, but causes increase in PM which can be controlled by employing DPF / CRT. Cold EGR further reduces the increase in PM due to reduction in peak combustion temperature. In general operation, it is desirable to have the amount of EGR opening proportional to throttle opening.

Three-way catalysts are the most popular type of catalyst used to control emissions from gasoline engines. The catalyst uses a ceramic or metallic substrate with an active coating incorporating

[15] U.S. EPA, Draft Regulatory Impact Analysis: Proposed Rulemaking for 201702025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, Ch 1, http://www.epa.gov/otaq/climate/documents/420d11004.pdf

alumina, ceria and other oxides and combinations of the precious metals - platinum, palladium and rhodium. Three-way catalysts operate in a closed-loop system including a lambda or oxygen sensor to regulate the air-fuel ratio on gasoline engines. The catalyst can then simultaneously oxidize CO and HC to CO2 and water while reducing NOx to nitrogen. Catalyst efficiencies can approach 99% under ideal conditions where the catalyst feedgas is closely controlled by a closed-loop feedback fuel control system with oxygen sensors both before and after the catalyst.

Diesel Oxidation Catalysts (DOC) remain a key technology for diesel engines where the high oxygen content of the exhaust precludes the use of three-way catalysts. These DOCs reduces CO and HC and also decrease the mass of diesel particulate emissions by oxidizing some of the hydrocarbons that are adsorbed onto the carbon particles. All new diesel engines used for passenger cars, light-duty and heavy-duty trucks and busses are now equipped with DOCs. DOCs may also be used in combination with NOx adsorbers, DPFs or SCR catalysts.

Selective Catalytic Reduction Aftertreatment uses a reductant (typically, ammonia derived from urea) continuously injected into the exhaust stream ahead of the SCR catalyst. Ammonia combines with NOx in the SCR catalyst to form N2 and water. The urea is typically injected at a rate 3-4% that of fuel consumed. SCR efficiencies can exceed 95%.

Diesel particulate filters are now used to meet Euro-V/VI regulations with the specific criteria for particle numbers. DPFs are capable of 99% or better efficiency The experimental studies show that the combination of Diesel Oxidation catalysts and DPF is the most effective solution in controlling CO, HC and Particulate number emissions, as the DOC increases the temperature of exhaust at the inlet face of DPF to assist the regeneration.

Different exhaust aftertreatment technologies and their combinations can be optimally selected based on engine design and emission behavior. Continuous improvement in substrate and noble metal coatings, electronic controls and fuel quality (sulfur and lead) are also important parameters related to exhaust after treatment technology in meeting highly stringent emissions norms.

2.2.2 Transmission Technologies

As with engine technologies discussed above, there are several advanced transmission technologies which are in production today, but are expected to make further inroads in the market in the future.

Only a few years ago, three speed automatic transmissions were standard world-wide. Four-speed automatics then became dominant. Currently, five- and six-speed automatics are making significant inroads and seven- eight- and even nine-speed automatics are entering the market. As a transmission adds ratios, the engine can operate in its most efficient area more often. Also more ratios can improve performance of lower-powered and more efficient cars while maintaining low engine speeds during cruises. It should be noted that as more ratios are added, the benefits diminish as the transmission begins to effectively approach a continuously-variable transmission (CVT).

CVT transmissions have been in production for some time, and offer the opportunity to operate the engine in an optimum-efficiency area under all conditions. Most CVT designs rely on a belt and pulley system where the pulleys change diameter by means of a split sheave design. There are other CVT designs that use other approaches including toroidal systems. Many CVT designs feature a very wide span of ratios compared to conventional automatic transmissions which allows for better performance from lower-powered vehicles and excellent fuel economy potential especially in city driving.

Automated manual or the more common dual clutch transmission (DCT) has been on the market for several years, and is gaining in popularity. These transmissions combine the inherent efficiency of a traditional manual transmission with automated controls and launch clutch so they drive like an automatic transmission. These transmissions eliminate the torque converter and essentially emulate the effect of a manual transmission operated by an expert driver, maximizing fuel economy.

Other transmission improvements can improve the efficiency of different types of transmissions. Improved controls and shift optimization strategies can be applied to any transmission type and can be utilized to maximize the engine efficiency for any operating condition. These controls can also be used to adapt the transmission to driving conditions or driver behavior. Improved torque converter lockup strategies can be employed with certain transmissions to increase the time this fuel-saving feature is active. Friction-reducing treatments and design features can also be employed on any type of transmission to reduce frictional losses.

As engine and transmission controls become more sophisticated and capable, and as environmental concerns and fuel costs increase, traditional manual transmissions will be increasingly replaced by automated transmission systems.

Table 4: EPA estimated effectiveness of selected transmission technologies[16]

Technology Package	Low	High
5-speed automatic (from 4-speed)	1%	1.5%
6-speed automatic (from 4-speed)	2%	2.5%
6-speed dry clutch DCT (from 4-speed auto)	6.5%	8%
Aggressive Shift Logic	2%	7%
High efficiency gearbox	4%	5.5%

[16] U.S. EPA, Draft Regulatory Impact Analysis: Proposed Rulemaking for 201702025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, Ch 1, http://www.epa.gov/otaq/climate/documents/420d11004.pdf

2.2.3 Hybridization and Electrification

The electrification of vehicle drivetrains presents an opportunity to significantly increase the efficiency of vehicles by utilizing certain inherent advantages of electric motors and batteries. These include their ability to recapture energy normally lost as heat during braking, and their very high torque at zero rpm which makes them ideally suited to provide vehicle launch assist. Hybrid electric vehicles (HEVs) combine a conventional engine with an electric motor and battery (and their necessary control system) in a vehicle with either a conventional transmission such as an automatic or a dedicated hybrid transmission, typically called a power split device. There are many configurations of HEVs that can be developed with various combinations of motors and clutches and even electric axles that allow for hybrid all-wheel-drive. Hybrids can have a single motor, multiple motors, motors integrated into the transmission or separate. Hybrids offer stop-start, power assist and regenerative braking capability, but in all hybrids, all the energy consumed ultimately comes from the fuel tank.

Hybrids can generally be informally classified as mild or strong. Mild hybrids tend to have small motors and batteries and offer very little power assist perhaps just enough to “creep” the vehicle for short distances in stop-and-go traffic. Some mild hybrids use an upgraded version of a belt-driven starter-alternator as used in a stop-start system. Strong hybrids, on the other hand, have significant electric launch assist and are capable of recapturing significant quantities of braking energy. Formal thresholds identifying mild and strong hybrids have not been established.

