A GLOBAL ROADMAP FOR AUTOGAS

Reaping the environmental and economic benefits of using more LPG in road transport

December 2019

WLPGA

WWW.WLPGA.ORG

LPG EXCEPTIONAL ENERGY

WLPGA

LPG
EXCEPTIONAL
ENERGY

The World LPG Association

The WLPGA was established in 1987 in Dublin and unites the broad interests of the vast worldwide LPG industry in one organisation. It was granted Category II Consultative Status with the United Nations Economic and Social Council in 1989.

The WLPGA promotes the use of LPG to foster a safer, cleaner, healthier and more prosperous world.

Acknowledgements

This report was prepared by Trevor Morgan of Menecon Consulting. Acknowledgement also goes out to the many representatives of the LPG industry in the countries surveyed in the report, who provided invaluable assistance. Cécile Nourigat, former Autogas Manager at WLPGA, and David Tyler, Director, WLPGA, were responsible for co-ordinating the project.

Copyright

Glossary

AFV	Alternative fuel vehicle
CNG	Compressed natural gas
CO	Carbon monoxide
CO_2	Carbon dioxide
EV	Electric vehicle
HDV	Heavy-duty vehicle
ICE	Internal combustion engine
IEA	International Energy Agency
LDV	Light-duty vehicle
LGE	Liquid Gas Europe
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
NGV	Natural gas vehicle
NOx	Nitrogen oxides
NO_2	Nitrogen dioxide
OEM	Original equipment manufacturer
PM	Particulate matter
SCC	Social cost of carbon
VOC	Volatile organic compounds
WHO	World Health Organization
WLPGA	World LPG Association
WTW	Well to wheels

CONTENTS

EXECUTIVE SUMMARY

This report examines the global potential for Autogas – liquefied petroleum gas, or LPG, used as a transport fuel – in the vehicle fleet through to 2040.

It considers two scenarios: a baseline 'business-as-usual' case, where policy support for Autogas is assumed to remain at current levels, and a more bullish 'alternative scenario', where the Autogas sector enjoys stronger support from governments, vehicle manufacturers and the LPG industry. In the latter case, the number of Autogas vehicles triples and demand for the product doubles compared with current levels over the next 20 years or so. The associated social, economic and environmental benefits are estimated at over US$54 billion.

The world is on the move: a growing population and an expanding economy are continuing to drive up demand for mobility – especially in Asia, Latin America and Africa. That means more vehicles (two- and three- wheelers, cars and trucks) and a need for more energy to run them. Rising mobility is a sign of greater prosperity and personal freedom, but it is also damaging our environment. The use of conventional gasoline and diesel for road transport is already the leading cause of outdoor air pollution – the leading threat to public health – in most major cities and the second-biggest source of emissions of carbon-dioxide (CO_2) worldwide. Public awareness about the environmental and health effects of road transport – and pressure on the authorities to act – is growing by the day. The need to switch to Autogas, and other clean alternatives to conventional oil-based fuels, has never been more urgent.

Autogas is the most popular alternative to gasoline and diesel for passenger cars and vans worldwide. Demand for Autogas has been growing steadily in recent years, reaching around 27 million tonnes in 2017, and, in some countries, accounts for a significant share of the overall transport fuel market. There are now over 27 million Autogas vehicles in use around the world – almost four times more than in 2000. This has not happened by chance: a growing number of governments around the world actively encourage use of the fuel in recognition of its notable environmental benefits, as well as its inherent practical and cost advantages over conventional and other alternative fuels.

"Autogas is the most popular alternative to gasoline and diesel for passenger cars and vans worldwide."

Autogas is a clean fuel. Numerous studies have shown that Autogas-related emissions of noxious and toxic air pollutants are among the lowest of all the automotive fuels commercially available today. The environmental performance of Autogas is particularly impressive with respect to regulated toxic gases, notably nitrous oxides (NOx) and particulate matter (PM). Emissions of NOx – the most important of the regulated gases for air quality – from Autogas are much lower than from gasoline and, especially, diesel. NOx is a toxic air pollutant in its own right as well as the main cause of smog. PM emissions are negligible for Autogas and very low for gasoline vehicles, but remain a major problem for diesel vehicles. Concerns about the health impact of emissions of fine PM from diesel vehicles in particular have been rising in recent years, as more evidence of their impact on health comes to light. PM emissions from diesel vehicles are now known to cause cancer.

Autogas also outperforms gasoline and diesel for CO_2 emissions, an advantage that is set to grow as more and more LPG originates from natural gas processing plants, which emit less than oil refineries. As such, Autogas could play an important role in mitigating greenhouse-gas emissions until such time as ultra-low or zero-emission vehicle technologies such as electric vehicles can be commercialised on a large scale. In this sense, fossil-based Autogas can be regarded as a "bridging fuel" in the transition to a clean, affordable and sustainable transport system. In the longer term, Autogas derived from bioLPG could play a major role.

In addition to its environmental credentials, Autogas holds a number of practical advantages over other fuels. Driving an Autogas car is safe and easy. Switching to the fuel involves spending only modest sums on converting an existing vehicle and refuelling infrastructure, and vehicle performance is as good, if not better, than with conventional fuels. LPG is competitively priced – at least if taxed appropriately – making it an affordable fuel. And supplies are plentiful, with rising production of natural gas and the enormous scope for diverting supplies away from other less valuable uses. In short, Autogas is the only alternative fuel that delivers a wide range of benefits, including lower emissions, without having to compromise on vehicle performance and autonomy.

For all the advantages of Autogas, the prospects for continuing growth in demand depend critically on government policies. Motorists will only switch to Autogas if it is cheaper at the pump than other fuels so that savings on running costs quickly repay the upfront cost of converting the vehicle. That means governments have to make sure that the fuel is taxed less than other, more polluting fuels. Financial incentives directed at the vehicle itself, such as grants or tax credits for converting to Autogas and other non-financial measures, can also boost the attractiveness of switching to Autogas.

Based on current policies, the global share of Autogas in the road-fuel market and the vehicle fleet is to stagnate. In a Baseline Scenario, in which no change in national policies is assumed, global Autogas consumption is projected to continue to grow, reaching a peak of a little over 31 Mt in 2030 – about 18% higher than in 2017. But it then goes into gradual decline, dipping to just under 30 Mt in 2040. Globally, the Autogas fleet reaches a plateau of around 39 million by the end of the 2030s – 45% up on 2017.

The fleet continues to expand in all regions throughout the projection period except in Europe, where it goes into long-term decline after 2030. The share of Autogas in the global vehicle fleet remains broadly constant at 2% to 2030, but then declines gradually to 1.7% by 2040.

But a far more positive future for Autogas is possible. An Alternative Scenario assumes that the number of Autogas vehicles and their share of Autogas in the overall vehicle fleet reach twice the levels of those in the Baseline Scenario in each region by 2040. Global Autogas consumption continues to grow steadily in the Alternative Scenario, reaching 60 Mt by 2040 – well over twice the current level. The Autogas vehicle fleet grows even faster as fuel economy continues to improve throughout the projection period, reaching almost 80 million in 2040 – nearly three times the current size. Worldwide, Autogas vehicles make up 3.4% of the total fleet in 2040, compared with 1.7% in the Baseline Scenario and around 2% today.

Making this Alternative Scenario a reality would require relatively modest strengthening of incentive policies in most countries in addition to support from the Autogas industry, vehicle manufacturers and fuel-system equipment producers and installers. The results of econometric analysis show that the average payback period for switching from gasoline to Autogas would need to fall on average from 26 to 18 months, either by an increase in the tax on gasoline relative to Autogas or by the introduction of a grant or tax credit to cover part or all of the conversion cost. But the need for these measures would be alleviated or, in some cases, removed entirely by additional measures to discourage the use of diesel on health and environmental grounds, including higher taxes. Diesel, which competes most with Autogas in high-mileage vehicles, is often – perversely – taxed less in energy terms than Autogas at present. Other non-financial measures, such as exemptions for Autogas vehicles from driving restrictions in city centres for environmental reasons, could also help boost the attractiveness of Autogas.

Making the vision of tripling the number of Autogas vehicles between now and 2040 a reality would bring major socioeconomic benefits in the form of cleaner air, improved human health and reduced climate change. By 2040, we estimate that it would lower global emissions of NOx from LDVs by over 4% and those of $PM_{2.5}$ by close to 5%, yielding social welfare gains, including savings on health costs and improved productivity, valued at almost US$40 billion. World emissions of CO_2 on a well-to-wheels (WTW) basis would also be cut by a cumulative total of around 130 Mt over 2018-2040, yielding additional welfare gains of more than US$15 billion. These gains would be complemented by the economic benefits enjoyed by end-users making the switch to Autogas. Motorists would enjoy lower fuel costs that quickly payback the upfront cost of converting their vehicle or buying a slightly more expensive OEM model. Additional economic benefits would also come from the additional jobs created in the Autogas installation sector.

These benefits will not be realised without concerted action by all stakeholders to tackle the barriers to market development. Autogas suppliers themselves are committed to taking action, including reaching out to citizens to inform them of the potential of Autogas to keep people on the move while protecting the environment, strengthening ties with car manufacturers to develop engines that are more conducive to the use of Autogas, continuing to ensure that Autogas supply worldwide matches demand, expanding filling station networks and promoting the training and certification of Autogas kit installers. But the role of policy makers is crucial: transport and fuel tax policies need to ensure that Autogas is financially attractive to end users. Other private sector stakeholders, including energy producers and fuel system equipment manufacturers and installers, also need to play their part by investing in new vehicle technologies and bioLPG.

INTRODUCTION

Autogas is the most popular alternative to the two conventional automotive fuels – gasoline and diesel – for two- and three-wheelers, passenger cars and vans worldwide, and a leading fuel for medium and heavy-duty vehicles.

Demand has been growing steadily in recent years, reaching around 27 million tonnes in 2017, and, in some countries, accounts for a significant share of the overall LPG and transport-fuel market. There are now over 27 million Autogas vehicles in use around the world – almost four times more than in 2000. This has not happened by chance: a growing number of governments around the world actively encourage use of the fuel in recognition of its notable health and environmental benefits, both in improving air quality and mitigating climate change, as well as its inherent practical and cost advantages over conventional and other alternative fuels.

But, in many cases, this message is not getting across. Motorists are not always properly informed about the financial benefit of switching to Autogas. And policy makers are not always aware of the potential for Autogas to contribute to transport and environmental policy goals, so that the fuel is not always taxed and priced appropriately. The focus of government policies in many cases is now increasingly focused on boosting the role of electric vehicles (EVs). Yet EVs are still far from being able to compete widely with either conventional fuels or Autogas. In any case, for as long as the electricity to power these vehicles is produced using fossil fuels, they will offer only limited environmental benefits.

The most practical approach in the short-term to reducing emissions of air pollutants and greenhouse gases in road transport is to encourage people and businesses to switch to cleaner-burning fuels that are already commercially available and competitively priced. Autogas is the obvious option. It outperforms conventional fuels and most other alternative automotive fuels for local and regional environmental benefits.

It can also play an important role in mitigating greenhouse-gas emissions until such time as ultra-low or zero-emission vehicle technologies become commercially viable on a large scale. And existing conventional vehicles can easily be converted to run on Autogas, bringing immediate benefits. In this sense, Autogas can be regarded as a "bridging fuel" in the transition to a zero-emission energy system that is likely to last decades.

The purpose of this report is to set out a roadmap for how Autogas can play that role to the full. It starts by setting the scene, with a review of the global prospects for road transport and the advantages of Autogas over other fuels. It then establishes an aspirational yet entirely realistic target of doubling the global share of Autogas in the overall road-transport fuel market built on a set of plausible projections of how the road-transport fuel market could evolve to 2040. And it presents quantitative estimates of just how big the social, economic and environmental benefits of reaching that target would be, relative to a business-as-usual baseline.

Meeting that target will require concerted action on the part of (i) the Autogas sector – fuel suppliers, distributors and retailers, (ii) the motor industry - vehicle manufacturers and producers and installers of fuel systems – and (iii) governments to make switching to Autogas attractive to end users. This roadmap identifies the barriers to market development and scopes out the actions needed to overcome those barriers and ensure that the vision of a vibrant Autogas market is achieved.

THE CHALLENGE

The world is on the move. Global population is growing and the economy is expanding, driving up demand for mobility – especially in Asia, Latin America and Africa. That means more vehicles – two- and three-wheelers, cars and trucks – and a need for more energy to run them. Rising mobility is a sign of greater prosperity and personal freedom, but it is also damaging our environment as increased consumption of gasoline and diesel contribute to climate change and to air pollution – the leading threat to public health worldwide. The need to switch to Autogas and other alternatives to conventional oil-based fuels has never been more urgent.

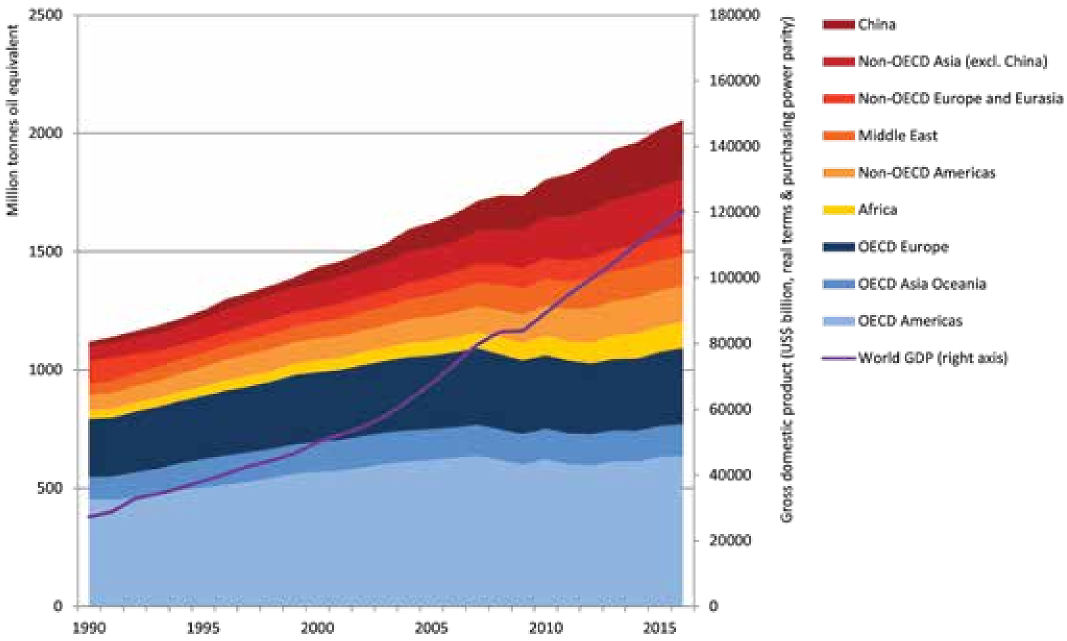
MEETING THE GROWING DEMAND FOR MOBILITY

The demand for mobility – of people and goods – is rising inexorably across the world as the population grows and people get richer. Most of this demand takes the form of road transport: two- and three-wheelers and passenger cars to move people and commercial vans and trucks to move goods. And unless the economy collapses, demand for road transport will keep on rising for the foreseeable future.

There is a close correlation between the size of the global economy, the total distance travelled by road vehicles and the amount of energy they consume. Most of the increase in road transport is occurring and will continue to occur in the emerging economies of Asia, Africa and Latin America, where population and economic activity are expanding most rapidly (Figure 1).

"Vehicle ownership rates in the emerging economies are still far below the saturation point reached in most of the advanced economies, pointing to further strong growth in the global vehicle fleet over the coming decades."

