LPG and the Global Energy Transition

A study on behalf of the World LPG Association

WLPGA

The World LPG Association

The World LPG Association was established in 1987 in Dublin, Ireland under the initial name of the World LPG Forum.

The World LPG Association 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 (ECOSOC) in 1989.

The World LPG Association exists to provide representation of LPG use through leadership of the industry worldwide.

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Summary

Liquefied petroleum gas (LPG) is set to play an increasingly important role as a “bridging fuel” alongside natural gas in the long-term transition to a truly sustainable global energy system. There is no doubt that the way we produce and use energy will eventually need to change profoundly. In part, because the bulk of the energy that we use today comes from finite and non-renewable fossil-energy resources, even if they are still so large as to be able support rising production for many more years to come. But mainly because the environmental harm wrought by our current energy mix – notably changes in global climate – threatens to become too great, long before fossil resources run out. The challenge is to set in motion a profound shift to low-carbon energy sources and technologies, while at the same time satisfying the growing energy needs of an expanding world economy and population – especially the billions of people in the developing world who are still deprived of access to modern energy services.

As a fossil fuel, LPG would appear to have no significant part to play in the low-carbon energy system of the future. Yet the specific characteristics of the fuel and its advantages over other fuels – fossil and non-fossil – mean that it is remarkably well-placed to help reconcile the world’s environmental, economic and social goals during the long period that it will take to complete that energy transition. The world will still need to use LPG and other fossil sources of energy to bridge the several decades that will be needed for competitively-priced low-carbon alternatives to be developed and commercialised on a large scale around the world. The pace of the transition will also be constrained by the generally very slow rate of turnover of energy-related capital stock – both the equipment that uses energy and that involved in supplying it – and by the sheer scale of investment needed in new infrastructure.

The impending transition to low-carbon energy will need to involve an intermediate shift to the lowest-carbon fossil sources of energy as well as a move to non-fossil energy in order to achieve the fastest possible reduction in CO2 emissions at least cost. LPG is close to natural gas as the least carbon-intensive fuel, so replacing coal – the most carbon-intensive – and heavier oil products with LPG and natural gas can generate big reductions in greenhouse gas emissions. Indeed, LPG can provide a natural stepping stone to the use of natural gas in places that currently lack gas-distribution infrastructure. The supply of LPG will, in any case, grow with rising gas production as LPG is largely a by-product of natural gas processing. In addition, the use of LPG can help mitigate deforestation – a major cause of global warming – as well as reduce indoor and outdoor air pollution: LPG produces virtually no soot and, relative to most other non-renewable fuels, low emissions of carbon monoxide, unburned hydrocarbons and nitrogen oxides – the principal precursors of ozone, which produces smog.

Providing modern energy to the billions of people in poor countries who are still forced to rely on dirty and inefficient traditional fuels and kerosene remains a major challenge. Expanding household use of LPG – a clean, efficient and practical fuel for cooking and heating – in those countries can make a major contribution to eradicating energy poverty, bringing considerable health, developmental and environmental benefits.

Government policies will be crucial to the pace and nature of the energy transition. Energy and climate plans need to be affordable, cost-effective and compatible with and supportive of national development goals. In the developing countries, there is a strong case for targeted policies to facilitate the expanded use of LPG by households in developing regions through actions both within and outside the LPG sector, in order to establish a virtuous circle of growing demand, increased investment and expanded availability of the fuel.

Chapter One

What is the Global Energy Transition?

The way mankind currently produces and uses energy is without doubt unsustainable in the long term. In part, because the bulk of the energy that we use today comes from finite and non-renewable fossil-energy resources, even if they are still so large as to be able support rising production for many more years to come. But mainly because the environmental harm – notably changes in global climate – caused by our current energy mix threatens to become too great, long before fossil resources run out. On current trends, rising consumption of fossil fuels would almost certainly drive up average global temperatures by several degrees before the end of the current century, resulting in catastrophic shifts in climatic patterns with potentially extremely costly effects on economic activity and the well-being of mankind. The challenge is to achieve a truly sustainable, low-carbon energy system while at the same time satisfying the growing energy needs of an expanding world economy and population – especially the billions of people in the developing world who are still deprived of access to modern energy services.

The energy system has always undergone constant change. That change has been largely market-driven, generally occurring in a very gradual fashion over periods of decades in response to the development and adoption of new technologies, and the emergence of new markets for energy, relative fuel prices and the usefulness of particular fuels. The oil shocks of the 1970s brought up, for the first time, the notion of proactively initiating an energy transition away from oil in pursuit of more secure and affordable energy supplies. Interest in and debate about the form and timing of that transition has grown considerably since then with the growing recognition of the threat posed by climate change and concern that the current energy system will not be capable of meeting the rapidly growing energy needs of the emerging economies. How successful we are in effecting a fundamental and rapid transformation of energy supply and use will have far-reaching and profound consequences not just the energy industry itself, but the entire world population.

What will that transition look like? As with past changes in the energy system, it will undoubtedly be a gradual process that will unfold over several decades: a "transition" is, by its very nature, not an abrupt change from one "reality" to another but rather a shift that unfolds generationally over considerable time (WEF, 2013). The need to initiate change is urgent, but the considerable time lags inherent in the development of new technologies and their commercialisation, and barriers to investment in new sources of energy and more efficient and cleaner ways of using traditional fuels will continue to constrain the pace of change. The transition will eventually have to involve wholesale decarbonisation of the energy system. But that does not necessarily require suddenly replacing fossil-technologies with zero-carbon ones: the transition can – and most likely will – involve an intermediate shift towards the least-carbon-intensive fuels: LPG and natural gas. Guessing which low- or zero-carbon technologies will eventually prevail is a risky enterprise. One or more technologies may eventually dominate at the global level, but in the medium term – say, the next 10 to 30 years – at least, a diverse range of technologies look set to come to the fore based on current patterns of investment and trends in deployment (IEA, 2014a). Among those technologies, those based on renewable energy sources are likely to be most successful over that period and probably in the longer term too – in the absence of technological breakthroughs in nuclear fusion and/or carbon capture and storage (CCS).

Public policy will be the primary driver of both the pace and character of the energy transition. Decisions about investment in energy supply infrastructure and consumer behaviour are influenced by a raft of external factors, including economic and demographic change, supply costs, market prices and technology; government interventions in many different forms can have a strong influence over all of these factors. The common goal of energy policies everywhere is to ensure secure supplies of modern energy to support economic growth and prosperity, while safeguarding the environment. Ultimately, the approach to achieving these aims must involve a strong emphasis on encouraging technological innovation and deployment, even though the impact will not be felt for many years.

The implications of the global energy transition for LPG are complex. As a fossil fuel, albeit a relatively clean one, it would appear to have no significant part to play in the decarbonised energy system of the future. Yet the specific characteristics of the fuel and advantages over other fuels – fossil and non-fossil – mean that it is exceptionally well-placed to act as a "bridging" fuel alongside natural gas, holding down the economic cost of the required long-term shift away from fossil fuels, minimising environmental impacts in the medium term and helping to satisfy immediate energy needs, notably in the developing world.