Plug-in hybrid electric vehicles (PHEV) offer the same features and benefits as HEVs, above, but in addition have provisions to charge the battery directly from an electrical source such as the local power grid. Typically, PHEVs have larger batteries than HEVs to take advantage of the grid power for propulsion. The amount of driving that can be done on battery power exclusively is typically referred to as all-electric range and varies depending on battery size. Some PHEV’s with smaller electric motors may not be capable of operating exclusively at higher power levels and will instead use their stored electric power to assist the conventional engine in a blended mode. When the excess stored electricity is consumed and the battery reaches a minimum state of charge, the PHEV will revert to HEV mode until the battery is recharged.

Pure Electric Vehicles (EV) operate exclusively on electric power supplied through a plug. These vehicles replace the conventional engine with one or more ~~a~~ large electric motor(s) and battery pack sized to deliver full performance for a specific range. The effective range of an EV can vary widely depending on driving conditions, driving style, weather conditions, and passenger comfort demands such as heating and air conditioning.

Table 5: Conventional, HEVs, PHEVs, and EVs Compared[17]

	Increasing Electrification			
Attribute	Conventional	HEV	PHEV	EV
Drive Power	Engine	Blended Engine/Electric	Blended Engine/Electric	Electric
Engine Size	Full Size	Full Size or Smaller	Smaller or Much Smaller	No Engine
Electric Range	None	None to Very Short	Short to Medium	Medium to Long
Battery Charging	None	On-Board	Grid/On-Board	Grid Only

The environmental benefits of electrification can vary widely depending on vehicle class, battery and motor sizing and expected usage including the amount of city and highway driving. Generally, electric drive vehicles excel in heavy traffic because they don't idle their engines (HEV and PHEV) and can creep forward at low speed without turning on their engines. They also recover braking energy during deceleration. During long highway cruises, hybridization benefits are lessened, but still significant due to engine downsizing and some regeneration.

[PHEV benefits are measured in terms of a utility factor (UF) which is the percent time the PHEV is expected to operate in electric mode[i] given the expected duty cycle. By definition, the UF of a hybrid, or a conventional vehicle is 0 since it never operates on utility power and the UF of an EV is 1 because it operates exclusively on utility power. If a particular PHEV has a UF of 0.4, it would mean that the vehicle could be expected to operate 40% of the time in electric mode and 60% in HEV mode with the resulting combined fuel economy the weighted average of the fuel economy in these two modes. (This is a simplified example) The Society of Automotive Engineers have established a methodology of calculating the UF in its standard J1711.[18] This standard was developed using the U.S. standard emissions testing cycles, but the developers were mindful to make it adaptable to other cycles.]

[17] U.S. EPA, NHTSA, Draft Joint Technical Support Document: Proposed Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, Ch 3, http://www.epa.gov/otaq/climate/documents/420d11901.pdf

[18] http://standards.sae.org/j1711_201006

Table 6:EPA estimated effectiveness of selected Electric-Drive Vehicle Technologies[19]

Technology Package	Low	High
Mild HEV (hybrid system only)	7%	8%
HEV (hybrid system only)	8%	16%
PHEV with 20 mile range	40%	40%
EV	100%	100%

Electric-drive vehicles have made inroads into the market in recent years, but the penetration has been slow. A major barrier has been battery costs. Battery costs are expected to decline considerably over the next few years, [20]making the technology far more cost-effective and accessible to consumers.

Another factor affecting the market appeal of EVs will be the availability of charging. Most EVs will be charged overnight at owner's homes. Those owners will need to have reliable access to electricity where they park. Public charging during the day will also be desirable, but in some cases, electricity providers will be reluctant to supply EVs with electricity during high-load periods. Finally, the fuel source for the electric grid must be considered. Electricity produced exclusively from coal in an inefficient plant and/or delivered over an inefficient distribution system may result in an EV being dirtier overall than a modern, high-efficiency hybrid vehicle.[21]

2.2.4 Fuel Cell Vehicles

Fuel cell (electric) vehicles (FCV) are receiving a lot of attention and development effort from automakers due to the promise of longer range than Pure EVs, zero tailpipe emissions, and fast refueling. An on-board fuel cell produces electricity directly from the reaction of hydrogen with oxygen, producing pure water as a by-product. In other respects, an FCV is an electrified car, but instead of charging a battery, it is fueled with hydrogen.

Great progress was achieved in fuel cell development in recent years with automakers globally announcing the start of series-produces FCVs starting around 2015. Costs of the fuel cell system still need to be reduced for mass-market deployment. Also, hydrogen production and distribution will need to be further developed. Hydrogen production is currently well-established using natural gas as a feedstock already providing substantial green-house-gas savings on a well-to-

[19] U.S. EPA, Draft Regulatory Impact Analysis: Proposed Rulemaking for 201702025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, Ch 1, http://www.epa.gov/otaq/climate/documents/420d11004.pdf

[20] U.S. DOE, Argonne National Laboratory, Modeling the Performance and Cost of Lithium-Ion Batteries for Electric-Drive Vehicles, ANL-11/32, Sept, 2011, http://www.cse.anl.gov/batpac/about.html

[21] U.S. DOE, Oak Ridge National Laboratory, Potential Impacts of Plug-In Hybrid Electric Vehicles on Regional Power Generation, January 2008, ORNL/TM-2007/150, http://www.ornl.gov/info/ornlreview/v41_1_08/regional_phev_analysis.pdf

wheels basis compared to incumbent technologies. High-volume production based on renewable energy sources will need to be further developed to maximize the potential of FCVs.

2.3 Advancements in Non-Powertrain Vehicle Technology

As with engine and transmission technology, there are multiple advancements in other areas of vehicle technology. Many of these are in use today in various ways and they will continue to be implemented and improved upon in the future. Aerodynamic improvements and weight reduction are two examples of these technologies that will continually be improved.

Aerodynamics is becoming increasingly important in all market segments and is especially important in vehicles that are expected to be operated at higher speeds were aerodynamic losses are greatest. Advances in computer modeling and testing of new vehicles enables manufacturers to optimize and tune vehicle aerodynamics earlier and more effectively in the design process leading to more and more benefits. Automakers are also adding active aerodynamic features to their vehicles such as active grill shutters and active ride height that reduce aero losses at higher speeds. Working against aerodynamic gains is often styling considerations. Some markets prefer the look of truck-like vehicles and/or large wheels which can both hinder aerodynamic efficiency.