Figure 1: World energy consumption for road transport by country/region and gross domestic product

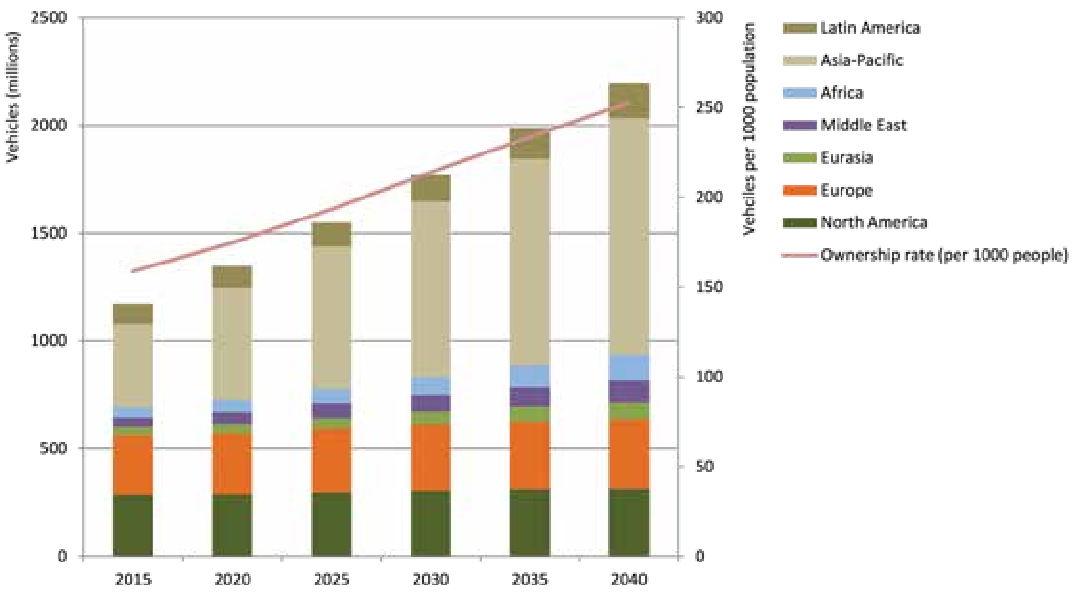


Source: International Energy Agency (IEA) online databases; International Monetary Fund, World Economic Outlook online databases.

The global fleet of road vehicles – the main indicator of the demand for mobility – will undoubtedly continue to expand for decades to come. It grew from 892 million in 2005 to 1.282 billion in 2015 – a rise of 44%.[1] Light-duty vehicles (LDVs), including passenger cars and commercial vans, currently make up about 85% of the total fleet. Growth in the global fleet has been strongest in the emerging economies, where ownership rates are still far below the saturation point reached in most of the advanced economies.

This points to further strong growth in the fleets in those countries over the coming decades as their populations grow and the income gap with the advanced economies narrows further. The latest long-term projections from the International Energy Agency show the global fleet rising by half by 2030 and by 87% by 2040, with most of the growth coming from Asia, Latin America, Africa and the Middle East (Figure 2). Vehicle ownership per 1000 people is projected to climb by 76% from 159 in 2015 to 280 in 2050.

Figure 2: World fleet of road vehicles by major region in the IEA Reference Technology Scenario



Source: IEA (2017a).

Meeting the growth in demand for road transport mobility will require more energy. Cars and trucks have been getting more efficient over the years, but the pace of improvement in fuel economy has never been fast enough to offset the underlying growth in demand for mobility.

Average fuel economy of light-duty vehicles (LDVs, including passenger cars and vans) improved by around 1.2% per year between 2005 and 2015, taking account of changes in the size and configuration of the fleet (GFEI, 2018). Over the same period, global road fuel consumption grew by more than 2% per year.

[1] http://www.oica.net/category/vehicles-in-use/

“Air pollution is the “new tobacco”. 97% of cities in low and middle income countries, and almost half in high-income countries, fail to meet the Air Quality Guidelines of the World Health Organization.”

THE ENVIRONMENTAL IMPERATIVE

Choices about vehicle technology and fuels to meet rising demand for mobility in the coming decades will have far-reaching consequences for the environment. The use of conventional gasoline and diesel for road transport is already the leading cause of ambient (outdoor) air pollution in most major cities and the second-biggest source of emissions of carbon-dioxide (CO_2) worldwide after power generation. Public awareness about the environmental and health effects of road transport – and pressure on the authorities to act – is growing by the day.

Outdoor air pollution is the fourth-largest overall risk factor for human health worldwide after high blood pressure, dietary risks and smoking. It caused an estimated 4.2 million premature deaths worldwide per year in 2016 due to cardiovascular and respiratory disease, and cancers.[2] Data for 2017 show that 97% of cities with more than 100 000 inhabitants do not meet the Air Quality Guidelines of the World Health Organization (WHO) in low and middle income countries, and 49% in high-income countries.[3] In some emerging economies, notably China and India, urban air pollution has reached catastrophic proportions. Emissions of nitrogen oxides (NOx), volatile organic compounds (VOC), carbon monoxide (CO) and particulate matter (PM) from cars and trucks are the main sources of this pollution in most cases. The head of the WHO recently called air pollution the “new tobacco”.[4]

Concerns about the health impact of emissions of fine PM from diesel vehicles in particular have been growing in recent years, as more evidence of their impact on health emerges. A 2012 assessment by the WHO’s International Agency for Research on Cancer (IARC) concluded that ambient air pollution is carcinogenic to humans, with $PM_{2.5}$ (particles with a diameter of less than 2.5 microns) most closely associated with increased incidence of cancer, especially lung cancer.[5] These worries, heightened by revelations about fraudulent emissions testing of diesel cars by the German carmaker, Volkswagen, have prompted some local and national authorities to restrict the movement of diesel vehicles and seek to discourage use of the fuel. For example, four German cities – Berlin, Frankfurt, Hamburg and Stuttgart – have introduced exclusion zones for diesel cars. In many countries, taxes on diesel have been raised. And more than a dozen countries, including France, India and the United Kingdom, have already announced long-term goals of banning the sale of both diesel and gasoline cars, while other countries are posed to follow suit.

---

[2] http://www.who.int/en/news-room/fact-sheets/detail/ambient-(outdoor)-air-quality-and-health
[3] http://www.who.int/airpollution/data/cities/en/
[4] http://www.who.int/news-room/detail/29-10-2018-more-than-90-of-the-world%E2%80%99s-children-breathe-toxic-air-every-day
[5] https://www.iarc.fr/en/media-centre/pr/2012/pdfs/pr213_E.pdf

There is also an urgent need to step up efforts to curb emissions of greenhouse gases from road transport. The sector accounts for almost a fifth of total energy-related emissions of CO_2, a share that has been rising constantly in recent years. According to the latest report from the Inter-governmental Panel on Climate Change (IPCC), global net emissions of greenhouse gases including CO_2 would need to fall by 45% between 2010 and 2030 and to zero by around 2050 to be on track to meet the long-term goal of limiting the temperature increase to 1.5 degrees under the 2015 Paris Agreement (IPCC, 2018).

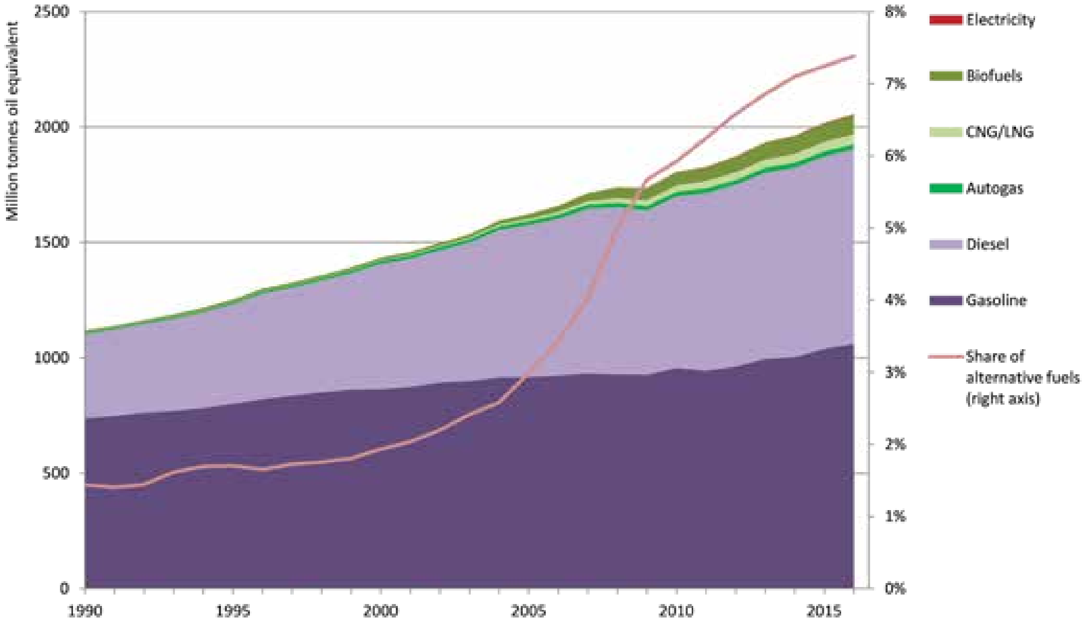
This will require far more radical policy action around the world than is currently planned. Under current policies, including nationally determined contributions under the Paris Agreement, global energy-related CO_2 emissions – the main greenhouse gas – are projected to carry on rising, levelling off at around 40 gigatonnes by 2060 – 16% higher than in 2014, implying a temperature increase of over 3 degrees (IEA, 2017a). It is clear that keeping the increase even to less than 2 degrees will require big reductions in emissions in all end-use sectors, including road transport. For example, the European Parliament has called for a goal of achieving a zero-emission car fleet by 2050; biofuels are expected to play a major role in meeting this goal (EAFO, 2017).

"Keeping the global temperature increase to under 2 degrees will require big reductions in emissions in all end-use sectors, including road transport; this will not happen without far more radical policy action around the world than is currently planned. "

THE ROLE OF ALTERNATIVE FUELS

Reducing drastically the environmental impact of road transport in the face of rising demand for mobility will not be possible without a major shift to clean alternative automotive fuels. Continuing improvements in fuel economy will also be needed. Today, gasoline and diesel refined from crude oil still dominate the transport-fuel mix in most parts of the world, though the share of alternatives, including Autogas, is growing rapidly: in aggregate, they accounted for around 7% of total road-transport energy consumption in 2016, up from less than 2% in 2000 (Figure 3). Total consumption of alternative fuels was 42% higher in 2016 than in 2010 and almost five-and-a-half times higher than in 2000.

Figure 3: World energy consumption for road transport by fuel and share of alternative fuels



Source: IEA online databases.

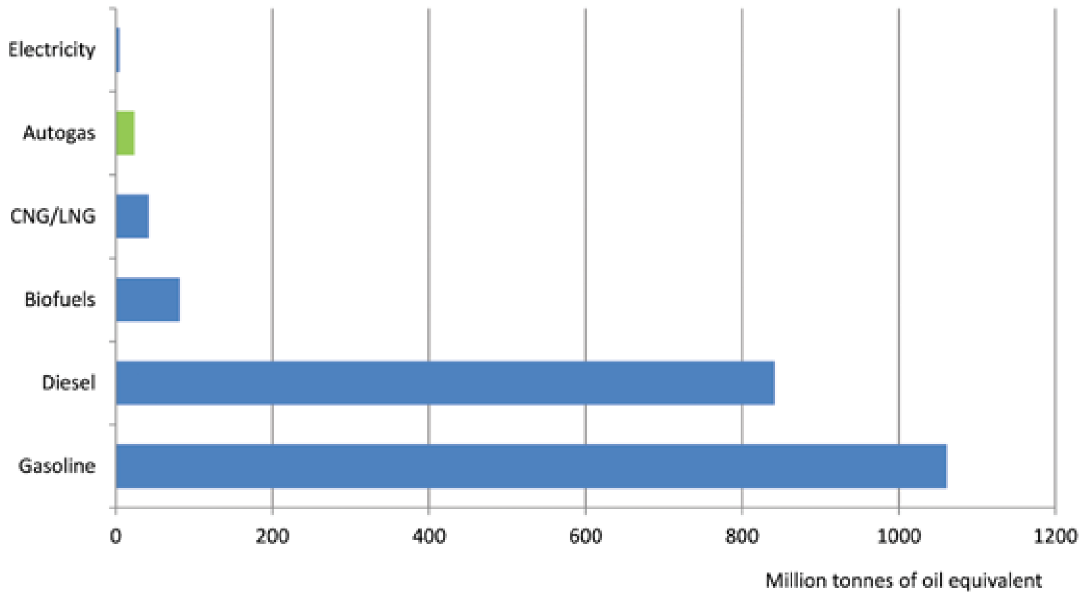
In volumes terms, Autogas is the leading unblended alternative fuel for LDVs and the second most important one for all vehicle types after natural gas, accounting for 1.2% of total fuel use.

Autogas consumption worldwide has almost doubled since 2000 (Figure 4 and Figure 5). Yet Autogas use is still concentrated in a small number of countries: just five countries – Korea, Turkey, Russia, Poland and Italy – together accounted for under half of global Autogas consumption in 2017.

The share of Autogas in total automotive-fuel consumption varies widely across countries, ranging from a mere 0.1% in the United States to about one-fifth in Ukraine. Autogas makes up more than 10% of the automotive-fuel market in four other countries: Bulgaria, Korea, Poland and Turkey. The enormous disparity in the market penetration of Autogas is explained mainly by differences in the strength of government incentive policies (WLPGA/Liquid Gas Europe, 2018). There is considerable potential for expanding the role of Autogas in all countries.

“The enormous disparity in the market penetration of Autogas around the world is explained mainly by differences in the strength of government incentive policies.”

Figure 4: World energy consumption in the road transport sector



Source: IEA databases.

BOX 1: **WHAT IS AUTOGAS?**

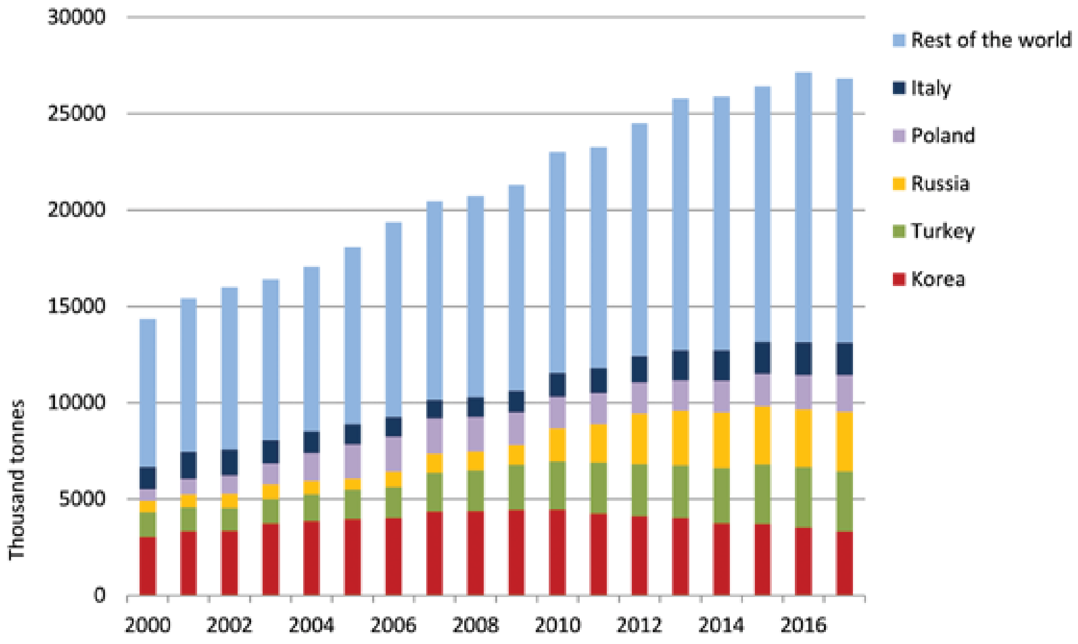
Autogas is the abridged name for automotive liquefied petroleum gas (LPG) – that is, LPG used as an automotive transport fuel. LPG is the generic name for mixtures of hydrocarbons that change from a gaseous to liquid state when compressed at moderate pressure or when chilled. The chemical composition of LPG can vary, but is usually made up of predominantly propane and butane (normal butane and iso-butane). Autogas generally ranges from a 30% to 99% propane mix. In some countries, the mix varies according to the season as the physical characteristics of the two gases differ slightly according to ambient temperatures.

LPG is obtained either as a product from crude-oil refining or from natural-gas or oil production. At present, more than 60% of global LPG supply comes from natural gas processing plants, though the share varies markedly among regions and countries. With both processes, LPG must be separated out from the oil-product or natural-gas streams. LPG is generally refrigerated for large-scale bulk storage and seaborne transportation as a liquid, but it is transported and stored locally in pressurised tanks or bottles (cylinders). BioLPG – renewable LPG derived from production processes that use biomass as the feedstock, usually as a co-product – is an emerging source of LPG.

LPG has high energy content per tonne compared with most other oil products and natural gas, and burns readily in the presence of air. It is also a particularly good engine fuel and is highly portable. These characteristics have made LPG an increasingly popular fuel for domestic heating and cooking, commercial use and agricultural and industrial processes, as well for transport as an alternative automotive fuel.