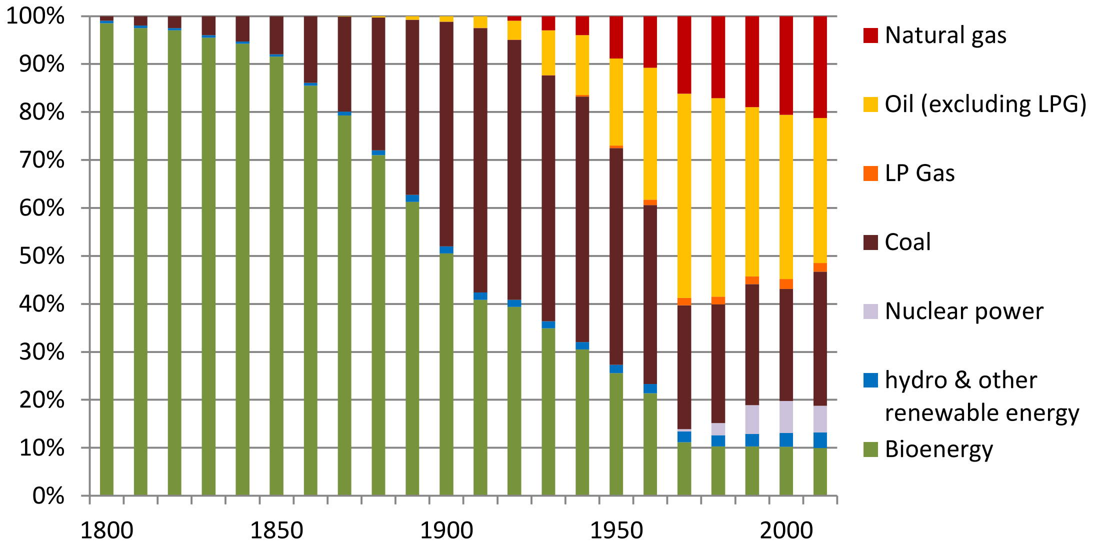
Chapter Two

A Brief History of Energy

The impending energy transition will be one of a series that have occurred during the modern era. Several major transitions have occurred since the 18th century. Before the industrial revolution, which got underway in Great Britain in about 1760, almost all the energy used worldwide came from wood and other forms of biomass (Figure 1). The take-off of manufacturing industry, based almost entirely on coal, initiated the first modern energy transition. Coal use grew rapidly through the 19th century and the early part of the 20th as industrial development spread throughout Europe, North America and the Far East. The only other major source of energy during this period was hydroelectricity generated mostly from small water mills and dams.

The next major energy revolution was oil. Though commercial oil production had begun in the mid-19th century, it was only at the beginning of the 20th century that the use of oil started to become more widespread, rapidly taking market share from coal in industry and power generation, and powering the boom in motorised road transportation. Natural gas emerged a little later, initially in the United States. The use of LPG from oil refining and increasingly from natural gas processing as a separate fuel gradually became more widespread, reaching about 1.5% of global energy use by the beginning of the 1970s and 2% today (equal to roughly 6% of total oil use).

Figure 1: Share of fuels in world primary energy use, 1800-2010



Source: Smil (2010); International Energy Agency databases; Menecon Consulting analysis.

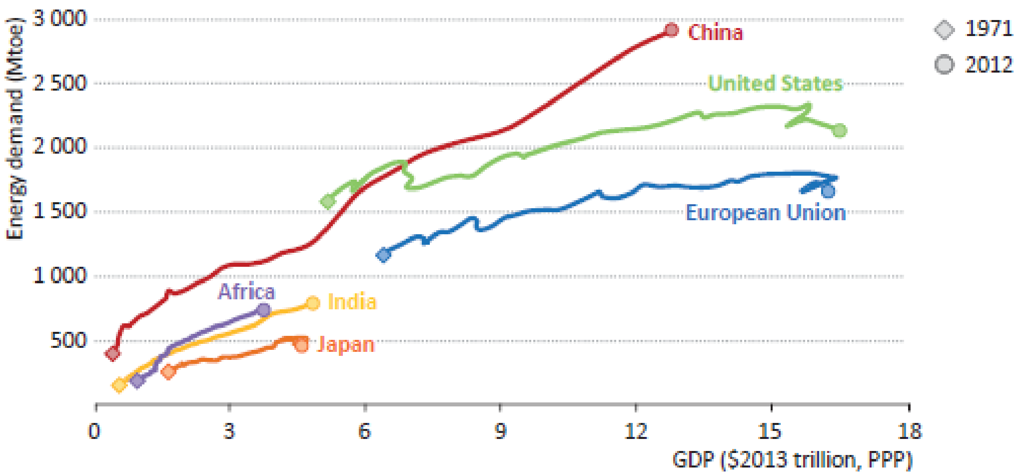
The use of oil as a whole has continued to grow since the price shocks of the 1970s, but more slowly; as a result, it has lost overall market share as other sources of energy have expanded more rapidly, notably nuclear power – especially in the 1970s and 1980s – and, more recently, modern renewables, particularly biofuels, solar and wind energy.

Renewables have been getting a lot cheaper of late with technological advances and scaling up. The result today is a more diversified energy mix than ever before.

Yet, unnoticed by many, coal has been making a comeback since the turn of the century: the consumption of coal actually grew far more than that of any fuel between 2000 and 2013 – more than twice the growth in that of natural gas and almost ten times that of renewables taken as a whole. This has been the result of rapid economic growth in China, India and other emerging economies, which has boosted demand for cheap, locally-sourced coal in industry and power generation. Worldwide, fossil fuels combined still account for over four-fifths of primary energy use, a share that is little changed from three decades ago.

Understanding the drivers of energy demand and fuel choice is crucial to responding effectively to the challenge of the next energy transition. The energy mix is strongly influenced by the overall demand for energy and the types of energy services demanded. Historically, economic activity has always been the principal driver of demand for each type of energy service, including mobility, electrical services and stationary uses of energy for generating heat and cooling. The result is that, in all major regions, overall energy demand has tended to grow in parallel with gross domestic product (GDP), though typically at a lower rate – especially in the most advanced economies, where saturation effects curb income-driven increases in demand (Figure 2). For example, between 1990 and 2012, world primary energy demand increased by 0.6% each year on average for every percentage point of GDP growth (expressed in real purchasing power parity [PPP] terms) (IEA, 2014b). GDP growth, in turn, is influenced by a host of factors, including population, the stage of economic development, resource endowment and the general business and investment climate. And the way in which GDP grows – that is, the types of goods and services demanded and the ways in which those demands are met – also impacts the types and amounts of energy needed. Energy demand is also affected by the effective prices of different fuels paid by consumers, including any taxes, subsidies and pollution or carbon penalties, as well as technological factors, such as the energy efficiency of appliances, mechanical equipment and vehicles.

Figure 2: Total primary energy demand and GDP in selected countries, 1971-2012



Note:Mtoe = million tonnes of oil equivalent.
Source: IEA (2014b).

In general, the actual choice of fuel used to provide an energy services in a particular location is determined largely by relative prices and practical considerations. Some types of energy services are more easily provided by certain fuels; for example, gasoline, diesel and LPG are currently the most practical and affordable fuels for road transport, though natural gas and electricity can, in principle, be used as alternatives. The growing importance of electricity in meeting energy needs has boosted demand for energy inputs to power generation more than any major sector in recent decades, which has underpinned growth in demand for coal, often the cheapest generating option, as well as nuclear power, natural gas and, more recently, renewables.