Manufacturers have also made great strides with weight reduction. Modern computerized design tools and many new steel and aluminum alloys have enabled manufacturers to design increasingly lightweight vehicles while maintaining safety and driving performance. Magnesium, plastics, and composites including carbon fiber along with other materials will play an increasing role in reducing vehicle mass and improving efficiency. A generally accepted rule of thumb is that for every 10% mass reduction, a vehicle's fuel consumption is reduced by 6%. As vehicles become lighter, other components such as brakes, wheels, and powertrains can also become smaller and lighter adding to the mass reduction. A 2010 study by Lotus engineering shows that by 2017-2020, mass reduction of 21% to 38% is possible with a minimal to moderate cost impact.[22] However, other studies have shown somewhat less reduction is feasible.[23]
Tire manufacturers are making continual advancements in the reduction of rolling resistance while maintaining high levels of durability, traction, and ride comfort. These trends are expected to continue as tire manufacturers continue to develop new rubber compounds, tread patterns, and construction techniques.

As electrical demands increase in vehicles for luxury features such as heated seats, manufacturers are looking to improve the efficiency of electrical systems. Technologies such as high efficiency alternators, LED lighting and high-efficiency motors and actuators are beginning

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[22] Lotus Engineering, An Assessment of Mass Reduction Opportunities for a 2017-2020 Model Year Vehicle Program, March 2010, http://www.theicct.org/sites/default/files/publications/Mass_reduction_final_2010.pdf
[23] U.S. EPA, NHTSA, Draft Joint Technical Support Document: Proposed Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, Ch 3, http://www.epa.gov/otaq/climate/documents/420d11901.pdf

to make inroads into the vehicle market. These technologies can be used to reduce electrical loads and improve fuel economy.

Climate control systems are also receiving attention to reduce fuel consumption and emissions. New refrigerants are entering the market and will reduce GHG emissions when and if they are released to the environment via leakage. Upgraded components will reduce leakage and improve system efficiency.

Table 7: EPA estimated effectiveness of selected Vehicle technologies[24]

Technology Package	Low	High
20% car aero drag reduction	4.5%	4.5%
20% reduction in car tire rolling resistance	4%	4%
Improved alternator and electrical accessories	1%	3.5%
Improved air conditioning systems		

2.4 Other Advanced Vehicle Technologies

There are many other vehicle technologies that are being developed to answer transportation needs. These technologies may be very appealing in particular markets with an abundance of particular resources such as sunshine for solar electric cars and particular driving needs. Additionally, some regions or nations may have especially abundant resources that can be employed to make specific fuels. A well-known success story is Brazil's exploitation of their abundant sugar cane resources to make ethanol for domestic vehicle fueling. Since a vehicle is essentially a device that is able to release stored energy and convert it to motion in a controlled manner, there are countless methods that can be devised to store and release energy to use for transportation.

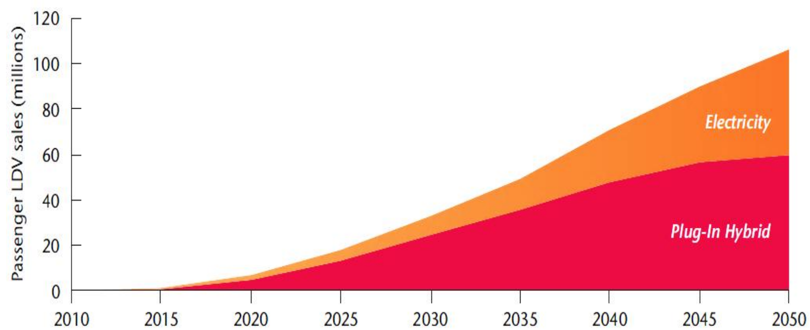
Solar electric cars that recharge while parked in the sun may be appealing in certain markets with high solar energy availability and shorter trip lengths. As solar panel development proceeds and efficiencies increase and costs decrease, vehicle capabilities will increase and this market may expand.
Compressed air cars, while not a new technology may be appealing in certain markets. Compressed air cars store energy on board in the form of compressed air. As the air is released, it expands in a motor, converting the energy into motion. The car is "refueled" by simply filling the tank with compressed air.

2.5 Driving the Future Today: The Pace of Technology Development and Technology Penetration Rates-

[24] U.S. EPA, Draft Regulatory Impact Analysis: Proposed Rulemaking for 201702025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, Ch 1, http://www.epa.gov/otaq/climate/documents/420d11004.pdf

The rate of change in technology has been advancing over the last 10 years since the first discussions of Environmentally Friendly Vehicles on the international stage in 2003. As discussed above the increasingly more stringent emission standards have driven up the penetration of the most promising technologies while increasing their efficiency. In one scenario, The International Energy Administration has demonstrated in the following chart the penetration rate to reach a goal of 50% of EV/PHEV sales by 2050 to reach their stated Electric and Plug-in Vehicle Roadmap goals[25].

Figure 2: Technology Penetration EV and PHEV



Source: IEA 2010.

In the race to bring new technologies to market to meet the growing demand for cleaner vehicles it is clear that the advancement in the use of computerized three dimensional development and simulations are increasing the rate of introduction and providing new opportunities for component suppliers to market new products.

In today's globally competitive market competitiveness is strongly influenced by a manufacturer's ability to turn over its product line-up and provide a steady stream of new products. Consumers have been becoming more interested in technology in general, and new technology is one way to distinguish an automaker's offerings. It is observed that the developmental time, from first production application to full market introduction, has been declining as manufacturers bring innovations to market faster.

Recent changes have reduced the time associated with engineering development. The most critical change has been the use of computer-aided design. The advances in the capability of computer design assists engineers in three dimensions allowing them to see and test how they will work and then make adjustments as needed. In addition, the use of computer based engineering development has allowed component suppliers to market new ideas to the automotive industry at a greater pace.