Autogas has different names in different countries. It is known as propane in North America and LPG or GPL in some European and African countries. Whatever it is called, the proven advantages of the fuel are the same: it is clean, safe, practical, affordable, portable, flexible and readily available.

Figure 5: World Autogas consumption by country



Source: WLPGA/Argus (2018).

The other main alternative fuels are biofuels, natural gas – in the form of compressed natural gas (CNG) or liquefied natural gas (LNG) – and electricity. Biofuels derived from vegetable matter such as ethanol or biodiesel, which are normally blended into conventional gasoline and diesel, have been making major inroads, their share of total automotive fuel consumption having risen eight-fold since 1990 to 4% in 2016 (Figure 3). But the scope for further increases in biofuel supply using conventional technology is likely to be limited by competition for land to grow food crops, as well as high production costs. Natural gas has also seen significant market growth, mainly for heavy-duty vehicles, though cost and fuel availability are constraining factors in many cases. Plug-in hybrids and pure battery EVs are now starting to be commercialised on a significant scale, boosting their share of total road transport energy use from just 0.1% in 2010 to an estimated 0.5% in 2018, but their attractiveness remains constrained for the moment by their high cost and limited driving range (Box 2).

The prospects for hydrogen-powered fuel cells, the use of which remains negligible for now, hinge on major technological advances and cost reductions.

The increasing market share of alternative fuels is largely the result of government policies. The initial impetus for the development of alternative fuels came from the oil-price shocks of the 1970s, as countries sought to reduce their dependence on imports of crude oil and refined products. Environmental and health concerns have since overtaken energy security as the principal driver of government policies to promote such fuels, as they are generally less polluting. The main approaches that governments use are financial incentives, in the form of differentiated taxes and subsidies according to the type of fuel or vehicle, and regulatory measures, including emission standards, purchase mandates for public and/or private vehicle fleets and exemptions from city-driving restrictions. Other measures include support for technology development and public awareness programmes (Table 1).

BOX 2: **EVs ARE COMING – BUT HOW QUICKLY?**

The attention of vehicle manufacturers and policy makers is increasingly focused on EVs, as the cost of producing batteries falls and their performance improves, particularly with respect to driving distance between recharges. It is widely believed that EVs will largely replace vehicles based on internal combustion engines in the coming decades. So far, EV deployment has mostly been driven by policy. Many countries have introduced financial incentives or mandates for purchasing EVs. China, the leading market by volume, and Norway, where EVs have the biggest market share, have the strongest policy push.

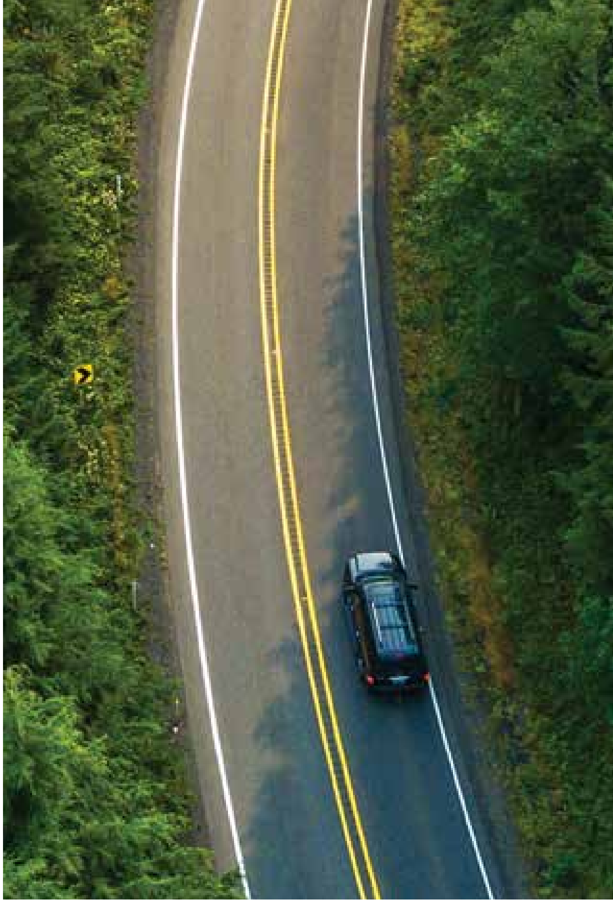
Global sales of EVs hit a record 1.15 million in 2017, or 1.2% of total LDV sales, boosting the EV fleet to more than 3.1 million. That number could rise to about 15 million by 2020 and 125 million by 2030, based on current policy plans (IEA, 2018a). Faster deployment is possible, but that would require much bigger subsidies to reduce the cost of purchasing or owning an EV and/or stronger mandates. EVs still struggle to compete with established alternative fuel technologies – including Autogas – in the mainstream car market because of the high purchase price of the vehicle, the relatively low distance between recharges, the time required to fully recharge the battery and limited recharging infrastructure. For example, in the United Kingdom, where the authorities in some cities are encouraging taxis to switch to EVs in the taxi sector, there are objections from drivers on the working time lost due to the time it takes to recharge the battery, as well as the perceived health effects of being in close proximity to batteries for many hours a day. Batteries are currently the main reason of the higher upfront costs of EVs compared with other vehicles, though their cost is likely to continue to fall and their performance improve significantly in the next few years with economies of scale and further technological progress. Battery life and their disposal continue to pose economic and environmental challenges.

Table 1: Typology of government policies and measures to promote alternative fuels

Fiscal/financial	Regulatory	Other
Excise-duty exemption or rebate	Mandatory sales/purchase requirements for public and/or private fleets (with enforcement)	Government own-use of AFVs
Road/registration-tax exemption or rebate	Standards to harmonise refuelling facilities	Information dissemination and public awareness campaigns
Vehicle sales-tax exemption or income/profit tax credit (purchasers and OEMs)	Vehicle-conversion standards	Voluntary agreements with OEMs to develop and market AFV technologies
Tax credits for investment in distribution infrastructure and R&D	Coherent and appropriate health and safety regulations	Direct funding for research, development, demonstration and deployment of AFVs
Grants/tax credits for AFV conversion/acquisition.	Exemptions from city-driving restrictions	
Rapid depreciation for commercial purchasers of Autogas vehicles and owners of distribution infrastructure		
Exemption from parking/road-use charges		

Source: WLPGA/Liquid Gas Europe (2018).

WHY AUTOGAS?



So why is Autogas used by more vehicles around the world than any other unblended alternative fuel? It is a clean fuel, emitting significantly less air pollutants such as NOx and PM, as well as less CO_2. Driving an Autogas car is safe and easy: switching to the fuel involves spending only modest sums on converting an existing vehicle. The cost of building refuelling infrastructure is inexpensive. Vehicle performance is as good, if not better, than with conventional fuels. LPG is competitively priced – at least if taxed appropriately – making it an affordable fuel. And supplies are plentiful, with rising production of natural gas and the enormous scope for reducing flaring and diverting supplies away from other less valuable uses. The potential economic benefits are not just limited to savings on health bills due to less pollution; switching to Autogas can also boost jobs in the conversion sector.

AUTOGAS IS CLEAN

The main rationale for Autogas – from a societal perspective – is its environmental advantages. Because LPG is made up of chemically simple and pure hydrocarbons, it mixes easily with air allowing almost complete combustion. Consequently, Autogas out-performs gasoline and diesel and most other alternative fuels in the majority of studies comparing the environmental performance of conventional and alternative fuels that have been conducted around the world in recent years.[6]

The results of these studies vary to some degree, according to the types of vehicles selected, the quality of the fuel, the types of emissions measured and the conditions under which they were carried out vary: actual vehicle emissions are highly dependent on vehicle technology and driving behaviour. But, overall, the picture is clear: switching to Autogas can bring major social, economic and environmental benefits.

"Autogas out-performs gasoline and diesel and most other alternative fuels in the majority of studies comparing the environmental performance of conventional and alternative fuels."

Numerous studies have shown that Autogas-related emissions of noxious and toxic air pollutants – both regulated and unregulated – are among the lowest of all the automotive fuels commercially available today. Autogas vehicles perform particularly well when a direct fuel injection system, which improves the anti-knock behaviour of the fuel and boosts fuel economy, is deployed.

The environmental performance of Autogas is particularly impressive with respect to regulated toxic gases, notably NOx and PM, or soot. Emissions of NOx – the most important of the regulated gases for air quality – from Autogas are much lower than from gasoline and, especially, diesel (Box 3). One of the key environmental advantages of Autogas over gasoline and, especially diesel, is the near-absence of PM emissions. They are negligible for Autogas and very low for gasoline vehicles, but remain a major problem for diesel vehicles. Autogas emissions are comparatively even lower for cold starts, since gasoline needs to be enriched when the engine is cold due to its poor vaporisation characteristics at low temperatures. Since most city car trips involve very short distances, urban emissions from Autogas are generally much lower than from gasoline. The environmental advantages of Autogas are even bigger with respect to unregulated emissions, including air toxics such as aldehydes, benzene, toluene and xylene, poly-aromatic hydrocarbons, as well as smog-forming components and acidification potential (through mixes of NOx and sulphur dioxide).

[6] Recent studies of the comparative environmental performance of Autogas can be found on the WLPGA website, www.wlpga.org, and www.auto-gas.net.

BOX 3: **HOW NOx HARMS HUMAN HEALTH AND THE ENVIRONMENT**

NOx is a toxic air pollutant in its own right as well as the main cause of smog – a leading form of air pollution and a major public health problem. When nitrogen is released during fuel combustion it combines with oxygen atoms to create nitric oxide (NO), which combines again with oxygen to create nitrogen dioxide (NO_2). Nitrogen dioxide and nitric oxide are referred to together as oxides of nitrogen, or NOx. NOx reacts with VOCs from industrial activities, vehicles and naturally occurring sources in the presence of sunlight to form photochemical smog – a cocktail of ground-level ozone and other toxic chemical compounds. Smog increases during the summer when solar radiation is highest, which is why this type of smog is commonly referred to as summer smog.

NOx harms human health in a variety of direct and indirect ways. NO_2 is an irritant gas, which at high concentrations causes inflammation of the respiratory system. Ozone causes damage to lung tissue and reduces lung function, especially among children, the elderly and asthmatics. The nitric acid vapour and related particles formed when NOx reacts with ammonia, moisture and other compounds can penetrate deep into lung tissue, causing severe damage and even premature death. Inhaling such particles can cause or worsen respiratory diseases, such as emphysema or bronchitis, and can aggravate existing cardio-vascular disease.

Smog also contributes to acid rain. NOx emissions also contribute directly and indirectly, through chemical reactions with other compounds in the atmosphere, to the greenhouse effect, accentuating climate change.

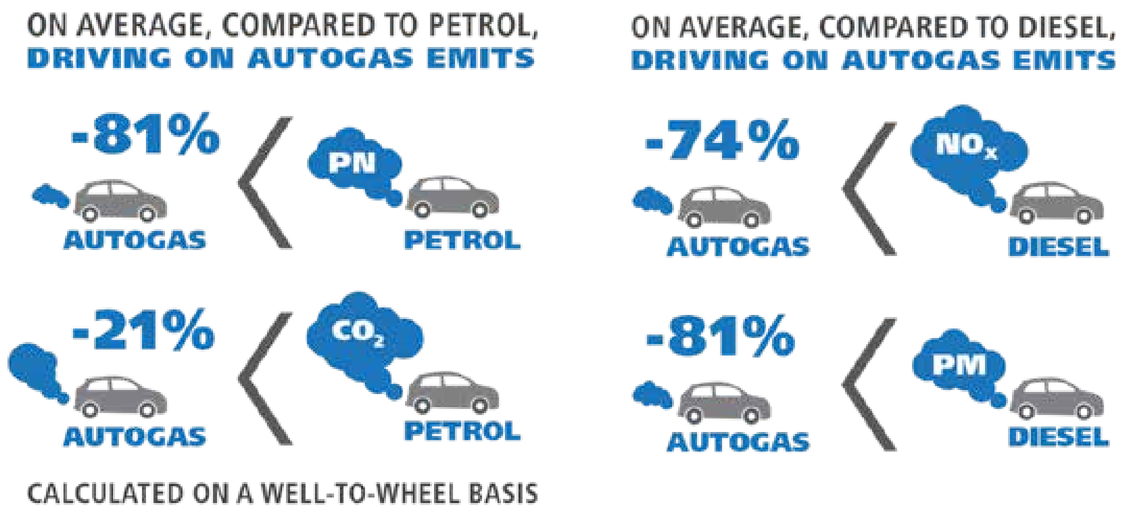
Evaporative and fugitive emissions of hydrocarbons from motor vehicles and refuelling facilities are also much less of a problem with Autogas than for conventional fuels and biofuels since it is used in gaseous form in sealed systems. Such emissions are known to make a substantial contribution to total VOC emissions. This is a particular problem with gasoline, due to its volatility. Because they have completely sealed fuel systems, Autogas vehicles and pumps have virtually zero evaporative emissions and fugitive emissions are normally limited to the very small release of gas when the fuelling coupling is attached and removed.

Switching to Autogas can also make a significant contribution to reducing greenhouse-gas emissions. With respect to CO_2, Autogas performs better than gasoline and, according to some studies, emits less than diesel, when emissions are measured on a full fuel-cycle, or "well-to-wheels" (WTW), basis and when the LPG is sourced from natural gas processing plants. Autogas also compares well with other alternative fuels. A recent study suggests that well-to-wheel emissions for Autogas are generally quite similar to CNG because of the much higher emissions associated with the processing and transportation of natural gas. Biofuels, in principle, can achieve significantly lower greenhouse-gas emissions on a well-to-wheels basis as the feedstock is renewable. However, in practice, these reductions are often minimal, as they depend on the type of feedstock and the process used to produce the fuel, which is often highly energy-intensive. As a result, Autogas emissions on a WTW basis are often no higher than those from ethanol or biodiesel.

In some cases, Autogas vehicles may also be cleaner than EVs. WTW CO_2 emissions, and those of other pollutants, from EVs can be higher than those from Autogas, especially if coal is used to produce the electricity (Hawkins et al., 2013). Only where renewables or nuclear power accounts for a large share of generation do electric vehicles deliver major reductions in greenhouse-gas emissions. In addition, EV factories also emit more toxic waste than conventional car factories.

In the future, bioLPG used as Autogas could help reduce CO_2 emissions from road transport even further. BioLPG is LPG derived from production processes that use renewable biomass as the feedstock, usually as a co-product. As such, net CO_2 emissions from the production and use of bioLPG are zero.

The molecular structure of pure biopropane is identical to that of conventional pure propane produced from hydrocarbons, so can be blended into conventional LPG as a "drop-in" fuel or sold in a pure form. The main source of commercial supplies of bio-LPG at present is a plant in Rotterdam operated by the Finnish company, Neste, with the output sold to SHV Energy. But a number of other companies and organisations around the world are producing bioLPG, which could be marketed as such, or conducting research into advanced biofuels production processes, some of which involve the production of bio-LPG as a co-product or the principal output.



Source: WLPGA (https://auto-gas.net/why-autogas/autogas-is-clean/)

“Autogas is the only alternative fuel that delivers a wide range of benefits, including lower emissions, without having to compromise on vehicle performance and autonomy.”

AUTOGAS IS PRACTICAL – AND SAFE

The operational characteristics of vehicles that run on Autogas compare very favourably with other alternative automotive fuels, making it a highly practical and safe fuel. The performance and drivability of vehicles that run on Autogas are as good, if not better, than those that run on petrol, diesel and most other fuels. It is the only alternative fuel that delivers a wide range of benefits, including lower emissions, without having to compromise on vehicle performance and autonomy.

“Autogas-electric hybrids offer bigger environmental benefits than standard gasoline-electric hybrids.”

Autogas has a higher octane rating than gasoline, so converted gasoline-powered spark-ignition engines tend to run more smoothly. This reduces engine wear and maintenance requirements, including less frequent spark plug and oil changes. The higher octane of Autogas also allows higher compression ratios, which can deliver increased engine-power output and better thermal efficiency, reducing fuel consumption and emissions. Acceleration and top speed using the latest generation of Autogas-fuel systems are comparable to gasoline or diesel. Autogas has a lower energy density than gasoline and diesel, which means that a larger volume of fuel and a bigger tank are required to achieve the same overall driving range, but this has no effect on engine performance. Autogas is fully compatible with electricity in hybrid configurations in the same way as gasoline, including plug-in hybrids. Autogas-electric hybrids offer bigger environmental benefits than standard gasoline-electric hybrids.