Chapter Three

How LPG Contributes to Meeting Current Global Energy Needs

LPG currently plays a small but increasingly important role in meeting the world's energy needs. LPG is the abbreviated name for liquefied petroleum gas – the generic name for mixtures of light hydrocarbons, predominantly propane and butane, that change from a gaseous to liquid state when compressed at moderate pressure or chilled. LPG is derived either as a by-product from crude oil refining (39% of world production in 2013) or extracted from natural gas or oil production streams; the share of LPG coming from gas processing has been growing for many years, as output of natural gas has grown faster than that of oil. With both processes, LPG must be separated out or removed from the oil product or natural gas streams.

LPG is generally liquefied for bulk storage and transportation, because its density is much higher as a liquid. LPG is normally refrigerated for shipment by sea and storage of large volumes at receiving terminals; smaller volumes are generally stored in pressurised vessels. LPG has a high-energy content on a per tonne basis (in a liquid state) compared to traditional fuels and most other oil products and burns readily in the presence of air giving off a hot flame.

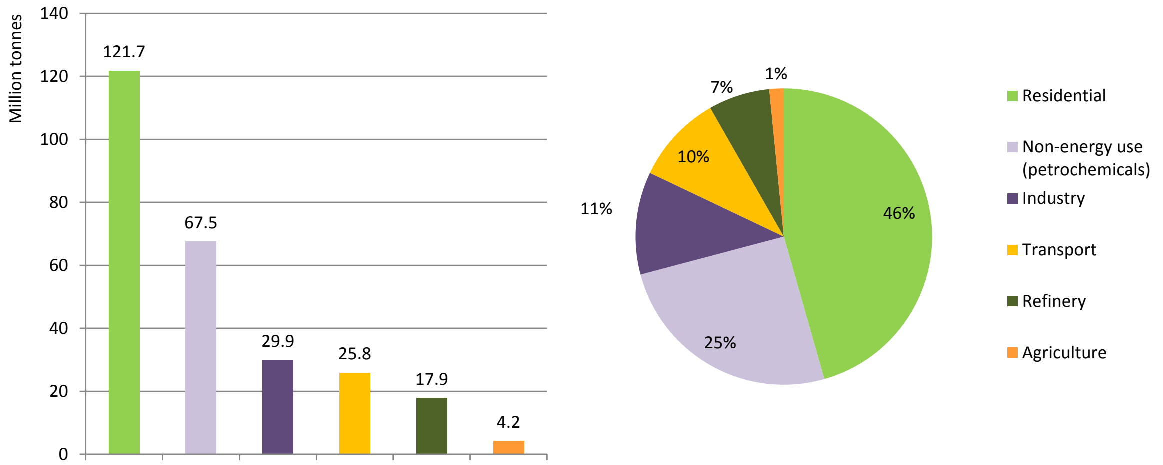
LPG is a highly versatile energy source which can be used in a wide range of applications, from water and space heating, to cooking and to use as an alternative transport fuel. LPG is used in all the major energy end-use sectors:

- Residential sector: LPG is well suited for cooking, and space and water heating. In some developing countries, it is also used for lighting where electricity is not available. In developed countries, it may be used for outdoor activities such as barbecues and camping.
- Agriculture: LPG is used to increase the production and the quality of farm products through weed flaming, crop harvesting and crop drying. It is also used to heat breeding houses for pigs and poultry and power farm equipment such as irrigation pump engines.
- Commercial sector: Applications include commercial cooking (restaurants and small and large-scale catering), and water and space heating in offices and other commercial premises.
- Industry: LPG is used in a wide range of industrial processes and activities, notably where a high degree of precision and flexibility in process temperatures – as well as a strong flame – are required. Common applications include heat treatment furnaces, direct firing of ceramic kilns, glass working, textile and paper processing, and paint drying. LPG can also be used as back-up fuel for electricity generators, including hybrid renewable energy systems in remote locations.
- Transport: LPG is increasingly used as a low-emission alternative to gasoline and diesel for taxis, buses and private cars.

LPG is also used as a feedstock in the petrochemical industry, as an alternative to ethane, naphtha and middle distillates in the production of ethylene, the main bulk petrochemical intermediate product used in the manufacturing of a wide range of plastics and specialist chemicals. It is also widely used as an aerosol propellant and refrigerant.

Worldwide, consumption of LPG amounted to 267 million tonnes in 2013 (Figure 3). The residential sector is by far the biggest user, accounting for close to half of all the LPG used, including for petrochemicals. Residential LPG use is highest in regions and areas where it is not economic to supply natural gas, because of the distance from and, therefore, high cost of linking up with the pipeline network (remote towns and villages) or because of low density of population (rural areas). Petrochemicals are the second-largest consuming sector, accounting for a quarter of total world LPG consumption. The transport and industrial sectors absorb the rest.

Figure 3: World final energy consumption of LPG by sector, 2013



* Including non-specified other final consumption.
Source: Menecon Consulting analysis; WLPGA/Argus Media (2014).

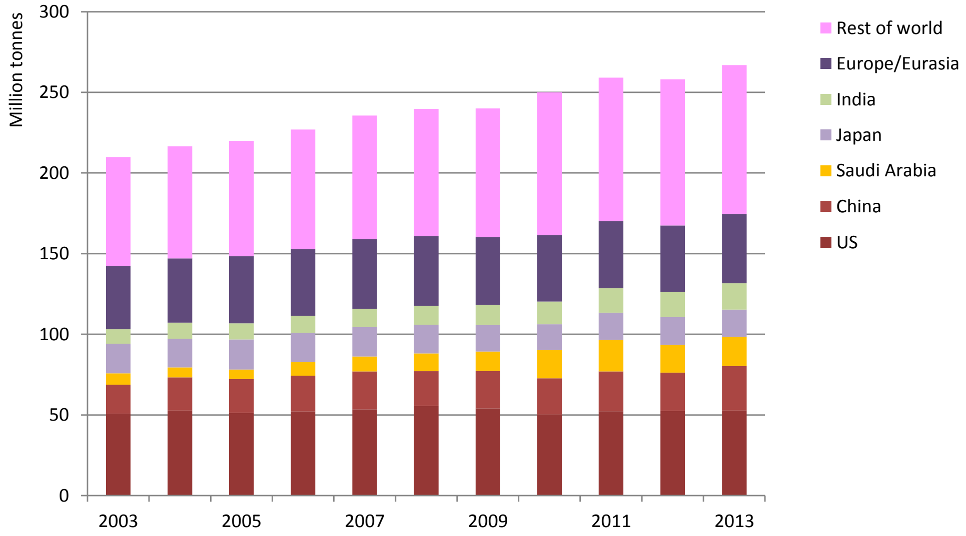
LPG consumption has been growing steadily in recent years, at a faster rate than that of oil generally. This is largely down to strong growth in supply from gas-processing plants and the increased price-competitiveness of the fuel. The LPG market as a whole is essentially supply-driven, as production is primarily determined by oil-refinery throughput and flows to upstream gas-processing plants. The United States remains far and away the largest market, but demand has generally grown faster in the emerging economies, notably China and the rest of Asia (Figure 4).