Finally, there have been major increases in manufacturing efficiency in the automobile industry. For example, many major manufacturers have reduced their number of brands and models which

[25] Electric and Plug-in Hybrid Roadmap/OECD/IEA, 2010

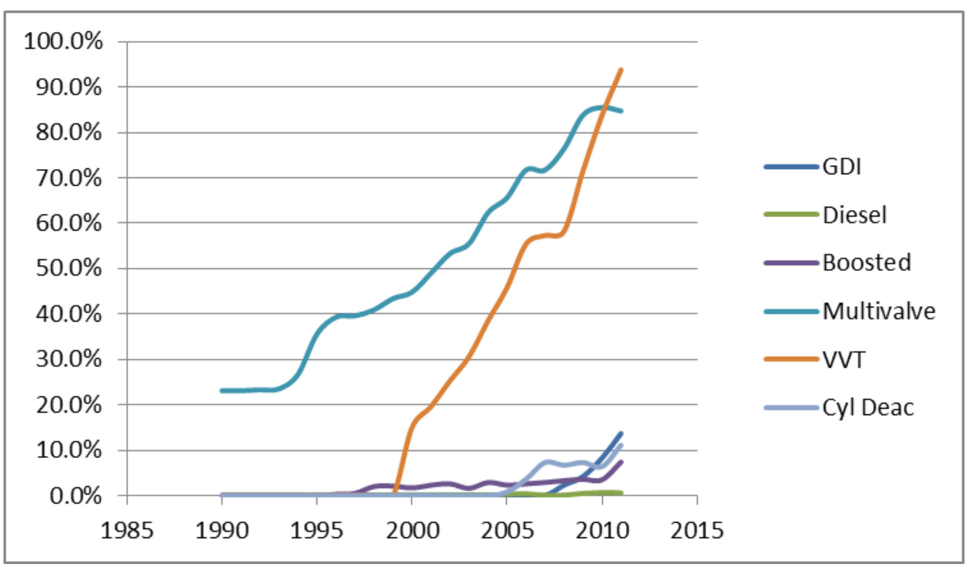
increases the ability to focus engineering and manufacturing resources on a much smaller number of models. Globally, there has been a significant industry-wide movement toward single platform architectures that can support multiple vehicles and enable significant parts utilization across manufacturer products. By reducing the number of platforms, yielding more vehicles per platform, frees up engineering resources to deploy new technologies across a greater number of vehicles more quickly and increases the rate at which new technologies can be introduced.

The combination of these three factors will most likely continue to increase the pace at which future technologies can be brought to market and have a global impact on the introduction of EFVs.

2.5.1 Recent Technology Penetration Rates in the U.S. 1990-2011

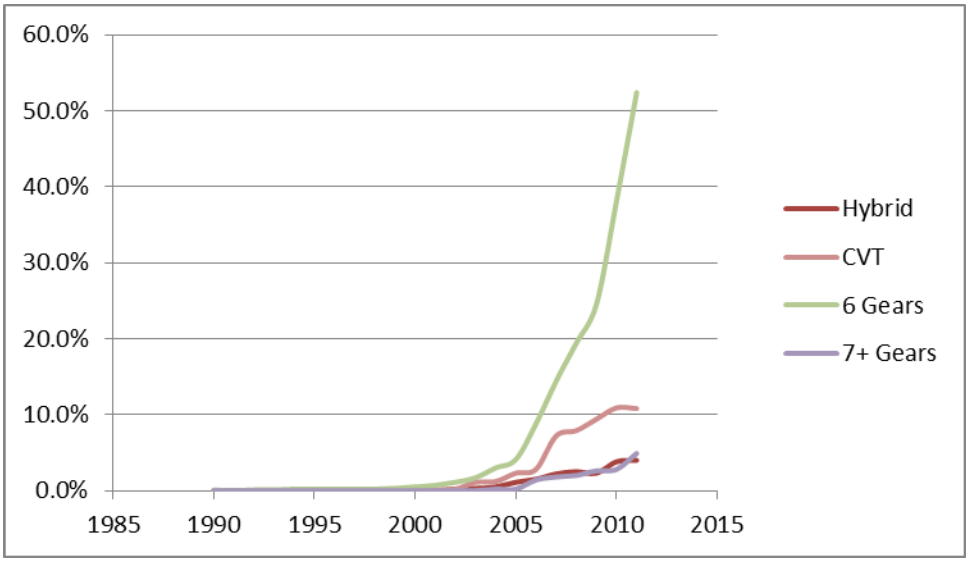
The charts below show the progression of market penetration of selected technologies in the U.S. from 1990 to 2011. Certain technologies such as multivalve cylinder heads, variable valve timing, and 6-speed automatic transmissions have shown dramatic increases in market penetration. Other technologies, such as gasoline direct injection are showing rapid penetration, but are at a comparatively early point in adoption.

Figure 3: Penetration of Engine Technologies 1990-2011[26]



[26] U.S. EPA, Light Duty Automotive Technology, Carbon Dioxide Emissions and Fuel Economy Trends: 1975 Through 2011, Tables 13 and 14, http://www.epa.gov/otaq/fetrends.htm

Figure 4: Penetration of Hybrid and Transmission Technologies 1990-2011[27]



2.6 Advancements in Fuel Diversification and Technology

In any vehicle market, the availability and cost of fuel will play a critical role in shaping what types of vehicles are purchased and how much they are driven. Brazil has developed a healthy market for domestically-produced ethanol and the vehicles sold in that country reflect this fuel choice. In parts of Europe, diesel fuel has provided the most economical option for many drivers, which has led to a large number of diesel passenger cars. In the U.S., the vast majority of the light duty fleet is gasoline powered, but there are large numbers of E85-capable vehicles and most of the U.S. gasoline pool contains up to 10% ethanol.

In the future, the volume of biofuels, including alcohols and biodiesel is expected to increase. Other technologies, such as coal-to-liquids may also play a role. However, one area that is garnering much attention is resurgence in natural gas from previously-unrecoverable reservoirs using new technologies such as hydraulic fracturing. Such "fracking" in the U.S. has driven natural gas prices down to very low levels, making CNG-fueled vehicles attractive from a refueling perspective, although the refueling infrastructure and vehicle market have not yet caught up with the fuel supply. However, it is important to note that natural gas can be used as a base stock to synthesize a number of liquid fuels and can be used to generate electricity for grid-connected vehicles.

[27] U.S. EPA, Light Duty Automotive Technology, Carbon Dioxide Emissions and Fuel Economy Trends: 1975 Through 2011, Tables 13 and 14, http://www.epa.gov/otaq/fetrends.htm

Other alternative fuels such as hydrogen for fuel cell vehicles for combustion engines and electricity are also poised for growth in the future as oil prices rise and vehicle technology is developed.

3.0 Environmentally Friendly Vehicles: Policy Innovation

3.1 Research and Development

Continued development of new technologies will lead to new generations of advanced environmentally friendly vehicles. Research and development into new areas, some of which may not yet be identified, will ensure these new technologies will be deployed as they become commercially viable. Sufficient investment in R&D with both private and public funds is necessary to encourage the development of these new technologies.