Autogas is not new. It has been used as a road transport fuel for over 70 years. These years of operation worldwide have amply demonstrated the integrity and safety of Autogas dispensers, as well as on-board vehicle tanks. In fact, the safety record of Autogas use in practice is at least as good as, if not better than, gasoline or diesel. In practice, Autogas vehicles meet the same standards for safety as conventionally fuelled ones:

- Autogas requires a much higher temperature to ignite compared to gasoline and diesel, and has the lowest flammability range of any fossil fuel.
- Autogas is fully contained under pressure in solid tanks, which limits the danger of leakage. Being stored in liquid form, gasoline is prone to leaks or vapour escapes. Autogas fuel tanks are 20 times more puncture resistant and can withstand far more pressure than typical gasoline tanks.
- Unlike gasoline and diesel, if Autogas leaks it does not pool or puddle, but instead quickly vaporises and dissipates into the air, eliminating the risk of fire.
- Since Autogas is released as a vapour, it cannot be ingested like gasoline, diesel or alcohol fuels. Autogas is virtually odourless and colourless in its natural state. The unpleasant smell you might associate with propane is added to help with detection in case of a leak.
- Autogas is a nontoxic, non-carcinogenic and noncorrosive fuel. It poses no hazard to groundwater, surface water or soil.

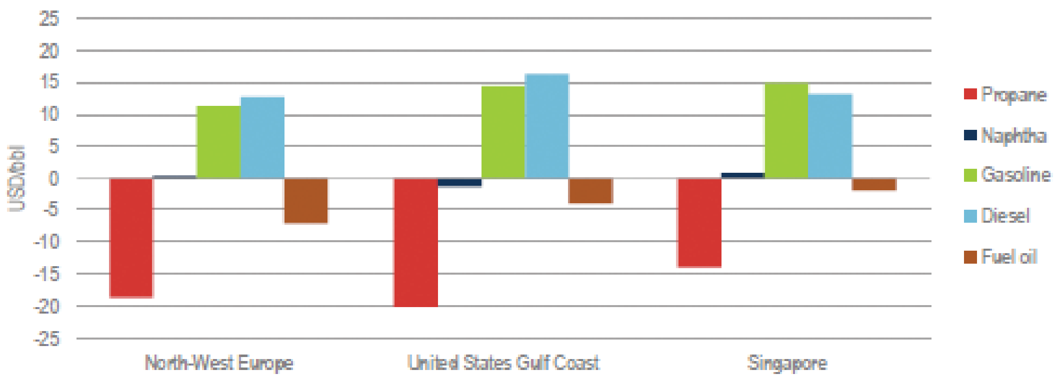
“Fuelling with Autogas is as safe and simple as filling up with gasoline or diesel. Around the world, millions of vehicles of all types – from cars to tuk-tuks, school buses to police cars – run safely on Autogas.”

AUTOGAS IS AFFORDABLE

Most alternative fuels have struggled to compete with conventional ones until now because they are more expensive; Autogas is the exception. The cost of converting vehicles and fuel-distribution infrastructure is generally lower than for other non-blended alternative fuels. And the fuel itself is highly affordable: on an energy-content basis, the cost of bulk LPG delivered to service stations is usually lower than that of gasoline or diesel, reflecting price differentials on international markets, as well as natural gas and biofuels. In volume terms, LPG is traded at an average discount of around US$30 per barrel to gasoline and diesel in Europe, US$35/barrel on the US Gulf Coast and close to US$30/barrel in Singapore in 2017 (Figure 6). Rising demand for Autogas is not expected to raise the cost of LPG on the international spot market relative to gasoline in the coming years given the abundance of supplies – even if demand for Autogas continues to rise (see below).

Converting vehicles to run on Autogas is easier and less costly than for most other alternative fuels like natural gas or electricity. Conversion costs for LDVs range from about US$500 in some developing countries to US$4 000 in North America, but are little more than US$1 500 in most cases (WLPGA/ Liquid Gas Europe, 2018). The premium for a dual-fuelled OEM vehicle also varies considerably: it used to be at least $1 000 in most countries and sometimes a lot more. But the premium has fallen sharply in some countries in the last few years, as some carmakers have cut the prices of their Autogas models to attract customers. In some cases, OEMs propose Autogas versions at the same price as gasoline versions (e.g. France and the Netherlands). In almost all countries, converting a gasoline car to Autogas – or opting for a dual-fuelled OEM Autogas vehicle – costs less than the price premium for a diesel car. Most conversions are for LDVs, though HDV conversions are becoming more commonplace (Box 4).

Figure 6: Average spot oil product price differentials with crude oil in selected locations, 2017



Notes: USD/bbl = United States dollars per barrel. Based on dated Brent crude for North-West Europe, the average of Sour and Light Louisiana Sweet crude for the US Gulf Coast and Dubai crude for Singapore. Source: IEA (2018b).

BOX 4: **CONVERTING A VEHICLE TO RUN ON AUTOGAS**

Autogas fuel systems are a proven and mature technology. Specialist companies have developed and market standardised Autogas conversion kits, including a parallel fuel system and tank, with specialist garages carrying out the installations. It involves some operational inconveniences, the most significant of which is the loss of boot/trunk space to accommodate the additional fuel tank. But the development of new technologies, including doughnut tanks and lightweight composite tanks, has helped to alleviate this problem for Original Equipment Manufacturer (OEM) vehicles, i.e. with factory-fitted dual-fuel systems, which represent the majority of new Autogas vehicles. For mainly technical reasons, most LDV conversions involve gasoline-powered spark-ignition engines, which are particularly well-suited to run on Autogas. However, it is also easy and relatively inexpensive to convert a light duty diesel engine to Autogas through the replacement of the cylinder head for a spark ignition one.

Sales of OEM Autogas vehicles, incorporating conversion kits at the point of manufacture, have been growing in many established markets in recent years. Most of the leading car manufacturers have introduced Autogas versions of at least one of their models, while others offer conversions at the time of sale, such that they are covered by their warranty (aftermarket conversions can sometimes invalidate the vehicle warranty). Worldwide, around 20 car brands currently market around 140 Autogas models (WLPGA, 2018). As Autogas has become more widely available, some OEM vehicle manufacturers have become involved in the development, design and manufacture of Autogas systems. They now produce and market dedicated Autogas vehicles with under-floor fuel tanks.

Converting a heavy-duty diesel engine in an existing vehicle can be technically more complex and expensive than converting a heavy-duty gasoline engine, but there are examples of Autogas being blended with the diesel fuel without changing the cylinder head. In recent years a number of heavy-duty Autogas spark-ignition engines (mostly adaptations of their diesel counterparts) have been commercialised by several of the larger engine manufacturers. These engines are used mainly in buses and mid-sized trucks, notably in the United States, Korea and China.

Source: WLPGA/Liquid Gas Europe (2018).

Among the various alternative fuels available today, CNG is probably the main alternative to Autogas on affordability grounds.[7] Both fuels have pros and cons, but Autogas is generally more cost-competitive for LDVs (if both fuels are taxed equally on an energy-content basis), whereas CNG/LNG in many cases can be a more viable option for heavy-duty vehicles (HDVs) (Table 2).

The cost of installing refuelling infrastructure and converting LDVs is significantly lower for Autogas, in large part because of the extra cost of CNG tanks (which need to be bigger and stronger because of their higher operating pressures). CNG refuelling stations are also much noisier than Autogas stations, making them undesirable in densely populated areas.

[7] The main exception is biofuels in places where production costs are particularly low, such as ethanol in Brazil, thanks to a favourable climate and fertile soil.

Table 2: Competitiveness of Autogas against compressed natural gas (CNG)

	Autogas	CNG
End-user price of fuel	Driven by the international LPG price (which follows other oil prices) but is generally lower than those of gasoline and diesel	Driven by bulk cost of delivered natural gas to major demand centres (low now in United States, but high in importing regions where the price is linked to that of oil)
Cost of refuelling infrastructure	Comparable to conventional fuels	Generally higher than for conventional fuels and Autogas as higher compression is needed; home refuelling costs are typically in excess of $10 000
Cost of vehicle conversion (LDV)	Ranges from around $400 to $4 000 depending on the type of car, type of conversion and local market conditions	Generally much more expensive, partly because a bigger tank is needed to deliver the same driving range (in the United States, the cost ranges from $12 000 to $18 000 due to licensing requirements)
Ease of refuelling	Refuelling is rather quick and the fuel is generally widely available as it is easy to transport by road	Refuelling usually takes longer; the fuel is not always available in all areas as it must be piped

Source: WLPGA/Liquid Gas Europe (2018).

The costs incurred in establishing or expanding an Autogas distribution network are also relatively low. These costs essentially relate to investments in service station storage and dispensing facilities. The plants and equipment that already exist to handle the importation, production, storage and bulk distribution of LPG for traditional uses are the same as for Autogas, although some additional investment may be needed to cope with higher throughput. Since Autogas generally makes use of the existing service station infrastructure for distribution of conventional fuels, additional costs for Autogas dispensing are low relative to some other alternative fuels. For example, the cost of installing a standard tank, pump and metering equipment for Autogas alongside existing gasoline and diesel facilities is typically around a third that of installing dispensing facilities for CNG with the same capacity. This is because of the added cost of dedicated supply pipelines, high-pressure compression, storage cylinders and special dispensers for CNG. In addition, the filling rate for CNG is much lower than for Autogas.

Despite the favourable environmental attributes of Autogas compared with other alternative fuels, the rate of switching to Autogas and overall consumption is highly dependent on the financial benefits to end users. A publicly-owned bus company may take account of the local environmental benefits as well as relative costs of different fuel options in deciding whether to switch to Autogas. But for most private fleet operators, truckers and individual motorists, the sole consideration is cost. As a result, private vehicle owners must be given an adequate financial incentive to switch to Autogas by converting their existing gasoline car or opting for Autogas when buying a new car: few people or companies are prepared to make a financial sacrifice individually to improve the environment for the common good. In practice, this means that the pump price in per-litre terms has to be well below that of both gasoline and diesel – typically less than half. That requires the government to tax Autogas less.

“Converting a gasoline vehicle to run on Autogas – or opting for a dual-fuelled OEM Autogas vehicle – costs less than the price premium for a diesel car and usually much less than switching to most other alternative fuels like natural gas or electricity.”

AUTOGAS IS AVAILABLE – AND A PROVEN FUEL

Autogas is a fuel of tomorrow, as well as a proven fuel of today. It is already the most widely used unblended alternative to the conventional oil-based transport fuels, gasoline and diesel, in terms of the size of its fleet. It is the leading alternative fuel for passenger cars and vans. Supplies of LPG are ample and growing fast, and can easily meet continuing strong growth in demand for Autogas in the years to come – even if demand for other energy uses of LPG grows too. With its diverse sources of supply, flexible supply chain and increasing production levels, increased reliance on LPG can help enhance the security of supply.

The supply of LPG is set to grow strongly in the coming years on the back of rising production of natural gas and associated liquids extraction – already the primary source of LPG worldwide. In addition to proven reserves in oil and gas fields, the flexibility of modern refining processes offers considerable potential for expanding supply to meet demand from the transport sector. And field and refinery supplies will also increase as wasteful flaring and venting practices, which are still common in many parts of the world, are eradicated. Indeed, a widespread concern in the LPG sector is that supply will outpace demand in the coming years, driving down prices. In the central scenario of the IEA’s latest World Energy Outlook, LPG supply is projected to grow by 2 mb/d, or around 20%, between 2016 and 2040, reaching over 12 mb/d (IEA, 2017b).

In addition, there is considerable scope for diverting supplies of LPG from other, less valuable end uses. In particular, LPG can easily be replaced in low-value petrochemical uses by other feedstocks such as naphtha, ethane and distillate. Availability of these oil products, which are currently used mainly for making gasoline and diesel, will inevitably rise as demand for those two fuels in the transport sector drops with switching to alternative fuels.

“Autogas is the only alternative fuel that delivers a wide range of benefits, including lower emissions, without having to compromise on vehicle performance and autonomy.”

AUTOGAS AS A BRIDGING FUEL

Ultimately, achieving a truly sustainable, low-carbon road-transport system will require a wholesale move away from fossil-based fuels in the long term. Although it outperforms gasoline and diesel fuels, as well as most other alternative automotive fuels, in terms of local and regional environmental benefits, Autogas – insofar as it is derived from oil refining or natural gas processing – is still a fossil fuel and so gives rise to emissions of CO_2, albeit lower than for conventional fuels. Yet Autogas could play an important role in mitigating greenhouse-gas emissions until such time as ultra-low or zero-emission vehicle technologies can be commercialised on a large scale. In this sense, fossil-based Autogas can be regarded as a long-term “bridging fuel”.

There are two ways in which Autogas can assist in driving down emissions during this transition:

- **Autogas could meet a bigger proportion of the incremental demand for new vehicles,** especially in the emerging economies, where demand for passenger cars, vans, trucks and buses is growing fastest. To the extent that Autogas-powered vehicles displace those using gasoline or diesel, overall emissions would be reduced. Ultimately, the vehicle fleet is expected to become fully electrified, either based on batteries or hydrogen fuel cells. But it will take decades to develop the infrastructure to produce all the vehicles that will be needed, build new power generation facilities to provide power for these vehicles, and install recharging facilities. In the meantime, other alternative fuels – including Autogas – will be needed to fill the gap.
- **Autogas can displace gasoline in existing vehicles.** LDVs have an average lifetime of more than ten years in the advanced economies and often far longer in the emerging economies, where maintenance costs are generally lower and restrictions on the use of old vehicles tend to be less tight. By switching to Autogas, emissions can be reduced immediately, rather than waiting until gasoline-powered vehicles in use are scrapped. The emissions benefit generated by converting older polluting vehicles can be very significant.

Many analysts believe that EVs will become the leading alternative-fuel technology in the medium term and the dominant technology in the long term. But the rate of take-up of EVs hinges on further reductions in the price of the vehicles, better performance, expanded recharging infrastructure and generous subsidies.

Ramping up production and sales of EVs will take time, simply due to the sheer scale of investment required. In the meantime, Autogas is well-placed to bridge the gap to a clean, affordable and sustainable transport system. In the longer term, Autogas derived from bioLPG could play a major role.

THE VISION

For all the advantages of Autogas, the prospects for continuing growth in demand depend critically on government policies, particularly with regard to how much the fuel is taxed in relation to other fuels. Based on current policies, global Autogas demand is projected to continue to grow for the next few years, but then peak by around 2030 before starting to decline slowly through to 2040 – our Baseline Scenario. But this version of the future is not carved in stone: a doubling of the number of Autogas vehicles by 2040 compared with the Baseline Scenario to around 80 million vehicles is entirely achievable. Making this Alternative Scenario a reality – the global target, or "vision", presented in this roadmap – would require relatively modest adjustments to the structure of fuel taxation or vehicle grants in most countries.

THE DRIVERS OF AUTOGAS DEMAND

The future of Autogas worldwide ultimately hinges on how well it can compete with both conventional fuels and other alternative fuels. Private motorists and the operators of commercial or public vehicle fleets decide which type of vehicle and fuel to use. These decisions are based on a number of factors, including vehicle performance, practicality, convenience and safety. But cost is far and away the most important one: vehicle owners almost always opt for the cheapest fuel, even when it involves some drawbacks. So, for Autogas use to grow, it has to be competitive.

Government policies, particularly with regard to how much the fuel is taxed in relation to other fuels, are the primary determinant of the competitiveness of Autogas in the near term. In practice, how attractive Autogas is to the motorist compared with other fuels

depends essentially on two factors: the net cost of converting an existing vehicle (or the extra cost of buying a factory-built Autogas vehicle compared with an equivalent gasoline or diesel vehicle) and the pump price of Autogas relative to diesel and gasoline. The vehicle owner needs to be compensated for the additional upfront cost through lower running costs, of which fuel is the most important. The time it takes for the savings in running costs to offset the capital cost – the payback period – depends on the usage of the vehicle, i.e. the average distance travelled monthly or annually. The payback period usually has to be less than two to three years to encourage commercial vehicle owners to switch; private individuals often demand an even quicker return on their investment.

The payback period – or breakeven distance – is very sensitive to the extent to which government incentives lower fuel costs relative to the other fuels and lower the upfront expenditure on the vehicle. Taxes on Autogas must be low enough relative to those on gasoline and diesel to compensate not just for the lower mileage of Autogas per litre (due to its lower energy-content-to-volume ratio), but also to ensure that the pump price of Autogas is low enough to provide an incentive for motorists to switch fuels. In practice, the lower the relative rate of tax on Autogas, the lower the breakeven distance. Financial incentives directed at the vehicle itself, such as grants or tax credits for converting to Autogas, which exist in a few countries, also help to lower the distance (Box 5).