Chapter Four

Why we Need to Transform Energy Supply and Use

The primary and most urgent rationale for the impending energy transition is the environment. The development of energy systems everywhere is being increasingly affected by a variety of environmental concerns. Until quite recently, the over-riding issue was air pollution at the indoor, local and regional levels, but much more emphasis is now being given to global climate change caused by emissions of greenhouse gases, two-thirds of which are generated by the burning of fossil energy. It is now widely recognised that the development of the energy sector and the planet's environment and climate are inextricably linked. It follows that energy policies, and broader economic and social policies, need to be fully integrated into environmental policies.

Figure 4: World final energy consumption of LPG by country/region, 2003-2013



Source: WLPGA/Argus Media (2014).

Air pollution in most parts of the world is caused almost exclusively by the burning of fossil fuels and biomass (from energy use and forest fires). Pollutants are emitted along the entire chain of energy supply, from upstream emissions during fossil fuel extraction and production to end-use emissions from burning coal, oil, gas and biomass for transport, heating, cooking, and industrial and commercial activities. The principal air pollutants are soot or particulate matter (PM), ozone, nitrogen oxides (NOx), which contribute to the formation of surface ozone, sulphur dioxide (SO2), carbon monoxide (CO), organic compounds (unburned hydrocarbons), metals and a range of compounds, such as benzene, known collectively as "air toxics".

These compounds have a range of harmful environmental impacts. Worldwide, indoor air pollution – primarily PM – from burning solid fuels is probably the biggest environmental problem associated with energy use today. Around 2.7 billion people across the developing world still rely on solid fuels – traditional biomass (wood, charcoal,

agricultural residues and animal waste) or coal – for cooking on primitive stoves or open fires, mainly in rural areas, where access to affordable modern energy is most restricted (IEA, 2014b).
Often, cooking stoves are highly inefficient and the rooms where they are used poorly ventilated. Biomass and coal smoke contains thousands of health-damaging substances, of which small soot particles of less than 10 microns in diameter (PM10), are among the most dangerous, as they penetrate deep into the lungs and are an important factor in the development of acute lower respiratory disease, chronic obstructive pulmonary disease, cancers and other illnesses.

Exposure to indoor air pollution from cooking with solid fuels causes the premature deaths of an estimated 4.3 million people annually from pneumonia, chronic lung disease and lung cancer, as well as ill-health and the loss of productivity among millions more (WHO, 2014). In fact, indoor smoke from solid fuels is one of the leading causes of avoidable deaths and ill-health worldwide (WHO, 2012). The majority of the people affected are women and children, as women are usually responsible for cooking and small children often remain close to their mothers (WLPGA, 2012), though more deaths occur among the male population due to other underlying factors (WHO, 2014). The estimated number of deaths from indoor pollution has recently been revised upwards sharply, reflecting the inclusion of additional health outcomes such as cerebrovascular diseases, ischaemic heart disease and non-communicable diseases.

Urban air pollution is the other main direct cause of health problems. It is estimated that more than one billion people are exposed to significant levels of air pollution, leading to up to one million premature deaths and one million pre-native deaths annually[1]. The resulting economic cost is put at approximately 2% of GDP in developed countries and 5% in developing countries. Rapid urbanisation has resulted in worsening urban air pollution in major cities, notably in China and other Asian countries. Pollution comes from both mobile sources – cars, trucks and buses – and stationary sources, such as factories, power stations and commercial and residential buildings. In most cities in the developing world, the overwhelming bulk of pollution comes from road transport – the result of a large number of older vehicles coupled with poor vehicle maintenance, inadequate infrastructure and poor fuel quality.

The effects of urban air pollution can extend well beyond the towns and cities where the pollution emanates. PM emissions can pollute the air over vast territories, sometimes augmented by accidental forest fires and forest clearings – a major problem in recent years in Indonesia and Brazil. Acid rain caused by emissions of SO2 and NOx, which react with the water molecules in the atmosphere to produce acids, can also occur far from the sources of those emissions, partly because tall smokestacks aimed at reducing local pollution release the gases into regional atmospheric circulation. For example, emissions from coal-fired power stations in Denmark used to be a major contributor to high levels of acidity in rainwater in the United Kingdom. Mountainous regions tend to be most affected, as rainfall there tends to be higher. Acid rain can have catastrophic effects on eco-systems, as well as causing serious damage to buildings, historic monuments and statues. Since the problem came to light in the 1960s, action has been taken to address the problem in most developed countries, notably in the United States and Europe, leading to major reductions in emissions. But elsewhere, the problem has generally worsened as a result of rapid population growth and industrialisation, and has become more widespread. China and other Asian countries are particularly badly affected.

Consciousness of the problem of indoor and outdoor air pollution continues to rise, bringing hope that the problem can be brought under control within a reasonable timeframe without necessarily curbing the use of fossil fuels. But the technological solutions that currently exist to control emissions, especially of local and regional pollutants, are costly and will take time to take effect. Emerging “clean” technologies, including renewables, and those based on natural gas and LPG may prove to be a better medium to long-term solution. Tackling climate change will surely be much harder than dealing with air pollution, as it will require nothing short of a fundamental transformation in energy supply and use across the planet.

[1] http://www.unep.org/urban_environment/Issues/urban_air.asp

Worries about the impact of burning fossil fuels on the global climate have grown enormously over the last two decades as the science has advanced and evidence of climate change has started to become apparent. According to the latest Assessment Report of the International Panel on Climate Change (IPCC), the fifth in the series, the global average temperature of land and ocean surface has already increased by 0.85°C since 1880 and it is extremely likely that human influence has been the dominant cause of this observed warming since the mid-20th century (IPCC, 2014). The evidence of human influence on global climate has grown since the previous Assessment Report was released in 2008. It is predicted that higher temperatures will lead to, among other things, more frequent and more intense extreme weather events. In September 2014, the World Meteorological Organization reported that the concentration of CO2 in the atmosphere reached 142% of the pre-industrial era and that radiative forcing – the warming effect on our climate – had increased by 34% since 1990, due to long-lived greenhouse gases, such as CO2[2].

The IPCC points the finger of blame for climate change firmly at rising man-made greenhouse gas emissions, mainly from fossil-energy use. According to the International Energy Agency (IEA), global energy-related emissions of CO2 – the leading greenhouse gas – reached 31.6 gigatonnes (Gt) in 2012, an increase of around 400 million tonnes (or 1.2%) over 2011 and 10.7 Gt (51%) over 1990. At present, coal, the most carbon-intensive fuel, contributes 44% of total emissions, oil 36% and natural gas – the least carbon-intensive – the remaining 20%. LPG accounts for just 1.8% of total emissions. Those from coal have grown more in absolute terms than from either of the other two fuels over the past decade. Overall CO2 emissions fell back in the United States and Europe in 2012 on the back of weak economic growth and stagnant energy demand, but continued to grow strongly in most of the rest of the world: China's emissions jumped by 3.1% and India's by 6.8%, largely due to surging use of coal for power generation. However, preliminary data for the last two years suggest that global emissions may have levelled off: emissions rose by a more moderate 2.2% in 2013 and were apparently flat in 2014, marking the first time in 40 years in which there was a halt or reduction in emissions of the greenhouse gas that was not tied to an economic downturn[3]. The IEA attributes the halt in emissions growth to changing patterns of energy consumption in China and OECD countries. In China, 2014 saw greater generation of electricity from renewable sources, such as hydropower, solar and wind, and less burning of coal, while in the OECD, recent efforts to promote greater energy efficiency and more renewable energy are at last helping to decouple economic growth from greenhouse gas emissions.