In the U.S., there are many government-funded research programs exploring new EFV technologies. Among these are programs funded by the U.S. Department of Energy (DOE) under the Vehicle Technologies Program covering areas such as hybrid and electric vehicle systems, energy storage, electric vehicle infrastructure, advanced combustion engines, fuels and lubricants, materials, and tools for analysis.[28] These R&D programs cover a wide range of technologies and fuels from conventional gasoline, alcohol, and natural gas powertrains, to hybrids, electric vehicles and hydrogen fuel cell vehicles. Their success relies on a partnership of government, academia, and industry who work together to identify potential technologies, and develop them through the pre-competitive phase for eventual commercial use.
U.S. government agencies also invest in R&D in other areas that directly affect the environmental performance of transportation systems. The U.S. Department of Transportation is funding research into Intelligent Transportation Systems (ITS)[29]. ITS research can lead to systems that improve the efficiency of road use, while improving safety. DOE is also funding research into Smart Grid technologies that will enable a more efficient utilization of the nation's electric grid capacity for charging grid-connected vehicles such as EVs and PHEVs.

In India, to tackle the problem associated with the air pollution in metropolitan cities like, New-Delhi, Mumbai, Pune etc. all public transport diesel buses and three wheeler auto-rickshaws running on two-stroke gasoline engines, were replaced by CNG. Under the program, all pre – 1990 autos and taxis were replaced with new vehicles on clean fuels like CNG by March 31, 2000. Financial incentive was given by the government for replacement of all post 1990 autos and taxis with new vehicles on CNG. Also, the mandate was given for buses older than eight years to be replaced from diesel to CNG stage-wise so that the city bus fleet will be steadily get converted to single fuel mode on CNG.[30]

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[28] U.S. DOE, http://www1.eere.energy.gov/vehiclesandfuels/pdfs/vtp_fs.pdf
[29] U.S. DOT, http://www.its.dot.gov/connected_vehicle/connected_vehicle.htm
[30] Report on "CNG programme in India: The future challenges", FACT SHEET SERIES, 2010, Centre For Science and Environment, India

The Central Pollution Control Board, the apex air quality monitoring agency in India, based on the air quality trends, has stated that after the implementation of the CNG programme the particulate levels dropped by about 24 per cent from the 1996 levels.

India is also working on the hydrogen and CNG blended fuels as an alternate automotive fuels. Presently, around 18% hydrogen- CNG blend can be used without doing any changes in present CNG kits. The first HCNG station has been established in Dwarka, at New-Delhi in India. Government agencies and scientists are working to increase the percentage blending of Hydrogen in CNG above 20%.

In Japan, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) considers measures to encourage the development and promotion of EFVs as an important issue for the government alongside the setting of emission regulations and fuel-efficiency targets. MLIT has been promoting the development of next-generation EFVs to replace current heavy-duty diesel vehicles since FY2002.

In response to this, the National Traffic Safety and Environment Laboratory (NTSEL) as a principal research agency spearheaded the launch of the project. Under this project, the development of new technologies for next-generation fuel-efficient low emission vehicles, including dimethyl ether (DME), natural gas, next-generation hybrids, bio fuel and super-clean diesel vehicles, have been promoted.

The German government supports R&D of alternative drive trains in various programs. This includes the national innovation program for hydrogen and fuel cell technology and the program of model regions for battery electric mobility from the Federal Ministry of Transport, Building and Urban Development. In addition, the Federal government funds four show cases for electric mobility. In all of these programs industry, academia, and government work together to further explore relevant practical questions and serve as an example.

To support the activities to develop Germany into a provider of and a market for electromobility by 2020 the Federal Government established the National Platform for Electromobility (NPE).[31] The representatives of industry, academia, government, unions and society in the NPE have agreed to pursue a systemic, market-focused and technologically neutral approach. The members believe that the key to the success of electromobility in Germany lies in cross-sectoral cooperation between all the stakeholders. The seven working groups of the NPE have developed research and technology roadmaps covering the key issues in the following thematic areas: battery, drivetrain technology, light weighting, information and communications technology (ICT) and infrastructure, recycling and vehicle integration. The experts will also present roadmaps covering international standardization and training/skills. Based on the recommendations of the NPE, the Government published the catalogue of national measures for

[31] BMU (German) http://www.bmu.de/verkehr/elektromobilitaet/nationale plattform_elektromobilitaet/doc/45970.php/
http://www.bmvbs.de/SharedDocs/EN/Pressemitteilung/2012/126-ramsauer-national-platform-electric-mobility.html?linkToOverview=js

the introduction of electric mobility such as the adjustment of the legal framework to the needs of electric mobility where required.

Given the objective of having one million electric vehicles on German roads by 2020, the NPE presents a joint forecast on the market ramp-up for electric vehicles and the infrastructure that will be required. Specific recommendations will pave the way for the implementation of a viable package of measures to support the installation of infrastructure and the commercialization of electromobility. This will also involve focusing the German energy system more on renewable energy and creating the infrastructure that will make this possible.

The Government of Canada has well-established ongoing federal research programs supporting more energy-efficient transportation, including plug-in hybrid electric vehicles and electric vehicles. Canada supports R&D in advanced automotive technologies, including a program in electric mobility focusing on issues surrounding adoption of electric vehicles in the Canadian marketplace. Project themes include energy storage systems; measurement protocols and testing for energy efficiency and emissions; light-weighting of electric drive components; advanced powertrain modeling; and cold-weather impacts.

In addition, the Government of Canada’s ecoTECHNOLOGY for Vehicles Program (eTV) conducts in-depth safety, environmental and performance testing on a range of new and emerging advanced vehicle technologies for passenger cars and heavy-duty trucks ensuring that Canada is ready, and that Canadians can benefit from these new innovations. Results are helping to inform the development of environmental and safety regulations to ensure that these technologies are introduced in Canada in a safe and timely manner.

3.2 Creating Incentives to Develop and Drive EFVs

EFV technology can be developed and deployed into the market more quickly if incentives are utilized to encourage their development and purchase. Incentives can take many forms, be very creative, and can be applied to technology developers, suppliers, manufacturers, sales organizations, consumers, fleet operators, and even fuel suppliers. For businesses, such as technology suppliers, auto manufacturers, and fuel suppliers, incentives typically consist ultimately of a monetary incentive. For consumers, incentives can be utilized to save the individual money or time. For fleet operators, the incentives can take the form of monetary incentives for operators such as rental car agencies, and/or can take the form of a means to meet air quality requirements for entities such as utilities and local governments.

Monetary incentives can take a variety of forms such as tax deductions and credits, government funding of R&D and manufacturing investment, and direct payments to entities anywhere along the line from manufacturer to distributor to consumer to recycler of the end-of-life vehicles. Emissions credits for sales of advanced technology vehicles under emissions regulations are also a form of monetary incentive because they allow manufacturers to sell more profitable conventional vehicles along with advanced vehicles. This allows for continued investment in newer technologies.