BOX 5: **HOW IMPORTANT ARE FUEL TAXES TO THE COMPETITIVENESS OF AUTOGAS?**

According to most recent edition of Autogas Incentive Policies – a joint annual report published jointly by the WLPGA and Liquid Gas Europe – the way in which Autogas is taxed vis-à-vis other fuels has an enormous impact on how competitive the fuel is and, by extension, its share of the overall market for automotive fuels (WLPGA/Liquid Gas Europe, 2018). In ten of the 25 countries surveyed in that report, Autogas pump prices per litre for private motorists were less than half those of gasoline in 2017. The price of Autogas as a proportion of that of gasoline ranged from 32% in Thailand to 104% in the United States, averaging 53% across all countries. Relative to diesel, the price of Autogas averaged 59%.

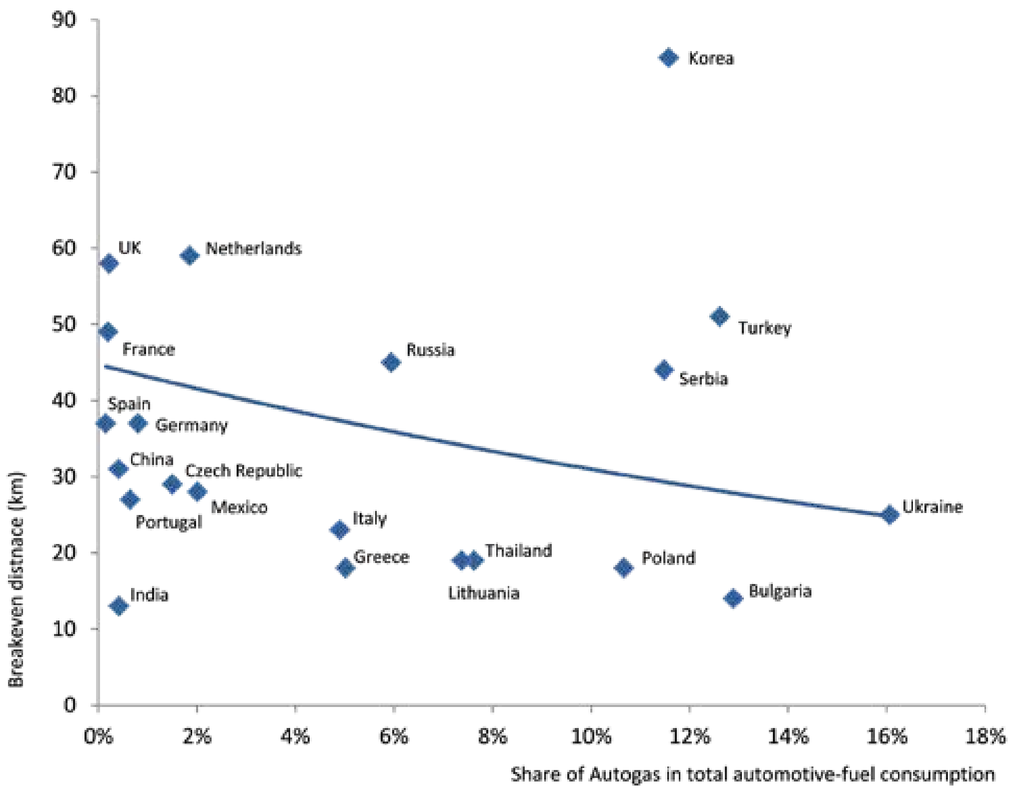
The wide variation in Autogas pump prices among the countries surveyed, both in absolute terms and relative to the prices of other fuels, mainly reflects differences in the way automotive fuels are taxed. Autogas taxes in 2017 were lower than those on gasoline on a per-litre basis in all the countries surveyed. Autogas is totally exempt from excise taxes in China, India, Mexico and Russia. The ratio of Autogas taxes to gasoline taxes was by far the highest in the United States (though most users were able to profit from a small tax credit); in all the other countries, excise taxes on Autogas were less than half of those on gasoline on a per-litre basis.

The pump price of Autogas relative to diesel and gasoline, together with the relative cost of converting a vehicle to run on Autogas (taking account of any incentives), determines the distance that needs to be driven before that cost is paid back through lower running costs. In all the countries surveyed except the United States, converted vehicles eventually break even with gasoline vehicles. In most, it is less than 50 000 km. The equivalent breakeven distance for OEM Autogas vehicles is generally higher, because it is more expensive to buy an OEM than convert a gasoline car in most cases.

Experience shows very clearly that, the market penetration of Autogas is strongly correlated with the breakeven distance of Autogas vis-à-vis gasoline. Based on 2017 data on pump prices and vehicle costs, Autogas use and rates of market growth are generally highest in countries where the breakeven distance is lowest, especially against gasoline (Figure 7). In two-thirds of the countries surveyed, the breakeven distance against gasoline is under 50 000 km – or about three years of driving. At 14 000 km, Bulgaria has the second-lowest breakeven distance and one of the highest rates of market penetration for Autogas – 13%.

Autogas is most competitive in India, where a converted vehicle breaks even with gasoline at just 13 000 km – less than one year of driving for a private motorist. Autogas is also highly competitive in Bulgaria, Greece, Italy, Lithuania, Poland, Thailand and Ukraine, all of which have a breakeven distance of less than 25 000 km for a converted car and where the market penetration of Autogas is high. At the other extreme, Autogas is never competitive with either gasoline or diesel in the United States.

Figure 7: Autogas share of automotive-fuel consumption and breakeven distance against gasoline



Note: The breakeven distances shown are the lowest for each country (a converted or OEM vehicle). The United States is not shown as Autogas is never competitive against gasoline. Australia, Canada and Japan are not shown as their breakeven distances are off the scale at above 100 000 km. Breakeven distances are based on 2017 data and market shares on 2016 data.

Source: WLPGA/Liquid Gas Europe (2018)

> “Experience shows very clearly that, the market penetration of Autogas is strongly correlated with the breakeven distance of Autogas vis-à-vis gasoline, which is determined by relative fuel prices and vehicle costs.”

Other factors drive the market penetration of Autogas and help to explain differences in recent rates of market growth across national markets. These include:

- **Government policy commitment:** The Autogas market has tended to develop more quickly where the government has shown a strong, long-term policy commitment in favour Autogas. Frequent changes of policy, including shifts in taxation, discourage end users, equipment manufacturers and fuel providers from investing in Autogas.
- **Non-financial policies and measures:** In some cases, the use of non-financial incentives or other measures such as public awareness campaigns run by the government – often in partnership with the Autogas sector – have helped to boost Autogas use. Mandates and public transport fleet conversion programmes have also been very successful in several countries, notably in China, India and the United States.
- **Restrictions on diesel vehicles:** Local and central government environmental restrictions on the use of diesel vehicles have been an important factor behind the success of Autogas in some countries, notably Korea and Japan. These restrictions are likely to become more widespread with growing concerns about the health effects of PM (soot) emissions from diesel vehicles, which could boost demand for Autogas.
- **Availability of equipment and fuel:** In some countries, Autogas has struggled to penetrate the fuel market where carmakers have been reluctant to market OEM models or where there is a limited number of refuelling sites selling Autogas. The issue of producing right- and left-hand drive vehicles complicates this.
- **Public attitudes:** Misconceptions about the safety and reliability of Autogas have clearly affected demand in several countries. For example, this appears to be one reason why Autogas demand remains weak in France, despite highly favourable taxation policies.

In the longer term, developments in vehicle technology will undoubtedly have a major impact on demand for Autogas. There are clear signs that the world is on the cusp of a road-transport revolution, with carmakers stepping up their research and development efforts in EVs and, to a lesser extent, hydrogen fuel cells, and launching new models. This is the result of recent advances in battery technology and stronger government incentives, driven largely by environmental concerns. The production of biofuels is also growing steadily. How quickly the transformation of energy use for transport takes place is a major uncertainty for the demand for Autogas and for road transport fuels generally. Ultimately, EVs may completely displace internal combustion engine (ICE)-based vehicles, including those fuelled by Autogas, but this will take decades. There will be opportunities for Autogas to replace gasoline and, in some cases, diesel in existing conventional vehicles during this period. Continuing advances in Autogas vehicle technology will be an important factor in exploiting these opportunities.

BUSINESS AS USUAL: THE BASELINE SCENARIO

The last few years have seen significant changes in policy in several countries leading to shifting fortunes – positive and negative – for Autogas, depending on the country. Further changes are to be expected in the future in the face of growing concerns about the environmental impact of rising demand for mobility. To better understand how these changes might impact the prospects for the global Autogas market and the potential for policy to drive strong growth in demand, we have prepared a set of projections of Autogas use using a scenario approach (Box 6). Two scenarios were formulated: a Baseline Scenario, which incorporates the assumption of no change in current government policies with respect to Autogas and other transport fuels and technologies; and an Alternative Scenario, in which the number of Autogas vehicles is assumed to reach twice that of the Baseline Scenario in each region in 2040. The aim is to show how Autogas use could evolve in a business-as-usual world and how much faster it could grow given concerted action on the part of all stakeholders to make Autogas a more attractive fuel option.

BOX 6: **HOW THE TWO SCENARIOS WERE DEVELOPED**

The Baseline Scenario was based on the transport market projections of the International Energy Agency's World Energy Outlook 2017 for the New Policies Scenario, which takes account of current and planned polices and measures. The IEA does not publish detailed projections of use for transport by fuel or sub-sector, but kindly agreed to provide aggregate projections of oil use in road transport by major region to 2040.[8] These projections were used to derive projections of Autogas use by region by applying assumptions about market share in a bottom-up manner based on information about policy developments, insights from WLPGA members and, where available, official national projections of road-transport fuel use. Projections of the Autogas vehicle fleet were then obtained by applying assumptions about the evolution of vehicle fuel efficiency, based on the long-term projections of the total vehicle fleet (also provided by the IEA).

For the Alternative Scenario, a back-casting approach was used, based on the assumption that the number of Autogas vehicles is twice that of the Baseline Scenario in each region in 2040 – the target set out in this roadmap.

[8] IEA statistics and projections treat LPG as an oil product, even though LPG is a gas and the bulk of LPG supply is actually obtained from natural gas processing.

The resulting projections were used to calculate total Autogas consumption by country and region using the same projections of vehicle fuel efficiency as in the Baseline Scenario. In order to verify the plausibility of the underlying assumption in the Alternative Scenario, detailed econometric analysis using time series and cross-country data of the implications of increased Autogas use for policy incentives was carried out, based on the results of the competitiveness analysis carried out for the Autogas Incentive Policies report (WLPGA/Liquid Gas Europe, 2018). In most cases, this analysis confirmed that the policy changes in the form of fuel-tax reform or financial incentives for Autogas vehicles were plausible. Nonetheless, for some countries, the assumption was adjusted, while ensuring that it was respected at the regional level.

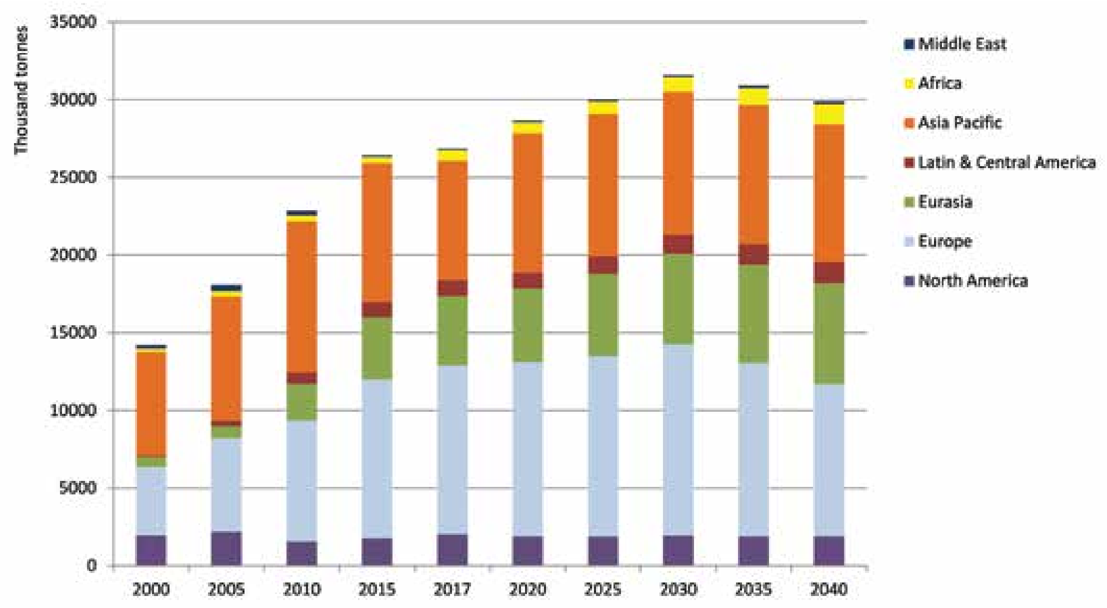
For both scenarios, the impact of changes in the share of Autogas in the total LPG market were calculated based on the global LPG supply projections of the IEA. The results confirm that the projected growth in global LPG demand in both cases is modest and would be unlikely to put significant upward pressure on international prices and, thereby, to hold back demand in national markets (see main text).

In the Baseline Scenario, global Autogas consumption continues to grow, reaching a peak of a little over 31 Mt in 2030 – about 18% higher than in 2017. Thereafter, it goes into gradual decline, dipping to just under 30 Mt in 2040 (Figure 8). Up to 2030, sales of EVs are not large enough to significantly affect sales of gasoline cars, which are boosted by both rising demand for mobility and a continuing slump in demand for diesel vehicles; the expansion of the gasoline vehicle fleet over this period increases the scope for switching to Autogas. Demand in all regions, including Europe, continues to rise over this period.

The reversal in the upward trend after 2030 is driven largely by a decline in the share of Autogas as end users opt increasingly for gasoline hybrids and EVs. Falling gasoline use in Europe – the main Autogas-consuming region – contributes to the overall decline in global demand for Autogas; gasoline demand in the rest of the world is either flat or continues to grow after 2030 – notably in the Asia-Pacific region. Total oil consumption for road transport worldwide grows only very slowly over 2017-2040, as rising energy needs in that sector are almost entirely offset by the steady decline in the share of thermal fuels with the increased penetration of EVs and, to a lesser extent, biofuels.[9]

[9] In the IEA's New Policies Scenario, on which the Baseline Scenario is based, the number of EVs on the world's roads climbs from just over 3 million in 2017 to almost 280 million by 2040 – equal to around 15% of the total car fleet and displacing around 2.5 mb/d (110 Mt) of oil demand. Over the same period, the use of biofuels almost triples to 4.1 mb/d (IEA, 2017b).

Figure 8: Autogas consumption in the Baseline Scenario by region



"On current trends, global Autogas consumption is projected to continue to grow, reaching a peak of just over 31 Mt in 2030 – about 18% higher than in 2017 – before going into gradual decline, as end users opt increasingly for gasoline hybrids and EVs."

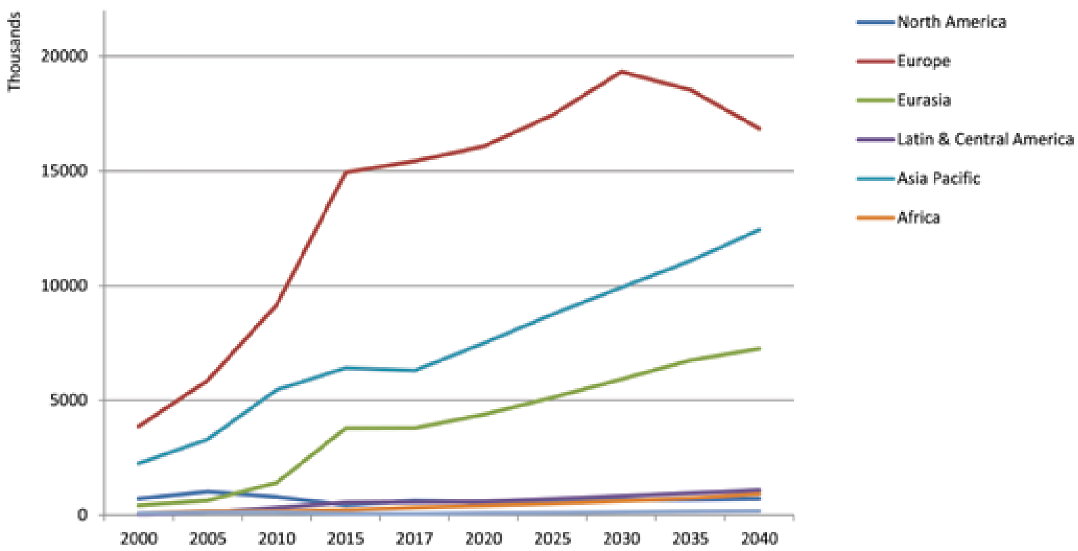
The rise in Autogas consumption to 2030 is driven by a steady expansion of the vehicle fleet, notably in Europe, where the market is already well-established. Globally, the Autogas fleet reaches a plateau of around 39 million by the end of the 2030s – 45% up on 2017 (Table 3). Fuel economy continues to improve worldwide over the entire projection period, which is why Autogas use goes into decline despite rising vehicle numbers. The fleet continues to expand in all regions throughout the projection period except in Europe, where it goes into long-term decline after 2030 (Figure 9).