Future trends in greenhouse gas emissions and their impact on global temperature and climate hinge critically on government actions to encourage or force changes in energy supply and use. Many governments have already adopted or proposed policies to achieve this, directly or indirectly, usually aimed at fuel switching, improving energy efficiency or promoting technological solutions such as CCS. Yet these measures, even if they are fully implemented, are collectively unlikely to be sufficient to ensure that the globally agreed target of limiting the temperature increase to two degrees Celsius. The IEA, for example, projects an increase of 20% in global energy-related CO2 emissions between 2012 and 2040 and, extrapolating beyond that period, a corresponding increase in the greenhouse gas concentration in the atmosphere from around 400 parts per million of carbon-dioxide equivalent (ppm CO2-eq) today to over 700 ppm in 2100; this would be expected to lead to a long-term global temperature increase of 3.6°C, compared with pre-industrial levels (IEA, 2014b)[4]. Emissions and temperature increases could be even higher if irreversible changes in the climate system, such as slowly melting permafrost, that are not yet factored into models prove to be significant.

With up to 4°C warming, severe and widespread changes are expected in human and natural systems, including extinction of a large number of species of flora and fauna and large risks to global and regional food security (IPCC, 2014).

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[2] http://www.wmo.int/pages/mediacentre/press_releases/pr_1002_en.html

[3] http://www.iea.org/newsroomandevents/news/2015/march/global-energy-related-emissions-of-carbon-dioxide-stalled-in-2014.html?utm_source=Alumni+-+IEA+Newsletter&utm_campaign=dad2d3d6c9-IEA_Monthly_Newsletter_March2015&utm_medium=email&utm_term=0_2195c94e8b-dad2d3d6c9-107334649

[4] The US Energy Information Administration (EIA), the other leading public source of world energy projections, projects a rise of 46% in emissions between 2010 and 2040 taking into account only those policies that have already been adopted.

Achieving the 2°C objective requires urgent action now to steer the energy system onto a lower emissions trajectory, involving a peak within the next few years and a rapid decline over the following decades.
Scarcity is the other main issue that has dominated energy debate for the past few decades and another rationale for shifting away from fossil fuels. Yet fears about whether the planet's fossil-energy resources will be sufficient to meet the world's rising energy needs over the coming decades have receded of late with rapid and largely unexpected developments in technology that have suddenly opened up vast new deposits of what are termed unconventional oil and gas, including those situated in shale rock. In the space of little more than a decade, shale gas and shale oil (more correctly termed light, tight oil) have emerged as important new sources of energy supply, undermining claims that the world is facing an imminent peak in production of oil and gas.

Remaining economically recoverable coal resources are even larger, representing around 2,900 years of production at current rates (IEA, 2014b). These developments, which have contributed to the recent sharp drop in international energy prices, have rendered far less urgent the need for a shift away from fossil energy for reasons of scarcity. However, the new sources of fossil energy are likely to prove more expensive to develop than conventional resources, requiring higher prices to make them viable in the longer term. This is expected to encourage the development of alternative sources of energy, as well as energy conservation and efficiency.

Energy poverty provides a further rationale for changing the way energy services are provided. Household access to modern energy is vital to achieving a range of social and economic goals relating to poverty, health, education, equality and environmental sustainability. At present, about 1.3 billion people – almost a fifth of all of the people in the world – have no access to electricity and about 2.7 billion, or 40%, rely almost exclusively on the traditional use of solid biomass for cooking (IEA, 2014b). The overwhelming majority of these people live in sub-Saharan Africa and developing Asia, largely in rural areas. Reducing this energy poverty calls for both an increase in income and a fall in the costs of providing modern energy services, to make them more affordable. Income will surely rise with continued economic development across these regions, but not quickly enough to solve the problem within a generation: IEA projections suggest that, on current trends, the electricity-deprived will still number almost one billion in 2030 and those dependent on traditional fuels close to 2.5 million (30%), barely fewer than today (IEA, 2013).

Chapter Five

How LPG can Contribute to Reducing Environmental Impacts

LPG will continue to contribute to minimising the environmental impact of energy use during the current period of transition to a low-carbon energy future. A century from now, it is plausible that fossil fuels – including LPG – will have been all but removed from the fuel mix, replaced primarily, if not entirely, by a range of renewable technologies. But in the intervening period, the world will still need to use LPG and other fossil sources of energy as bridging fuels to allow time for cost-effective low-carbon alternatives to be developed and commercialised around the world. The transition to low-carbon energy will undoubtedly involve an intermediate shift to the lowest-carbon fossil sources of energy as well as a move to non-fossil energy in order to achieve the fastest possible reduction in CO2 emissions at least cost. LPG is close to natural gas as the least carbon-intensive fuel, so replacing coal and heavier oil products with LPG and natural gas can generate big reductions in greenhouse gas emissions; the supply of LPG will, in any case, grow with rising gas production as LPG is a by-product of natural gas processing. In this sense, LPG and natural gas can be seen as complementary fuels. In addition, the use of LPG can bring other environmental benefits, including greatly reduced indoor and outdoor pollution, and can help mitigate deforestation – a major cause of global warming.

LPG is a low-carbon fossil fuel. On a full fuel-cycle or "well-to-wheels basis", taking account of the emissions that occur in the production and distribution of energy as well as its final use, LPG emits barely more CO2 or other greenhouse gas emissions than natural gas, and beats all other types of liquid oil products and coal across a range of different uses. The emissions associated with the final use of different types of fossil fuel depend not just on the inherent carbon intensity of each fuel but also on the efficiency with which the fuel is used to provide a given amount of useful output, such as kilometres driven or litres of water heated. In general, lighter hydrocarbons – those with fewer carbon atoms per molecule – release less CO2 during combustion than heavier hydrocarbons. The carbon intensity of LPG is slightly higher than that of natural gas but is lower than that of all the other major oil products and is considerably lower than of coal. But the amount of fuel consumed to achieve a comparable amount of useful output, i.e. the efficiency of energy conversion, also matters. As LPG is a relatively clean-burning fuel, efficiency tends to be higher than for most other fossil fuels. For example, a recent study of 18 different types of cook stove in widespread use in developing countries found that LPG stoves were the most efficient with the sole exception of the parabolic solar cooker (Aprovecho Research Center, 2011). Coal-based stoves, even where the efficiency is as good as that of an LPG stove, give off around 50% more CO2; allowing for differences in stove efficiency, emissions are often twice as high.

LPG also results in fewer emissions than biomass-based fuels that are produced unsustainably. Most biomass cook stoves are very inefficient, because of the incomplete burning of the fuel and poor heat transmission, leading to excessive emissions of CO2 and other greenhouse gases such as methane and nitrogen oxides. When biomass is produced in a sustainable manner, the CO2 emitted in combustion are entirely offset by the CO2 absorbed by the biomass grown to replace it. However, in reality, much of the biomass used in poor developing countries is not replaced, so net emissions are positive.