Non-monetary incentives can be applied to any entity as well, but a major non-monetary incentive that can be applied to consumers is saving them time. Special parking, high-occupancy lane access, and access to city centers are three areas where consumers can save significant time in their daily routines by driving an EFV. Streamlined and/or standardized building codes can help consumers more easily add charging capability to their garages. Monetary incentives targeted directly to consumers can include tax credits and rebates for the purchase of an EFV, and reduced registration and insurance fees for EFVs.

In the U.S., incentives for EFVs are applied at several levels on both a national and local scale. Beginning in 2012, manufacturers selling advanced technology vehicles such as EVs, PHEVs and FCVs can receive credit for each vehicle so that each vehicle counts as more than one in a manufacturer's fleet-wide compliance calculation. In addition, manufacturers of flexible fuel vehicles which are capable of running on any mix of gasoline and ethanol up to 85% ethanol currently receive credits under the Corporate Average Fuel Economy (CAFE) program.

U.S. consumers can also take advantage of tax credits for the purchase of certain advanced technology vehicles and charging equipment. These credits are available both federally, and in some states. Consumers in certain areas can also take advantage of special access to HOV lanes and preferred parking for grid-connected vehicles with free electricity. Finally, as stated above, the U.S. has a comprehensive R&D funding program providing an incentive to technology suppliers and vehicle manufacturers.

The legal basis for giving special subsidies depends on regional or national action plans. The incentive scheme implemented by Sweden depends upon the several vehicle performance parameters. Over a period from 01/04/2007 to 31/12/2009 in Sweden, private persons get a subsidy of 10000 Skr (~ 1100 €) for registration of a new ″eco-car″ which meets certain environmental requirements. For this purpose the Swedish government provided the funding of 250 Million Skr. The definition of eco-cars is as follows:

• Vehicles with alternative fuels (e.g. ethanol):
  Energy consumption less than
  - 9,2 l/100 km
  - 9,7 m^3 CNG/100 km
  - 37 kWh electric energy/100 km

• Vehicles with conventional fuels (including hybrids):
  CO_2- emissions less than
  - 120 g/km
  - and additionally for diesel-engined vehicles: PM < 5 mg/km

Auto manufactures in Japan made all-out efforts to achieve early compliance with 2010 fuel efficiency targets in response to consumer demand. Also, the central government introduced tax incentives for the purchase of low-emission and fuel-efficient vehicles, which are designated as such by means of an environmental performance certification system. Japan introduced the Green Tax Scheme under which the automobile taxes for low emission and fuel-efficient cars were reduced. Also Japan's top runner approach focuses solely on energy aspects which are associated with some measures like, labeling, tax incentives, and subsidiary[32].

The Government of India in its effort to encourage and popularize new and environment friendly technologies towards reducing vehicular pollution and thus consequently improving quality of urban air, has announced a Central Subsidy of upto Rs. 75,000 for each REVA Electric Car. The beneficiaries of this subsidy are Public Institutions including Government organization and departments, Public Sector Undertakings, Educational institutions, Hospitals, Tourism and Archaeological sites.[33] The government has also initiated action as a national hybrid project under public-private-partnership mode (PPP) to develop hybrid vehicles in the country with the participation from many leading auto makers[34].

Besides the funding of R&D programs, the German government has published a catalogue with numerous measures to promote electric mobility. This includes tax breaks for zero-emission vehicles as well as policy measures such as the exploration of special lanes or parking spots for zero-emission vehicles.

It is important that these measures are applied technologically neutral, so all vehicles with electrified powertrains should be considered.

3.3 Consumer Information and Labels

During the course of the discussion and information sharing in both the EFV conferences and within the EFV informal group at WP.29 it was recognized that an important aspect to the market success of EFVs is an informed consumer base. Information provided, through labeling or consumer guides, by consumer groups, vehicle manufacturers, NGOs, and governments all can help consumers weigh various performance aspects and vehicle features and identify those positive environmental factors. Importantly, if properly presented, this information can be used on a comparative basis to illustrate how various vehicles match up and give consumers a useful tool when making purchasing decisions. In the discussions it was clear that consumer education would serve to provide critical information to the vehicle purchaser and potentially raise the importance of the environmental impact during the purchase decision.

While there is growing public awareness of the environmental impact of the automobile, environmental concerns are often a secondary factor rather than a primary consideration in the vehicle purchase decision. Consumer information on the relative environmental performance of

[32] Informal Document GRPE-58-02 : Background document regarding the Feasibility Statement for the development of a methodology to evaluate Environmentally Friendly Vehicles (EFV) - 2009

[33] ET Bureau news, June 2012

[34] Report on "STATUS OF THE VEHICULAR POLLUTION CONTROL PROGRAMME IN INDIA" (March, 2010), PROBES/ 136 /2010, Central Pollution Control Board, India.

vehicles can raise the value of and preference for EFVs, thus fostering social change, as well as provide the necessary tools to allow the consumer to make an informed choice.

The vehicle purchase process is complex and iterative, and messages presented beyond the label may be even more helpful in getting consumers the information they need about energy use, cost, greenhouse gases, and other emissions. Because many consumers now do research online before ever visiting a car dealership and seeing a label, websites that allow the user to compare vehicles on their environmental attributes may be particularly helpful in guiding vehicle choice toward EFVs. Public education campaigns can raise the public valuation of environmental attributes, as well as educate the public about new vehicle technologies that may otherwise be intimidating to some purchasers.

For consumer information to be effective, it needs to be clear, simple, and demonstrate effects that are relevant and motivating to the public. For example, monetary savings are more motivating to most people than are costs. In order to foster social change, the label needs to be eye-catching and attract attention. Detailed information does not belong on a label, since most consumers spend very little time looking at it and will make a very quick impression. It is most useful if the label creates interest in the environmental attributes of the vehicle, leaves the consumer with a quick and accurate impression of the relative environmental friendliness of that vehicle, and points them to a website where they can gather additional information. This combination of approaches provides the tools that allow purchasers to choose a more environmentally friendly vehicle, and increases the value society places on EFVs.

United States: Vehicle Labels

In the U.S., new vehicles have had fuel economy labels for 35 years, which provide estimated fuel economy and projected annual costs of refueling. The labels were recently redesigned to increase their usefulness in helping consumers choose EFVs by providing comparative ratings on fuel economy and greenhouse gases and emissions of smog-forming air pollutants. The new labels also reflect the likelihood of a much more diverse vehicle technology marketplace in the near future, providing information on the capabilities of these new labels in terms of energy use, driving range, and recharging time.