By 2040, 93% of all the Autogas vehicles in the world are in just three regions: Europe, Asia-Pacific and Eurasia. The share of Autogas in the global vehicle fleet remains broadly constant at 2% to 2030 and then declines gradually to 1.7% by 2040.

Table 3: Autogas consumption and vehicles in the Baseline Scenario by region

	2000	2010	2017	2020	2030	2040
Consumption (Mt)						
North America	1.96	1.56	2.04	1.89	1.95	1.89
Europe	4.40	7.78	10.86	11.21	12.31	9.80
Eurasia	0.65	2.37	4.46	4.75	5.83	6.49
Latin & Central America	0.08	0.74	1.01	1.00	1.20	1.37
Asia Pacific	6.68	9.73	7.70	8.99	9.21	8.87
Africa	0.21	0.39	0.70	0.72	0.96	1.30
Middle East	0.25	0.30	0.07	0.10	0.14	0.18
World	**14.22**	**22.85**	**26.83**	**28.67**	**31.59**	**29.89**
Vehicle numbers (millions)						
North America	0.72	0.79	0.63	0.56	0.66	0.72
Europe	3.88	9.17	15.43	16.08	19.33	16.85
Eurasia	0.43	1.41	3.80	4.38	5.92	7.25
Latin & Central America	0.03	0.33	0.58	0.59	0.83	1.08
Asia Pacific	2.26	5.46	6.30	7.49	9.92	12.44
Africa	0.08	0.18	0.34	0.42	0.62	0.93
Middle East	0.08	0.12	0.06	0.09	0.13	0.18
World	**7.46**	**17.47**	**27.14**	**29.62**	**37.42**	**39.46**

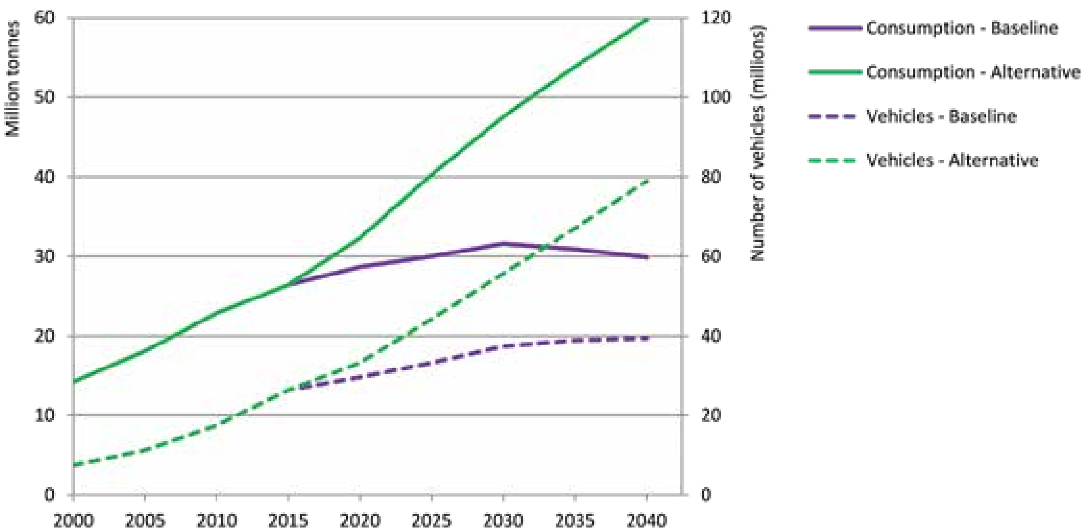
Figure 9: Autogas vehicles in the Baseline Scenario by region



DOUBLING MARKET SHARE: THE ALTERNATIVE SCENARIO

Ultimately, achieving a truly sustainable, low-carbon road-transport system will require a wholesale move away from fossil-based fuels in the long term. The Baseline Scenario paints one picture of how Autogas demand could evolve to 2040 in a business-as-usual world: other outcomes in which Autogas plays a much more important role are possible. The Alternative Scenario assumes that the number of Autogas vehicles and their share of Autogas in the overall vehicle fleet reach twice the levels of those in the Baseline Scenario in each region by 2040, while taking account of country-specific differences. This requires a strengthening of incentive policies, including lower taxes on Autogas relative to other fuels and/or bigger financial incentives for converting existing vehicles (OEM or aftermarket) to run on the fuel, as well as support from the Autogas industry, vehicle manufacturers and fuel-system equipment producers and installers. In some countries, it might be necessary to raise public awareness about the benefits of Autogas, especially where it is not yet established. Global Autogas consumption continues to grow steadily in the Alternative Scenario, reaching 60 Mt by 2040 – well over twice the current level. The Autogas vehicle fleet grows even faster as fuel economy continues to improve throughout the projection period, reaching almost 80 million in 2040 – nearly three times the current size (Figure 10 and Table 4). Worldwide, Autogas vehicles make up 3.4% of the total fleet in 2040, compared with 1.7% in the Baseline Scenario and around 2% today.

Figure 10: World Autogas consumption and vehicles by scenario



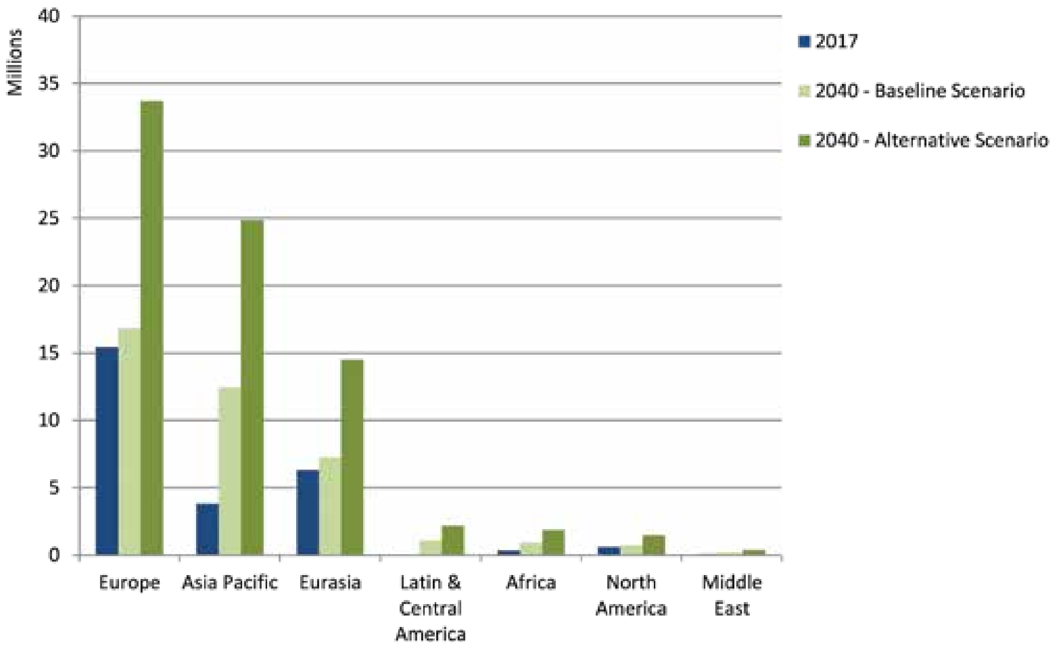
Europe, Eurasia and Asia-Pacific continue to account for the bulk of the global Autogas fleet throughput the projection period in the Alternative Scenario, contributing almost all of the increase in vehicle numbers. Their combined share of the global Autogas fleet nonetheless falls slightly, from 94% in 2017 to 93% in 2040 (Figure 11).

The fleet in Asia grows the most in absolute terms, quadrupling to 25 million, yet still accounts for just 2.3% of the region's total vehicle fleet – up from 1.6% now. In Europe, the fleet more than doubles to 34 million – the largest of any region – while its share of the total vehicle fleet rises from 4.4% at present to 8.6% in 2040.

Table 4: Autogas consumption and vehicles in the Alternative Scenario by region

	2000	2010	2017	2020	2030	2040
Consumption (Mt)						
North America	1.96	1.56	2.04	2.59	3.29	3.78
Europe	4.40	7.78	10.86	12.34	16.88	19.61
Eurasia	0.65	2.37	4.46	5.90	9.78	12.98
Latin & Central America	0.08	0.74	1.01	1.04	1.80	2.74
Asia Pacific	6.68	9.73	7.70	9.34	13.96	17.73
Africa	0.21	0.39	0.70	0.99	1.63	2.60
Middle East	0.25	0.30	0.07	0.10	0.21	0.35
World	**14.22**	**22.85**	**26.83**	**32.30**	**47.55**	**59.78**
Vehicle numbers (millions)						
North America	0.72	0.79	0.63	0.79	1.13	1.45
Europe	3.88	9.17	15.43	17.62	26.38	33.71
Eurasia	0.43	1.41	3.80	5.45	9.96	14.50
Latin & Central America	0.03	0.33	0.58	0.63	1.27	2.16
Asia Pacific	2.26	5.46	6.30	8.13	15.74	24.88
Africa	0.08	0.18	0.34	0.49	0.99	1.87
Middle East	0.08	0.12	0.06	0.08	0.19	0.36
World	**7.46**	**17.47**	**27.14**	**33.20**	**55.66**	**78.92**

Figure 11: Autogas vehicle fleet by region and scenario



This scenario is broadly consistent with other sustainable transport scenarios. For example, the share of non-renewable gaseous fuels in total transport energy use in the REMap Case of the Global Energy Transformation Roadmap of the International Renewable Energy Agency (IRENA) doubles to 4% over 2015-2050 (IRENA, 2018).

The share of renewables (essentially biofuels, including bioLPG) rises from 4% to 58% over that period and that of electricity to 33% (28% renewables-based). This reflects the constraints on moving to a totally carbon-free transport system within little more than 30 years and the need to rely more on the least carbon-intensive non-renewable transport fuels such as fossil-based Autogas.

"Making this Alternative Scenario a reality – doubling the number of Autogas vehicles and their share in the global vehicle fleet – would require relatively modest adjustments to the structure of fuel taxation or vehicle grants in most countries."

The projected increase in global Autogas demand in the Alternative Scenario is modest relative to overall LPG supply, which is set to continue to expand in the coming decades. In the IEA's New Policies Scenario, on which these projections are based, total production of natural gas liquids – the primary source of LPG – increases by more than 28% between 2016 and 2040 (IEA, 2017b). Were total LPG demand to grow faster as a result of higher Autogas use, refiners could increase LPG yields at the margin and upstream companies could pursue more liquid-rich fields, tempering any significant upward pressure on international prices. Re-directing flared gas to support the faster growth in demand for Autogas in the Alternative Scenario would also be an option.

In addition, there is considerable scope for replacing LPG as a petrochemical feedstock with naphtha, ethane or distillate, freeing up more LPG for use as Autogas. The increase in global Autogas demand in the Alternative Scenario vis-à-vis the Baseline Scenario in 2040 amounts to 30 Mt – equal to only 8% of total supply in the latter scenario and around one-third of the projected increase in total LPG supply over 2016-2040. In addition, a significant part of the increase in Autogas demand could be met with bioLPG, depending on technological advances and investment.

Making this Alternative Scenario a reality would require relatively modest adjustments to the structure of fuel taxation or vehicle grants in most countries. An econometric analysis was carried out based on the results of the study of inter-fuel competition in the countries surveyed in the 2018 edition of Autogas Incentive Policies (WLPGA/Liquid Gas Europe, 2018). The results of that analysis show that the average payback period for switching from gasoline to Autogas would need to fall on average from 26 to 18 months to achieve a doubling of the share of Autogas in total automotive fuel use. This could be achieved either by an increase in the tax on gasoline relative to Autogas or by the introduction of a grant or tax credit to cover part or all of the conversion cost.

The need for these measures would be alleviated or, in some cases, removed entirely by additional measures to discourage the use of diesel on environmental grounds beyond those already taken into account in the Baseline Scenario. Diesel, which competes most with Autogas in high-mileage vehicles, is often – perversely – taxed less in energy terms than Autogas at present. Other non-financial measures, such as exemptions for Autogas vehicles from driving restrictions in city centres for environmental reasons, could also help boost the attractiveness of Autogas, further reducing the need to lower the tax on Autogas or offer financial incentives for converting vehicles to Autogas.

QUANTIFYING THE BENEFITS OF MAKING

THE VISION A REALITY

The vision of tripling the number of Autogas vehicles between now and 2040 is undoubtedly achievable. And making that vision a reality would bring major social, economic and environmental benefits in the form of cleaner air, improved human health and reduced climate change. By 2040, we estimate that it would lower global emissions of NOx from LDVs by over 4% and those of $PM_{2.5}$ by close to 5%, yielding social welfare gains, including savings on health costs and improved productivity, valued at almost $40 billion. World emissions of CO_2 on a WTW basis would also be cut by a cumulative total of around 130 Mt over 2018-2040, yielding additional welfare gains of more than $15 billion.

CLEARING THE AIR

Doubling the number of Autogas vehicles on the road in 2040 compared with business-as-usual trends – the vision set out in this roadmap – would yield significant improvements in local air quality. To evaluate the scale of those benefits, the WLPGA in partnership with Liquid Gas Europe (LGE) commissioned a study by the Belgium-based research group, Transport & Mobility Leuven (TML), to estimate the emissions reductions and social welfare benefits that would be achieved in the Alternative Scenario relative to the Baseline Scenario for LDVs in Europe. We then extended this analysis to the rest of the world and to the overall vehicle fleet using the same set of emission factors (Box 7).

BOX 7: **MODELLING OF EMISSIONS SAVINGS IN THE ALTERNATIVE SCENARIO**

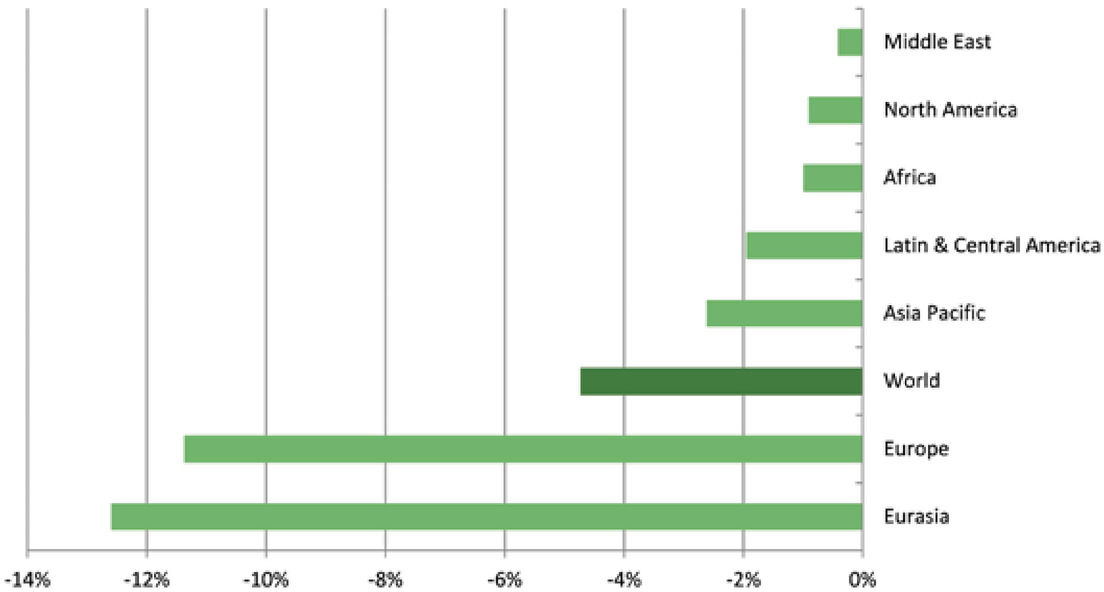
In an effort to better understand and quantify the potential benefits that would stem from a greater penetration of Autogas, the WLPGA and LGE commissioned a study by the research group, Transport & Mobility Leuven (TML), based in Belgium. Having already carried out numerous studies on transport and energy on behalf of the European Commission, TML is particularly well-placed to analyse the potential impact of the emergence of Autogas as a more significant player in Europe's road transport fuel mix. In the framework of its collaboration with the European Commission, TML developed TREMOVE, an econometric modelling tool used to predict emissions from the European passenger-car sector on the basis of policy scenarios. To evaluate the potential impact of an increased role for Autogas, TML developed a specific model using relevant modules of TREMOVE covering the total vehicle stock, road-transport fuel consumption and the resulting emissions, as well as the implications for social welfare in terms of reduced external impacts resulting from climate change.