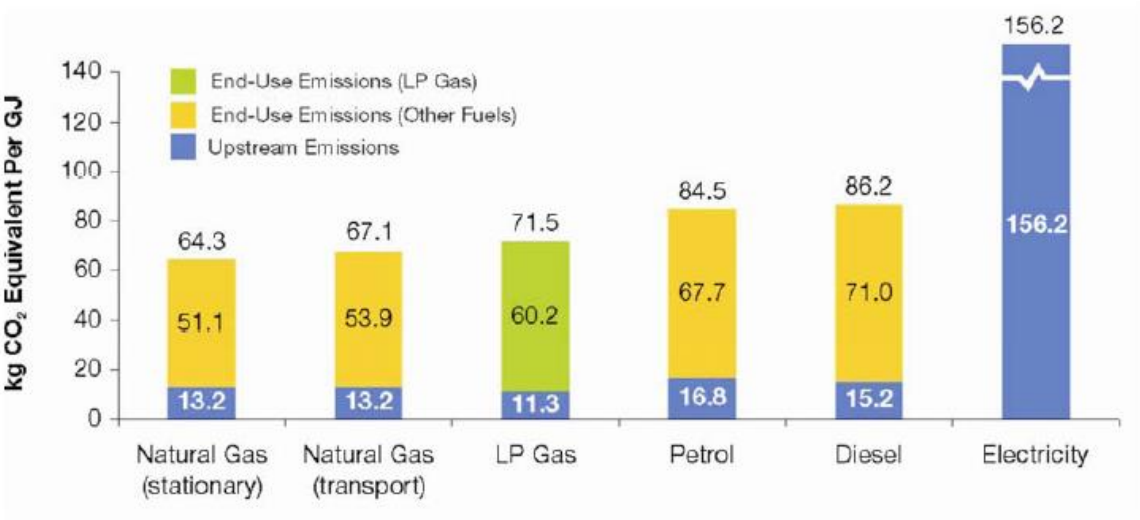
In addition, in the case of charcoal, emissions arise not only from its eventual use as a cooking fuel in the household, but also from the initial preparation of charcoal, a process which generates high levels of methane and other products of incomplete combustion (Hutton et al., 2006). Wood-burning stoves also five off much higher emissions of black carbon – another major contributor to global warming (WLPGA, 2010). As well as reducing carbon sinks and causing global warming, deforestation due to the unsustainable use of firewood and charcoal use can lead to soil erosion, desertification, and, in hilly areas, landslides. Reducing deforestation through switching to LPG can also improve agricultural productivity: animal dung and agricultural residues are often used as low-grade cooking fuel rather than natural soil fertilizer in poor countries. Removing these sources of nutrients interrupts the normal composting process and, in the absence of any chemical fertilizers, degrades the quality of the soil, ultimately reducing farm productivity. Reducing the use of such fuels, therefore, helps to reduce the need to buy chemical fertilizers, boost productivity and enhance food security (WHO, 2006).

Other greenhouses gases are emitted when fossil fuels are burned because of incomplete combustion. While the quantities are very small compared with CO2, their global warming potentials are a lot higher. For example, methane (natural gas) has a potential 25 times higher than CO2 and nitrous oxide 298 times higher. These emissions also tend to be significantly lower for LPG than for other fuels. For example, emissions of NOx – the most important of the regulated toxic gases – from LPG used in light-duty vehicles (Autogas) are less than half those from gasoline and a tiny fraction of those from diesel, especially for vehicles that meet the most recent emission standards and for driving short distances (WLPGA, 2014)[5]. In addition, LPG is not a greenhouse gas when released into the air as it is primarily a combination of propane and butane molecules. LPG vapour does not persist in the atmosphere if released accidentally, as it is quickly removed by natural oxidation in the presence of sunlight or by precipitation before it can become well-mixed with other molecules in the air and have any impact on the climate (IPCC TAR 2001). Fugitive emissions of natural gas (methane), whether from leaky pipelines or deliberate venting, are a particularly significant cause of global warming. For example, methane accounted for about 9% of all US greenhouse gas emissions from human activities, much of it from gas production and transportation[6].

A number of studies have been conducted to compare full fuel-cycle greenhouse gas emissions from different fuels used in various end-use applications, though few of them include LPG. One study carried out on behalf of the WLPGA quantifies emissions for LPG and other competing energy sources, including natural gas, petrol, diesel, ethanol and electricity, in five end-use applications in seven regions (WLPGA, 2007). Overall, emissions from LPG on average across the regions per energy output were found to be marginally higher than those from natural gas, 15-17% lower than those from petrol and diesel, and less than half those from electricity (Figure 5). The emissions advantage over other fuels calculated on the basis of the useful energy service provided were generally even bigger, due to the higher efficiency of LPG appliances and equipment.

Figure 5: World average greenhouse gas emissions per energy provided by fuel

Source: WLPGA (2007).



[5] Based on data compiled principally from the results of the European Emissions Test Programme (EETP) completed in 2004, the most recent major comparative study of LDV emissions in Europe.
[6] http://epa.gov/climatechange/ghgemissions/gases/ch4.html

The results of that study clearly demonstrate that LPG is among the most attractive energy options for minimising emissions:

- Cooking: LPG has among the lowest greenhouse gas emissions of any fuel sources for cooking in many regions of the world. In India, for example, LPG emits 60% less than electric-coil stoves, 50% less than some biomass stoves and 19% less than kerosene stoves.
- Distributed power generation: LPG emits less than diesel in power generation in every region and for every size of turbine. In regions that rely heavily on liquefied natural gas (LNG), such as Japan and Korea, LPG also has lower emissions than natural gas.
- Light-duty vehicles: Overall, emissions per 100 km driven were lower for LPG than for any of the other fuels analysed. They were lower than for petrol and diesel in almost every region and 12% lower than corn-based ethanol (E85) in North America. In Japan, LPG emissions were 30% lower than for petrol and 33% lower than for diesel.
- Residential space heating: In Europe, LPG emits on average 15% less than fuel oil, while the advantage over electricity is even more dramatic: 30% less emissions in South America, 35% less in Japan, 38% less in Korea and up to 54% less in North America.
- Residential water heating: LPG is also among the most attractive fuels for heating water. An LPG instant water heater with electronic ignition offers 14% less emissions than an electric storage heater in South America, more than 35% less in North America and more than 50% less in India. Switching from fuel oil to LPG cuts emissions by 15% in Japan. Pumped solar water heating with an LPG instant water heater back-up offers the best combination of low emissions and reliability of any of the hot water supply system assessed.