For many consumers, environmental preference will be less relevant than monetary concerns. Therefore, the label also provides an estimate of how much more (or less) the vehicle will cost to fuel over five years relative to the average new vehicle, as well as the estimated annual refueling cost. This allows the purchaser to easily consider fuel savings in the context of the up-front cost of purchasing the vehicle, and can point purchasers toward more efficient vehicles even if they have a higher purchase price. The information on the labels is a first level of information, more comprehensive information and direct comparisons can be made at a website: www.fueleconomy.gov.

ACEEE i.e. American Council for an Energy-Efficient Economy's Green Book

The rating methodology for vehicles belonging to model year 2011 is proposed in this green book. The methodology is based on:

- Use of Emission Certification values to rate the vehicles
- Incorporation of Results for Life Cycle Analysis
- Treatment suggested for Plug-in electric vehicles

Additionally emission factors for power generation are also taken into the consideration while formulating the rating criteria. However, these factors are designed only for electricity generation and consumption in US.

Australian Green Vehicle Guide

Australia also initiated the green vehicle guide so as to inform the consumers about the vehicle performance to increase proportion of EFV's in the market. A website is designed, providing access to a searchable database including sole source of model specific environmental data on all light vehicles in the Australian fleet which also covers new vehicles released on the market from mid2004 onwards. The green book covers following performance measures to address all key areas:

- conventional air polluting emissions
- greenhouse gas emissions
- fuel consumption

The criteria used for evaluation, divides the vehicle into three classes based on vehicle area and thereby rate it depending upon its CO2 emission and fuel consumption. Much more detailed consideration of the following parameters will help in better frame work of the EFV assessment criteria.

3.4 Other Considerations

3.4.1 Quiet Cars and Pedestrian Safety

With the introduction of road transport vehicles that rely, in whole or in part, on alternative drive trains (e.g. electromotive propulsion) are significantly reducing both air and noise pollution. However, the very positive environmental benefits achieved to date by these electrified road vehicles have resulted in the unintended consequence of removing a source of audible signal that is used by various groups of pedestrians, (e.g. in particular blind and low vision persons), to signal the approach, presence and/or departure of road vehicles.

The UNECE World Forum WP.29 has determined that road transport vehicles propelled in whole or in part by electric means, present a danger to pedestrians. The World Forum directed the Working Party on Noise (GRB) to assess and determine what, if any, steps might be taken by

WP.29 to mitigate potential pedestrian hazards through the use of acoustic means, recognizing that other means of communication may also be appropriate.

An informal group on Quiet Road Transport Vehicles (QRTV) was established under GRB to carry out the activities that are considered essential to determine the viability of "quiet vehicle" audible acoustic signalling techniques and the potential need for their global harmonization. The informal group held the first meeting in February, 2010.

The plan included activities to identify, review and assess the status of various researches being carried out by various governments, universities and non-governmental organizations regarding audible signalling technologies for quiet vehicles and their respective mandated time frames. Followed by activities to determine, based on survey and experimental investigation with blind and low vision people, those human factors believed necessary to decision making in vehicular traffic situations. Based on that information, the QRTV informal group issued a report on how to transform human factor needs into technical performance parameters for road vehicles, including the types of vehicle movement and position information required by the blind, low vision and other persons to facilitate their safe passage, navigation and orientation in the presence of vehicular traffic.

The QRTV has recently begun a second phase of activities designed to develop a GTR based on the information developed in the first phase and on-going data and information exchange. The QRTV will:

- Continue to identify, review and assess the status of various researches being carried out by various governments, universities and non-governmental organizations on audible warning and signalling technologies for quiet vehicles;
- Invite, consult with and consider the input of safety experts from other working parties within WP.29.
- Determine potential audible sound characteristics and mechanisms that convey desired vehicle performance information to the human receiver.
- Develop harmonized test procedures for evaluating the conformity of potential audible sound characteristics and mechanisms.
- Determine the costs and benefits associated with a QRTV GTR including potential adverse impact on the public at large or existing vehicle noise emission standards and regulations. Note that the analysis is not intended to address specific countries or regions, but rather general considerations each Contracting Party (to WP.29) should consider when implementing the potential GTR.

The effort has been designed to provide a GTR for WP.29 consideration in November 2014.

3.4.2 Worldwide Harmonized Light Vehicles Test Procedure (WLTP)

The proposal to establish a Global Technical Regulation (GTR) for light duty vehicle emissions, including; a common test cycle reflecting the actual driving conditions in real world and consideration of OBD detection capabilities and off-cycle emissions was presented to WP.29 in June 2007.

While regulations governing the exhaust-emissions from light duty vehicles have been in existence for many years, the test cycles and methods of emissions measurement vary significantly around the world. To be able to correctly determine the impact of a light duty vehicles on the environment in terms of its exhaust pollutant emissions as well as the efficient use of energy, it was deemed desirable by WP. 29 that as many countries as possible use the same technical regulations. The agreement to move toward a Global Technical Regulation within WP.29 was an important consideration following similar efforts for other wheeled vehicles.

The GTR No.2: Worldwide Motorcycle Test Cycle and GTR No.4: Worldwide Heavy Duty Test Cycle were successfully established and it was deemed beneficial to develop a common set of test procedures for light-duty vehicles as well. Light duty vehicles are increasingly produced for the world market. The discussion at WP.29 stated that it is economically inefficient for manufacturers to have to prepare substantially different models in order to meet different regulations and methods of measuring emissions, which, in principle, aim at achieving the same objective. To enable manufacturers to develop new environmentally friendly models more effectively and within a shorter time, it is desirable that a GTR should be developed reflecting the global nature of the products, the need for robust test procedures to provide a common platform for comparison of emissions reductions and to reduce costs for the testing burden . The savings will benefit not only manufacturers, but consumers as well.

It is believed that a GTR for WLTP would contribute to ensure better air quality and provide more accurate data for consumers with the substantial growth in the popularity of low-emission vehicles.