Two of the scenarios prepared by TML were calibrated to the Baseline and Alternative Scenarios used in this report.

For the rest of the world, we adopted the same set of emission factors deployed by TML, which we applied to our projections of Autogas and other transport fuels based on the long-term projections of the IEA's World Energy Outlook (see Box 6, above). For all regions, we calculated the difference in emissions and the social welfare implications between the two scenarios, applying region-specific estimates of the social welfare benefits of lower CO_2 emissions and the reduced external impacts of pollutant emissions on public health. In addition, we extended the analysis for all regions, including Europe, to HDVs.

Achieving the Autogas vision would have the biggest impact on $PM_{2.5}$ emissions from LDVs worldwide, which fall by 4.7% by 2040 in the Alternative Scenario compared with the Baseline Scenario. The large reduction in emissions relative to the size of the shift in the fuel mix of the LDV fleet reflects the much higher per kilometre emissions from diesel vehicles compared with both Autogas and, to a lesser extent, gasoline. The increase in the Autogas fleet in the Alternative Scenario is assumed to be offset by a corresponding fall in the numbers of gasoline and diesel cars, according to their shares of the total fleet in 2040 in the Baseline Scenario. This yields a big net reduction in emissions, especially in regions where diesels represent a large share of the overall LDV fleet. Thus, the biggest reductions in percentage terms occur in Eurasia and Europe, where the penetration of Autogas and diesel are highest and, therefore, where the shift from diesel to Autogas is biggest (Figure 12). For all types of vehicle, including buses and trucks, global $PM_{2.5}$ emissions are reduced by close to 1%.

Figure 12: Reduction in global emissions of $PM_{2.5}$ from LDVs in 2040 in the Alternative Scenario by region



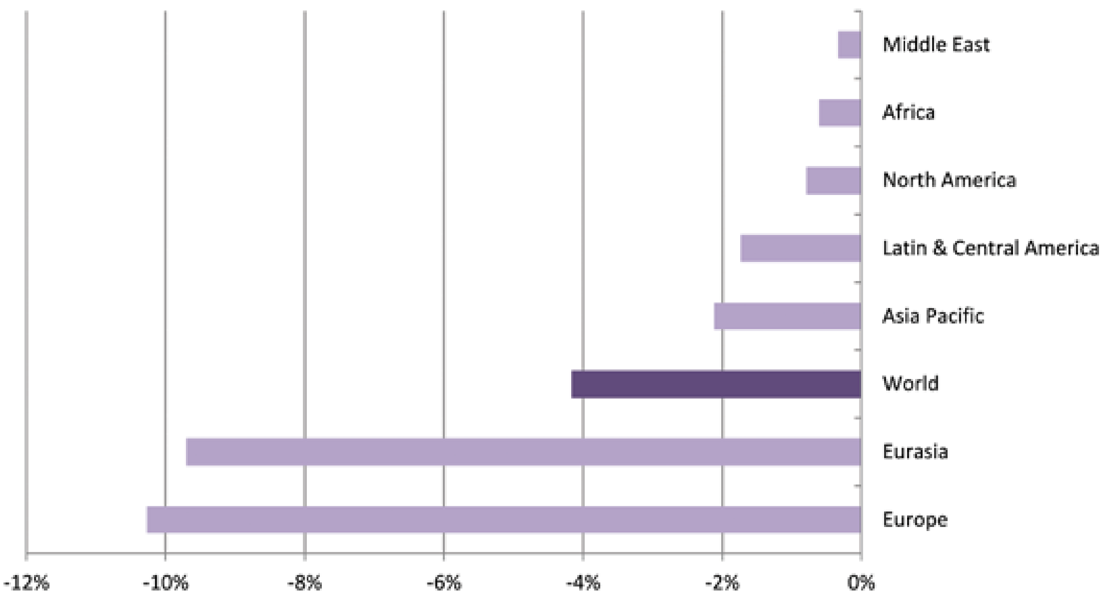
Note: Relative to the Baseline Scenario. Emission include PM_{10} and $PM_{2.5}$.

"Realising the Autogas opportunity in the Alternative Scenario would lower global emissions of NOx from LDVs by over 4% and those of PM by close to 5%, yielding social welfare gains, including savings on health costs and improved productivity, valued at almost $40 billion."

The reduction in global emissions of NOx – the leading cause of smog – are almost as big as those of $PM_{2.5}$. Globally, NOx emissions from LDVs are 4.2% lower in 2040 in the Alternative Scenario compared with the Baseline Scenario. Again, the emissions reductions are biggest in Europe and Eurasia, where the share of diesel cars – the main source of transport-related NOx emissions – in the overall fleet is highest (Figure 13). The fall in emissions is lowest in the Middle East, Africa and North America, where most LDVs run on gasoline. Gasoline-powered vehicles on average emit slightly less NOx than Autogas-fuelled ones. Global emissions of NOx from the vehicle fleet as a whole, including buses and trucks, are cut by around 0.6%.

While the switch to Autogas from gasoline and diesel for LDVs in the Alternative Scenario yields significant reductions in emissions of $PM_{2.5}$ and NOx, those of CO and VOC increase marginally. For the world as a whole, emissions of CO rise by 0.7% for LDVs and 0.4% for all vehicle types, while those of VOC increase by 0.6% and 0.3% respectively. The overall environmental impact of these increases would, nonetheless, be substantially less than the effect of the large reductions in $PM_{2.5}$ and NOx emissions, resulting in an important net environmental improvement.

Figure 13: Reduction in global emissions of NOx from LDVs in 2040 in the Alternative Scenario by region



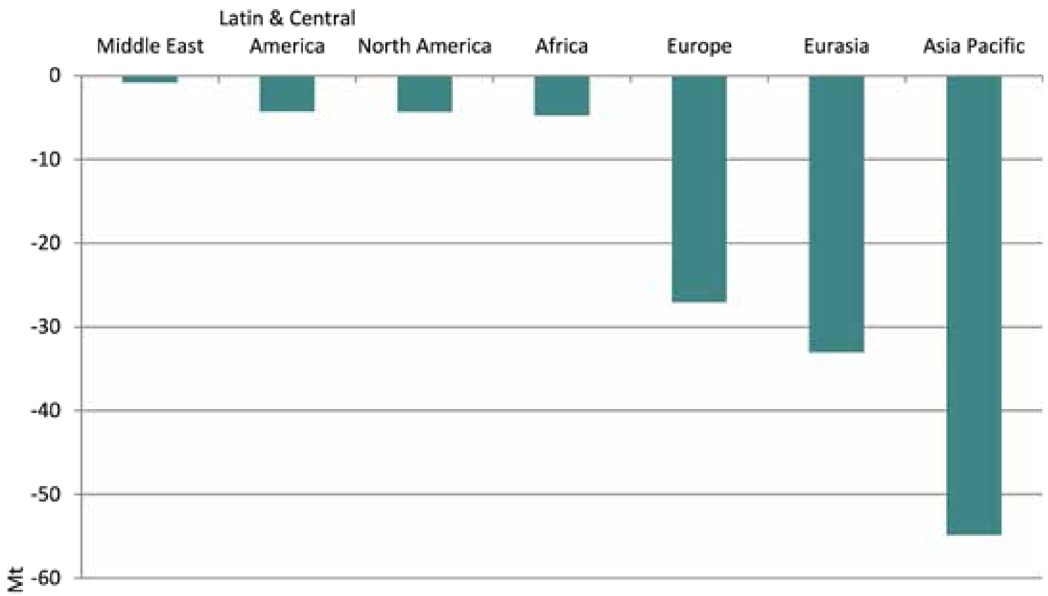
Note: Relative to the Baseline Scenario.

MITIGATING CLIMATE CHANGE

As well as improving air quality, achieving the vision of doubling the global market share of Autogas by 2040 would also make a significant contribution to lowering emissions of CO_2 and combatting climate change. We calculate that, on a WTW basis, emissions of CO_2 from LDVs would fall by 0.3% for the world in the Alternative Scenario relative to the Baseline Scenario.

But for some regions, the fall in emissions is more significant: close to 1% in Europe and Eurasia. The cumulative reduction in CO_2 emissions between 2018 and 2040 totals around 130 Mt – equal to the current total annual CO_2 emissions of Algeria from all sources. The bulk of the savings come from Asia-Pacific, Eurasia and Europe (Figure 14).

Figure 14: Cumulative reduction in global well-to-wheel emissions of CO_2 from LDVs in 2018-2040 in the Alternative Scenario by region



Note: Relative to the Baseline Scenario.

ESTIMATING THE SOCIAL WELFARE BENEFITS

The social welfare benefits of achieving the Autogas vision as described by the Alternative Scenario would be substantial, totalling at least US$54 billion over the period to 2040. This is roughly equal to the annual GDP of Croatia. Most of this benefit comes from the reduced damage to human health resulting from lower emissions of NOx and $PM_{2.5}$, mainly for LDVs, and less smog (Table 5).

Reduced emissions of NOx alone contribute around US$35 billion and $PM_{2.5}$ another US$4 billion. More than half of these savings come from Europe, with around one-quarter coming from the Asia-Pacific region (Figure 15). The increase in emissions of CO and VOC would have a negligible impact on overall societal cost, as the health effects of those increases, which are modest, are far smaller than for NOx and $PM_{2.5}$.

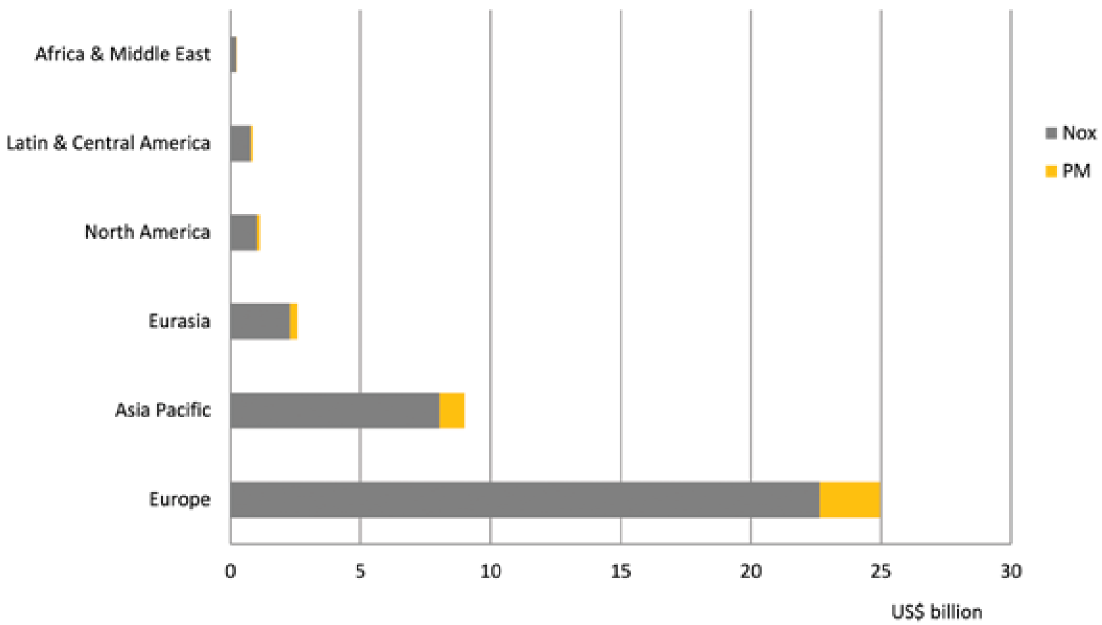
Table 5: Global emission savings and cumulative associated social welfare benefits in 2018-2040 in the Alternative Scenario

Type of emission	Emission savings (Mt)	Social welfare benefits (US$ billion)
NOx	2.788	34.97
PM	0.049	3.80
CO_2 (well-to-wheels)	130.280	15.24
Total	**n.a.**	**54.01**

Note: Relative to the Baseline Scenario. Welfare gains from lower CO_2 emissions assume a social cost of carbon of US$115/tonne.
Sources: Menecon Consulting analysis based on TML data and Clean Air for Europe data From DG Environment of the European Commission.

"The societal benefits of achieving the Autogas vision in the form of cleaner air, better health and reduced climate change would be substantial, totalling at least US$54 billion over the period to 2040."

Figure 15: Cumulative social welfare benefit of reduced emissions of NOx and $PM_{2.5}$ in 2018-2040 in the Alternative Scenario by region



Note: Relative to the Baseline Scenario.
Sources: Menecon Consulting analysis based on TML data and Clean Air for Europe (DG Environment of the European Commission) data.

The value of the socioeconomic benefits of lower CO_2 emissions over the period to 2040 is estimated at around US$15 billion worldwide. This is an indicative estimate based on an assumed social cost of carbon of around US$115 per tonne for all regions.[10] Asia-Pacific accounts for over 40% of the global societal benefits and Europe and Eurasia for most of the rest.

The societal benefits from improved air quality and reduced climate change advantages would be complemented by the economic benefits enjoyed by end-users making the switch to Autogas. Motorists would enjoy lower fuel costs that quickly payback the upfront cost of converting their vehicle or buying a slightly more expensive OEM model. Switching to Autogas would entail a modest loss of government revenue as a result of lower excise taxes on Autogas, but this would be far outweighed by the societal benefits of reduced environmental damage. Additional economic benefits would also come from the additional jobs created in the Autogas sector.

[10] The social cost of carbon (SCC) represents the economic cost associated with climate damage (or benefit) that results from the emission of an additional tonne of CO_2. It is typically calculated as the net present value of the difference between climate change damages caused by anthropogenic emissions of CO_2. It provides an economic valuation of the marginal impacts of climate change. The value of SCC is subject to considerable debate and estimates vary widely according to the country concerned and methodology used. The figure adopted here is that used by the European Commission (2014).