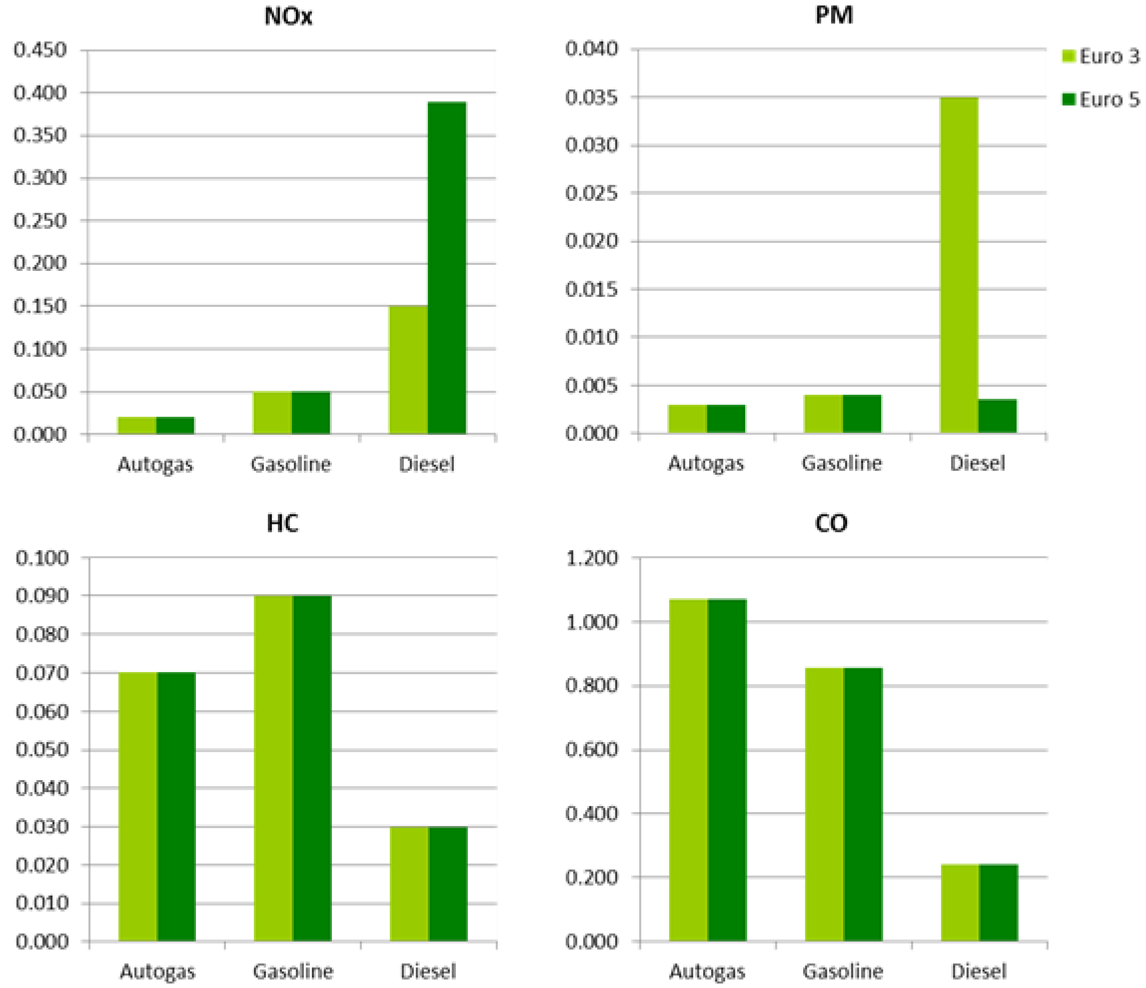
There are also important broader environmental benefits of switching to LPG from traditional fuels and most other fossil fuels. LPG produces virtually no PM and, relative to most other non-renewable fuels, low emissions of CO, unburned hydrocarbons and NOx. There are negligible emissions of toxic gases that can cause serious health problems if breathed in close to the point of combustion, which makes LPG highly suitable for cooking and as a transport fuel. Because LPG is transported and stored in sealed cylinders, there are virtually no evaporative emissions; even if it is released accidentally, LPG usually evaporates quickly and disperses into the atmosphere with little risk of igniting unless trapped in a confined space. This is a significant advantage compared to kerosene, a popular household fuel in many countries and one of the principal causes of destruction of property and deaths by fire in urban areas.

LPG used as a transport fuel (Autogas) to replace gasoline or diesel in both light and heavy-duty vehicles can make an important contribution to improving air quality in towns and cities. Data compiled principally from the results of the European Emissions Test Programme (EETP) completed in 2004, the most recent major comparative study of light-duty vehicle (LDV) emissions, show that emissions of NOx from Autogas are much lower than from gasoline and diesel, especially for Euro-5 compliant vehicles (Figure 6). 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. But the key environmental advantage of Autogas over gasoline and, especially diesel, is the near-absence of PM emissions. The importance of this factor has increased greatly with the announcement on 12 June 2012 by the International Agency for Research on Cancer (IARC) – part of the World Health Organization (WHO) – that diesel-engine exhaust causes cancer. It claims that diesel fumes could potentially be as big a public health threat as second-hand smoke, increasing the chances of lung cancer and bladder cancer[7]. Although Autogas performs less well than diesel and gasoline with respect to CO emissions, and less well on emissions of unburned hydrocarbons with respect to diesel, the differences on a well-to-wheels basis do not influence significantly the overall comparison of the environmental impact of the different fuels.

[7] http://www.iarc.fr/en/media-centre/pr/2012/pdfs/pr213_E.pdf

A more recent study by Atlantic Consulting reinforces the overall findings of the EETP. The Atlantic Consulting study draws on a database of actual test data of cars and vans that are available for sale in Germany compiled by Germany's Federal Agency for Motor Transport (Atlantic Consulting, 2014). The study finds that Autogas-fuelled vehicles emit less NOx and non-methane hydrocarbons, though slightly more CO and methane than equivalent gasoline-fuelled vehicles. Gasoline vehicles also emit some PM, whereas Autogas vehicles emit virtually none at all. Diesel vehicles emit about one-third less CO and hydrocarbons than Autogas, but five times as much NOx – in addition to significant amounts of PM. It also finds that vehicles running on natural gas emits about three to four times more methane and about 50% more CO. Cars running on ethanol (E85) emits more of all pollutants, but 7% less NOx.

Figure 6: Regulated emissions from light-duty vehicles by fuel (g/km)



Note: Euro-5 results are based on vehicles equipped with diesel particulate filters; NO_x emissions for Euro-5 vehicles were adjusted to reflect current vehicle tehnology. Average emissions of the other pollutants were already low for Euro-3 vehicles, so were not adjusted.
Source: WLPGA (2009).

The benefits of switching to Autogas in heavy-duty vehicles (HDVs) are even bigger than those for LDVs. Almost all HDVs in use today around the world are diesel-fuelled. The main environmental advantage of Autogas over diesel for HDVs relates to emissions of PM and NOx, which are significantly lower – especially for older vehicles. A 2009 WLPGA report, which compiled data on emissions drawing on the results of comprehensive series of test programmes commissioned by the Australian government and carried out over the period 2000-2005, finds that Autogas beats diesel on all the regulated emissions except hydrocarbons.

Another way in which LPG can reduce environmental impacts is by complementing renewables-based technologies for generating heat and electricity and for cooling that would otherwise not be economically viable or practical. There is considerable interest at present in developing LPG hybrid technologies, especially for applications located in places not served by the natural gas or electricity network, to take advantage of the fuel's versatility and its easy-handling, high-efficiency, low-carbon and clean-burning characteristics.