3.4.3 Infrastructure and Power Demand

As new technologies and new fuels enter the market, a reliable and cost-effective means of fueling them must be deployed alongside. Whether the fuel consists of liquids, gaseous fuels or electricity, every fuel has infrastructure demands. Liquid fuels must be transported and dispensed and as more fuel options are added such as alcohols, the infrastructure needs to be adapted to accommodate them. Alcohols are hydrophilic, absorbing water, and can be corrosive to some materials that are otherwise fully compatible with gasoline and/or diesel fuels. It is also important to prevent mis-fueling when a variety of liquid fuels are available. A common way to avoid this is to mandate different-sized nozzles on dispensers, although this does not prevent every possible mis-fueling scenario. Liquefied natural gas (LNG) requires refrigeration and specialized refueling equipment and is most likely to be used on large trucks.

Gaseous fuels such as CNG and Hydrogen need to be transported either in high-pressure pipelines or pressure vessels by truck or train. At the dispensing location, further compression is typically necessary to provide acceptable range for the vehicle, as range is directly related to fuel storage pressure. Some fueling concepts involve high pressure vessels in the form of trailers delivered directly to the fueling station by truck from which the fuel is dispensed directly to vehicles through a metering device. When the trailer is empty, it is swapped with a full one and the empty trailer is returned to a central location to be refilled.

Electricity for EVs and PHEVs is very accessible to vehicle owners and operators, however, the battery charging process is considerably slower than fueling with either liquid or gaseous fuels. Most EV and PHEV owners will likely do the bulk of their charging at night when at home, so the major infrastructure concerns revolve around the ability of the grid to supply sufficient nighttime or off-peak power to charge vehicles and the ability of the local transmission and distribution system to reliably supply sufficient power to individual homes and charging units. A significant portion of EV and PHEV charging is also expected to take place during working hours while vehicles are parked at businesses and other employers. This on-peak charging can present challenges to overall electrical supply if vehicle charging demand is significant during typical late-afternoon peak electrical demand periods. In this case, protocols should be established to prevent the grid from becoming unstable due to excess demand attributable to vehicle charging.

Grid-connected vehicles can be charged rapidly (in about 30 minutes or less) using Level 3 DC fast charging systems. These systems require very high power levels. Peak power demand issues will be the most acute one with these types of stations.

In the U.S., liquid fuels currently dominate the refueling infrastructure. The U.S. uses significant amounts of ethanol, most blended into gasoline, but some blended into E85. While natural gas in the U.S. is abundant and currently very inexpensive, the CNG fueling infrastructure for vehicles is quite limited, but this may change as manufacturers introduce CNG-capable vehicles to take advantage of the inexpensive fuel.

U.S. electricity generation capacity is considered to be sufficient for even a large population of EVs and PHEVs charging overnight.[35] Evening charging, which includes some peak hours, may require additional capacity or demand response.[36] Isolated problems may occur, especially in neighborhoods where many EVs charging at night may prevent power pole transformers from cooling off after a day of work. The U.S. is actively studying the role a smart grid can have in managing daytime, on-peak charging and demand response.

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[35] U.S. DOE, Pacific Northwest National Laboratory, Impacts Assessment of Plug-In Hybrid Vehicles on Electric Utilities and Regional U.S. Power Grids Part 1: Technical Analysis, May 2007, http://www.ferc.gov/about/com-mem/wellinghoff/5-24-07-technical-analy-wellinghoff.pdf

[36] U.S. DOE, Oak Ridge National Laboratory, Potential Impacts of Plug-In Hybrid Electric Vehicles on Regional Power Generation, January 2008, ORNL/TM-2007/150,

4.0 Conclusion

The international EFV conferences have an important role to play by exchanging information on the various public policies in place or planned in the various countries or regions to promote development and introduction of new generations of vehicles, taking into account the society demands for mobility. Such debates may ultimately result in a catalogue of best practices for the automotive sector to ensure that the mobility needs of society are met in a sustainable way.

Since the beginning in 2003 there was a close relationship between the EFV conferences and WP.29 activities. While WP.29 and its subsidiary bodies focus more on technical issues and the development of vehicle regulations, the EFV conferences give the opportunity to exchange views and share experience between policy makers, legislators, industry, scientists and consumer groups, and to deal with topics that open up perspectives and areas beyond pure vehicle technology questions.

One of the main activities entrusted to the Informal Group on EFV was to study in detail the possibilities to define EFV, such that a uniform ranking among the various EFV concepts and technology strategies could be established globally. After detailed consideration of the various possibilities, one has however to conclude that such unified ranking is at this stage not possible, nor even desirable, taking into account the various parameters and different priorities in the various regions or countries.

Many aspects determine the environmental impact of a road vehicle. Depending on the various regions or countries, the priority ranking of each of these may be different and the technologies needed to respond to these demands may differ. As an example explained in this report, while Electric Vehicles (EV) may bring clear environmental benefits, questions remain unanswered at this stage on the electric energy production process and an overall ranking valid for all regions/countries/applications does not appear possible at this time.

Furthermore, as explained in this report, one of the key issues to be addressed is the consumer information, in order to ensure that he or she makes the right purchasing decision. Such information therefore needs to be as clear and concise as possible. With so many parameters to be taken into account, it is thus vitally important that the consumer does not become confused by a multiplication of different, potentially even contradictory, information.

The work performed by the informal group enabled a good overview of the various technologies having been developed already or in the pipeline to further reduce the environmental impact of road vehicles. It has to be recognized that governments, by setting the desired goals, and industry, by their continuous investments in R&D, have managed over the last years to strongly reduce the environmental impact of road traffic, and further improvements can be expected continuously, as new technologies enter the market in ever larger numbers. The EFV concept is therefore a moving target, whereby it can be considered that each new generation of vehicles is more environment-friendly than the generation it replaces.

On the other hand, such new technologies often are very costly, especially at their early stages. This in turn may act as a deterrent to their mass introduction, as replacement of older, far more polluting fleets; consumers indeed need to find the products not only attractive and meeting their individual or collective needs, they also must be in a position to financially afford these new technologies. As history has shown, introduction of new technologies needs time to reach a "critical mass" which in turn allows cost reduction, and therefore further acceleration of the market penetration. The market for new concepts is therefore like a huge wheel: quite some effort is needed to make it roll in the beginning, but once it has reached a certain momentum, it moves on (almost) by itself. The market for EFVs in general does appear to be rolling now, with its ultimate destination to be determined.

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[i] PHEVs are typically described as operating in three possible modes: In electric mode, the PHEV operates exclusively on utility power stored in the battery, like an EV. In hybrid mode, also called charge sustaining, the PHEV operates as a hybrid vehicle with little-to-no change in battery state of charge. This mode is used when excess energy from the utility grid stored in the battery is exhausted. In blended mode, the PHEV uses some energy from the utility power stored on board, and some from the on-board engine. PHEVs use blended mode to optimize energy consumption and reduce required battery size.