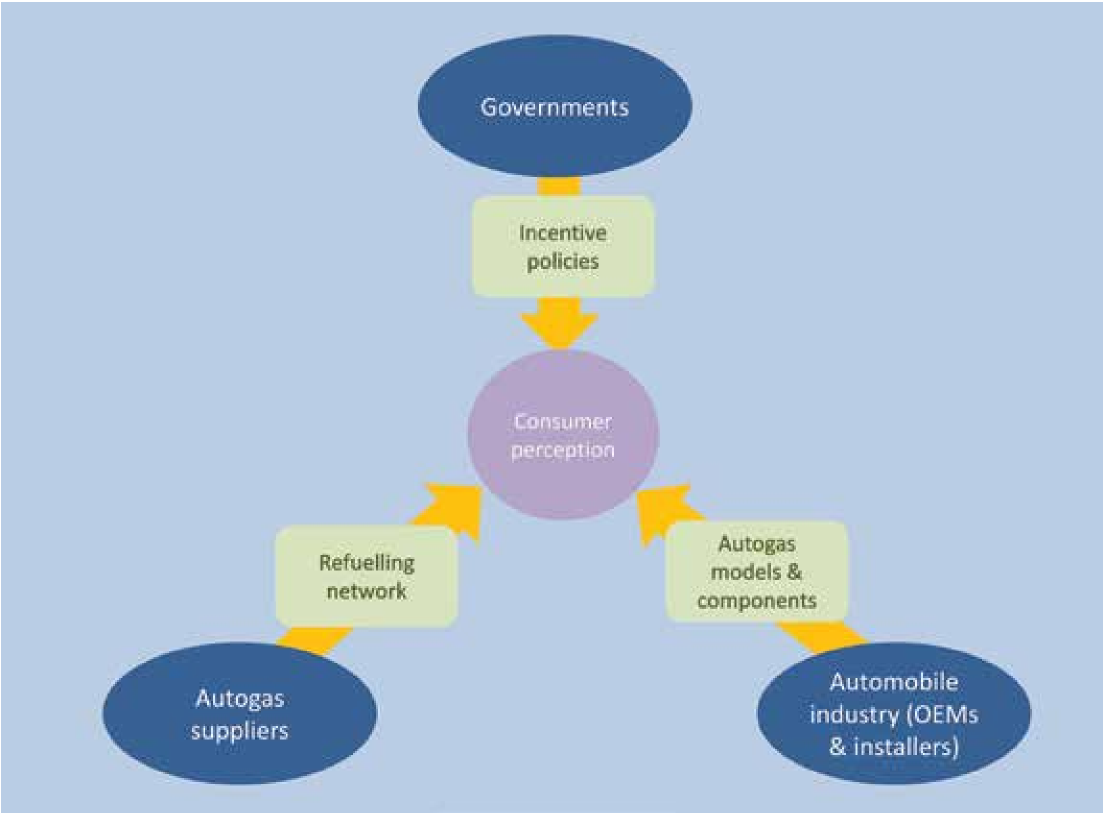
A PLAN OF ACTION

The benefits that would result from faster growth in Autogas use around the world are substantial, but will not happen without concerted action by all stakeholders to tackle the barriers to market development. Autogas suppliers themselves are committed to taking action. But the role of policy makers is crucial: transport and fuel tax policies need to ensure that Autogas is financially attractive to end users. Other private sector stakeholders, including energy producers and fuel system equipment manufacturers and installers, also need to play their part by investing in new vehicle technologies and bioLPG. And the consumer – the motorist – needs to be fully committed to Autogas. This will be particularly important where Autogas is new to the market or where there are public concerns about using the fuel. Investment in education and training programmes will be needed as well as developing positive brand awareness.

FROM POTENTIAL TO REALITY

Autogas is well-placed to play an important role in the transition to a genuinely sustainable, clean road-transport sector. But for this to happen, concerted action by all stakeholders – from policy makers, to vehicle manufacturers, to Autogas fuel-system producers and installers, and to the Autogas supply industry itself – is needed to influence consumer perception (Figure 16). This action needs to focus on addressing the barriers to developing the Autogas market in each country and region, and building momentum.

Figure 16: The role of key stakeholders in enhancing consumer perception of Autogas



Sources: : Based on WLPGA (2018).

A plan of action needs to be based on an understanding of the critical success factors for the development of a sustainable Autogas market. The principal factor, as explained above, is the financial attraction of switching to Autogas for vehicle owners. This is largely determined by the structure of fuel taxes and the cost of converting vehicles. In practice, the crucial variable in the choice of fuel is the speed of payback on the initial additional cost of converting a gasoline vehicle to run on Autogas or the higher price of an OEM vehicle relative that of a new gasoline or diesel vehicle. The payback period has to be sufficiently short to justify the investment and to compensate for the inconvenience associated with Autogas.

The achievement of critical market mass is the other key factor: even where strong financial incentives exist, Autogas use will not necessarily take off until the market reaches a certain size:

- **The market needs to be large enough to demonstrate to potential Autogas users and fuel providers that the fuel is safe, reliable and cost-effective alternative to conventional fuels.** The more Autogas vehicles there are on the road, the more confidence other vehicle owners will have to switch fuels.
- **Autogas must be widely available and the general public must be aware of this.** A lack of refuelling stations is a major impediment to persuading vehicle owners to switch to Autogas, even where there is a strong financial incentive.
- **The Autogas market must be big enough to support a viable network or properly-trained mechanics to convert and maintain Autogas vehicles and ensure the availability of spare parts and equipment.**

All stakeholders in the Autogas sector need to work together to ensure that Autogas remains an attractive fuel option and to make sure that critical market mass does not constitute a barrier to market growth. If all stakeholders contribute, the vision of can become a reality.

> "For Autogas to play its role in the transition to a genuinely sustainable, clean road-transport sector to the full, concerted action by all stakeholders – from policy makers, to vehicle manufacturers, to Autogas fuel-system producers and installers, and to the Autogas supply industry itself – is needed."

WHAT THE AUTOGAS INDUSTRY WILL DO

Meeting the growth in demand envisioned in the Alternative Scenario calls for a major expansion in Autogas supply infrastructure. This will require major additional investments along the supply chain, notably in supply, transportation and distribution facilities, such as rail tank cars and, bulk road tank cars, delivery trucks and storage depots, and in refuelling stations. Capacity at many existing stations will need to be expanded and new refuelling facilities at existing stations installed (or dedicated Autogas outlets built). Safety will remain paramount, requiring extensive training of personnel, clear communication of safe practices and emergency management plans and equipment (WLPGA, 2018).

Commensurate with the requests for support from policymakers, the Autogas industry worldwide is prepared to make a considerable commitment of human and financial resources in order to realise this ambition. The members of the WLPGA have agreed to take the following action to support the vision set out in this roadmap:

- **Reach out to citizens to inform them of the potential of Autogas to keep people on the move while protecting the environment.** Research suggests that a key obstacle to the development of alternative fuels is a lack of awareness among citizens. The Autogas industry is committed to addressing this through a renewed effort to communicate with the public. The Autogas industry in a number of countries has already undertaken mass media publicity campaigns to highlight the wide-ranging social, economic and environmental benefits of Autogas, particularly to the end consumer.
- **Strengthen ties with car manufacturers in order to develop engines that are more conducive to the use of Autogas.** Most of the leading car companies have developed factory-fitted Autogas versions of their best-selling models, which generally perform at least as well as their gasoline-powered equivalents.
- **Continue to ensure that Autogas supply worldwide matches demand.** This will entail stepping up investment in maintaining and expanding the LPG and Autogas supply chain.
- **Continue to develop filling station networks in accordance with projected needs.** The coverage of filling stations is sufficient in most countries where an established Autogas market exists, but further investment will be needed in areas and countries where the network is less dense and where demand is poised to grow strongly.
- **Promote and facilitate the training and certification of Autogas kit installers.** There are currently a number of national schemes which aim to guarantee the quality of retrofit of Autogas vehicles (see next page).

“Long-term fuel tax measures – in the form of a low rate of excise duty or its complete exemption – to ensure that the price of Autogas at the pump is well below that of gasoline and diesel is the single most important policy incentive.”

WHAT POLICY MAKERS NEED TO DO

The role of the government in giving an initial strong impetus to the simultaneous development of Autogas demand and supply infrastructure in collaboration with all stakeholders is vital. Financial incentives are critical, notably those directed at the fuel itself. They can also be directed at vehicles that are able to use Autogas or fuel suppliers to encourage investment in the distribution and refuelling network by offering tax breaks, for example.

Long-term fuel tax measures to ensure that the price of Autogas at the pump is well below that of gasoline and diesel is the single most important policy incentive. In practice, the Autogas price must be no more than 50-60% of that of the other fuels. Those measures can take the form of a lower rate of excise duty (and/or sales tax) or its complete exemption. The lower the rates of duty and tax relative to other fuels, the bigger the financial incentive to switch. Since differences in excise duty show up in prices at the pump, the measure is highly visible, raising public awareness of the potential cost savings from using Autogas. Reducing the tax on Autogas would inevitably lead to a fall in overall tax revenues from transport fuels, albeit small in modest cases. But this could be offset by a modest increase in the rate of tax on gasoline and diesel. In any case, any fall in revenue would be compensated by lower health costs resulting from the improvements in air quality associated with more Autogas use. This measure can be reinforced by incentives for Autogas vehicles, such as a grant or tax credit, to compensate for the higher cost of buying an OEM vehicle or the cost of converting an existing conventional fuel vehicle.

Other measures, including mandates for public and private fleets to switch to alternative fuels and traffic regulations, can also be highly effective in boosting the use of Autogas. Mandates have been the main driver of switching to alternative fuels in the United States. Many countries promote Autogas and other alternative fuels through traffic-control regulations; for example, AFVs may be granted exemptions from city or highway-driving restrictions, such as those imposed during periods of severe pollution. They may also be exempt from on-street parking charges and road-pricing schemes. Government can also facilitate the development of coherent standards, in partnership with industry, covering vehicle conversions, refuelling facilities and health and safety aspects of alternative fuel supply and use, in addition to supporting the research, development, demonstration and deployment of alternative-fuel technology. Campaigns in countries focusing on high-profile Autogas vehicles can help create a positive perception. Spain has a fleet of driving-school vehicles running on Autogas to give young drivers the confidence to use the fuel. In the United States there is a large fleet of school buses that run on Autogas that help to promote the safety message.

Technical and safety standards are another important area of responsibility for governments in partnership with LPG suppliers, vehicle converters and OEMs. Fuel providers and end users need to be reassured that the transportation, handling and storage of Autogas pose no safety risks. It is essential for the authorities to lay down and enforce harmonised operating standards for aspects of both Autogas distribution and vehicle equipment, including installation. Poor-quality conversions can undermine engine and emission performance and jeopardise sustainable development of the market. But the drafting and implementation of safety regulations specific to Autogas need to be based on an objective assessment of risk. In certain countries, regulations still limit unnecessarily access and parking of Autogas vehicles, the siting of refuelling stations and the on-site location of dispensers. Studies have shown that many of these restrictions are unjustified.

There is no single model or approach to formulating and implementing a government programme of incentives to promote the development of a sustainable Autogas market. The appropriate strategy for each country depends on specific national circumstances. These include budgetary considerations, which might limit available funds for subsidies, the seriousness of local pollution problems, fuel-supply and cost issues, the stage of development of the Autogas market and the prevailing barriers to fuel switching, including restrictive regulations and the local availability of dedicated vehicles and cost of vehicle conversions.

Policy stability and a strong, long-term commitment by the government to achieving environmental-policy objectives are crucial to success in promoting the development of alternative-fuel markets. Stakeholders need to be given clear advance warning of any major shift in policy. Without policy stability, coherence and consistency, neither fuel suppliers, nor OEMs nor consumers will be confident that they will be able to make a reasonable return on the investments required to switch fuels.

In light of the above, the WLPGA, in consultation with its members, has drawn up the following set of recommendations for policy makers:

- **Establish a wider and complementary role for all alternative fuels within the transport fuel mix, taking a technology-neutral approach so as to allow all alternatives to compete fairly.** This will ensure that the environmental benefits of Autogas are delivered at least cost.
- **Recognise officially the status of Autogas as a clean alternative fuel and seek long-term policy stability and consistency across policy areas to provide a long-term commitment to Autogas.** This will give confidence to OEMs, fuel suppliers and consumers.
- **Establish emission standards on a WTW basis that takes account of emissions along the fuel supply chain, not just at the tailpipe.** WTW emissions from Autogas vehicles are generally lower than from vehicles powered by conventional fuels and, in some cases, alternative fuels too. This approach will also be useful to assess EVs on a level playing field, particularly where power generation in the country is based on coal or fuel oil.
- **Adopt measures aimed at guiding consumers toward cleaner technology such as Autogas and communicate the benefits of alternative fuels.** They may take the form of regular communications, such as websites, newsletters and advertising campaigns, to inform the public and to indicate how to apply for subsidies where available.
- **Introduce mandates for government fleets to acquire Autogas vehicles and fuelling systems so that government can take a leadership role in protecting the environment and reducing operating costs.**
- **Continue to apply a low excise duty on Autogas to reflect its lower environmental impact compared with conventional fuels.** As a rule, the tax on Autogas needs to be in the range 50-60% of conventional fuels. If the price of Autogas is too low, it will attract unlicensed operators and illegal activities.
- **Introduce or step up grants or tax credits for equipping OEM vehicles with an Autogas system and converting existing vehicles to Autogas.** This has the effect of reducing the payback period and drawing attention to the benefits of switching.
- **Adopt traffic measures that encourage Autogas and other low emission vehicles.** These include exemptions from congestion charges, free parking for alternative fuel vehicles, access to high-occupancy lanes and restrictions on access to town centres during peak pollution periods for polluting vehicles.
- **Address pollution from the existing fleet of old, "dirty" cars by encouraging their replacement with new, clean Autogas vehicles or their retrofitting with Autogas fuel systems.** Conversion of existing vehicles is often a highly cost-effective means of achieving rapid improvements in air quality.

HOW OTHER STAKEHOLDERS NEED TO CONTRIBUTE

Other stakeholders, including OEMs and equipment installers, can also contribute to the continuing growth of a dynamic and sustainable Autogas market. OEMs will need to keep investing in the development of Autogas fuel-system technologies to improve their performance. For example, recent work on direct injection Autogas engines, has yielded tremendous improvements in environmental performance. OEMs also need to actively promote Autogas versions of their vehicle models – both right- and left-hand drive. It is particularly important that they provide a full warranty and after-sales support and service for vehicles that are converted to Autogas after leaving the factory, prior to their initial sale.

The installers of Autogas conversion kits need to ensure that they make use of state-of-the-art components and guarantee the quality of installations. They need to employ staff that are both knowledgeable and well-trained, and able to advise motorists on the most appropriate fuel system to install and safety aspects (WLPGA, 2018).

ANNEX 1:

AUTOGAS MARKET DATA

Autogas consumption, vehicle fleet and retail sites in leading countries

	Consumption (thousand tonnes)		Vehicle fleet (thousands)		Retail sites	
	2016	2017	2016	2017	2016	2017
Australia	532	411	360	300	2 500	2 000
Bulgaria	396	405	500	505	2 900	2 800
Canada	242	247	53	54	2 200	2 250
China	990	1 007	165	168	550	560
Czech Republic	99	94	185	180	1 100	1 200
France	72	64	210	198	1 670	1 610
Germany	400	385	448	421	7 034	7 100
Greece	260	268	290	300	860	880
India	346	399	2 250	2 320	1 250	1 300
Italy	1 696	1 675	2 211	2 309	3 913	3 979
Japan	1 002	728	221	200	1 440	1 406
Korea	3 515	3 314	2 185	2 122	2 031	2 037
Lithuania	114	106	100	95	390	379
Mexico	1 278	1 101	430	420	2 150	2 150
Netherlands	169	148	144	133	1 650	1 550
Poland	1 790	1 915	2 977	3 082	5 390	6 287
Portugal	36	36	55	55	355	370
Russia	3 000	3 100	3 000	3 000	4 900	4 900
Serbia	148	135	200	185	700	650
Spain	47	51	62	65	1 000	1 050
Thailand	1 466	1 320	1 150	1 065	1 550	1 450
Turkey	3 142	3 116	4 440	4 617	10 426	10 297
Ukraine	1 385	1 503	2 250	2 500	3 500	3 800
United Kingdom	71	68	120	120	1 250	1 250
United States	625	689	147	155	3 700	3 800
Rest of the world	4 327	4 550	2 419	2 567	12 398	13 212
Total World	**27 148**	**26 835**	**26 571**	**27 136**	**76 807**	**78 267**

Sources: : WLPGA/Argus Media (2018).

ANNEX 2:

REFERENCES

EAFO (European Alternative Fuels Observatory) (2017), The transition to a Zero Emission Vehicles fleet for cars in the EU by 2050, EAFO, Brussels.

European Commission – DG Mobility and Transport (2014), Update of the Handbook on External Costs of Transport, EC, Brussels

GFEI (Global Fuel Economy Initiative) (2017), International comparison of light-duty vehicle fuel economy 2005-2015: Ten years of fuel economy benchmarking, OECD/IEA, Paris.

IEA (International Energy Agency) (2018a), Global EV Outlook, OECD/IEA, Paris.

— (2018b), The Future of Petrochemicals, OECD/IEA, Paris.

— (2017a), Energy Technology Perspectives, OECD/IEA, Paris.

— (2017b), World Energy Outlook 2017, OECD/IEA, Paris.

World LPG Association (WLPGA) (2018), Guide to new Autogas markets, WLPGA, Paris.

World LPG Association (WLPGA)/Argus Media (2018), Statistical Review of Global LPG 2017, WLPGA/Argus Media, Paris/London.

World LPG Association (WLPGA)/Liquid Gas Europe (2018), Autogas Incentive Policies, WLPGA/Liquid Gas Europe, Paris.

WLPGA

WLPGA
182, avenue Charles de Gaulle
92200 Neuilly-sur-Seine, France
Tel: +33 1 78 99 13 30

association@wlpga.org
www.wlpga.org

LPG
EXCEPTIONAL ENERGY