LPG hybrids hold particular promise in three areas (WLPGA, 2011):

- Heat pumps: LPG can provide the supplemental energy boost that conventional (compression) heat-pumps typically need in colder climates, as well as directly firing sorption heat-pumps[8], which are increasingly attractive for heating and for cooling as well. Heat pumps and solar thermal systems capture energy from the outside environment and use that to supply indoor heat and sometimes cooling; they work in a similar way to ordinary refrigerators, using latent energy to transfer warmth from a source to a sink.
- Solar heating: In particularly sunny regions, domestic water heating can be "hybridised" to include solar power alongside LPG. In principle, it can be as simple as adding a water tank to the roof of a building that uses solar energy to heat the water. Solar systems need a back-up heat source for unfavourable weather conditions (a lack of sunshine or cold weather, when more heat is needed). An auxiliary LPG boiler can plug the gap at these times.
- Photovoltaic power generation: PV is emerging as a major source of renewable electricity: a record amount of PV capacity – 39 GW – was commissioned worldwide in 2013, and for less money than the smaller 2012 total of 31 GW thanks to a sharp fall in the cost of PV panels (FS-UNEP/BNEF, 2014). PV is becoming a particularly attractive option for providing electricity in remote, off-grid locations to rural communities, telecommunication facilities and pipelines. But PV systems still need a back-up for non-sunny hours, as storing power in batteries is still prohibitively expensive. LPG-fired generators are an obvious solution.

[8] Sorption heat pumps use that absorption or adsorption rather than mechanical force to drive the condensation-evaporation cycle. The refrigerant is condensed by absorption (to water) or adsorption (to a solid, usually a zeolite), and evaporated by heat, which can be conveniently provided by LPG in conjunction with solar power in a hybrid system.

Chapter Six

How LPG can Alleviate Energy Poverty

Providing modern energy to the billions of people in poor countries who are still forced to rely on dirty and inefficient traditional fuels and kerosene remains a major challenge (Box 1). Switching to LPG – a clean burning, efficient, safe and practical household fuel for cooking and water heating – can make a major contribution to eradicating energy poverty, bringing considerable health, developmental and environmental benefits. The physical properties of LPG enable significant amounts of energy to be transported easily as a liquid under moderate pressure in specially designed bottles. This portability makes it particularly suitable for applications in remote locations that cannot economically be supplied with natural gas via a pipeline network. Its high calorific value in liquid form reduces transportation costs and makes it easier to handle than other oil-based fuels, wood and coal. For example, a 13-kilogramme bottle provides around 180 kWh of energy; 25kg of coal and 91kg of wood would be needed for the same amount of energy. In use, LPG shares similar advantages as natural gas and electricity. Because it is a clean-burning fuel, it can be used in direct contact with food with no risk of contamination, unlike kerosene or traditional fuels, as well as fragile articles such as ceramics. Households recognise these advantages and are usually prepared to pay a premium for LPG over other fuels – if they can afford it and if the fuel is physically available.

Box 1: The Sustainable Energy for All and Cooking For Life initiatives

In recognition of that central role that access to LPG and other forms of modern energy services plays in helping developing countries alleviate poverty and achieve their development objectives, including the Millennium Development Goals, the Secretary-General of the United Nations, Ban Ki-moon, launched in 2010 Sustainable Energy for All – a global initiative aimed at achieving universal energy access, improving energy efficiency and increasing the use of renewable energy[9]. It was launched to coincide with the designation of 2012 as the International Year of Sustainable Energy for All. The initiative seeks to stimulate action by governments, international development agencies, non-governmental organisations (NGOs) and the private sector. Within the framework of this initiative, the WLPGA launched in 2012 the Cooking For Life initiative[10] – a five-year campaign to help bring LPG to the billions of people in the developing world whose health and safety are threatened daily from cooking with solid fuels and whose prospects of a better life are being held back by lack of access to modern cooking fuels. The campaign convenes governments, public health officials, the energy industry and global NGOs to seek practical ways of expand access to LPG.

A long-term transition away from solid fuels and towards modern forms of energy for cooking, including kerosene, LPG, natural gas, biogas and electricity, has been underway for decades with rising incomes and improved access to modern commercial energy services across the developing world.

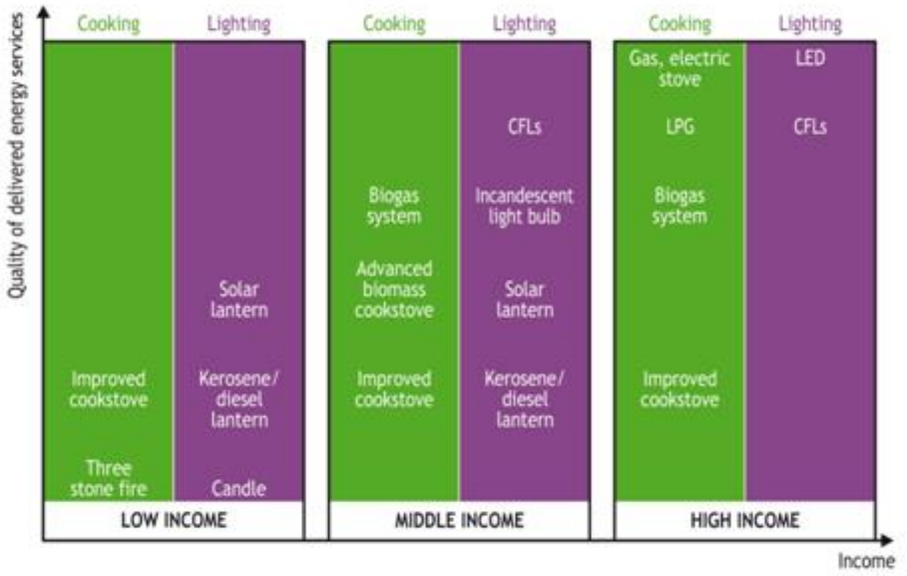
In some cases, supportive government action, including direct fuel subsidies, have helped to accelerate this process.

[9] http://www.se4all.org/
[10] http://www.cooking-for-life.org/

At the initial stage in this process, there is a shift from wood, straw and dung to charcoal and intermediate modern fuels such as kerosene and coal, as well as the deployment of more efficient biomass-stoves. As incomes rise further, the use of advanced modern fuels, including LPG, expands.
Growing concerns over the environmental impact of energy use are also helping to drive a shift towards renewable energy technologies, such as biogas and wind and solar power for local power generation, although they remain in most cases more expensive than fossil-fuel-based technologies.

In reality, the household energy transition is not a simple “ladder”, with households moving up from one fuel to another, because households use a combination of fuels and technologies at all income levels (Figure 7). In most countries, most energy is provided by modern fuels at per capita household incomes of more than US$ 4,000, though some richer households may persist in using solid fuels or kerosene (Kojima, 2011). Where natural gas becomes available through the establishment of local distribution networks as the economy matures, LPG may itself be displaced to a large degree by natural gas. However, LPG often remains the main fuel for residential cooking (and heating) in areas remote from the natural gas grid and may be preferred by some households even where natural gas is available. In most developing countries, the distribution of natural gas to residential customers is unlikely to become widespread for many years, if ever. The initial stage of switching from traditional fuels or kerosene to LPG in developing countries typically involves the use of a cylinder attached to a simple burner. As familiarity with LPG grows and incomes rise, the user may install a modern cooker inside the home, possibly with the gas supplied by rubber pipe from a cylinder placed outdoors or in a separate room.

Figure 7: Quality and means of providing household energy services by income level



Notes: CFL is compact fluorescent light bulb; LED is light-emitting diode. Improved cookstoves have higher efficiency than cooking over a three-stone fire, but emissions are not reduced considerably, while advanced biomass cookstoves have equivalent efficiency and emissions reductions as liquid-fuel, gas and electric stoves. The indicator of the quality of delivered energy services on the vertical axis is designed to capture a variety of dimensions, including cleanliness, efficiency and affordability.
Source: IEA (2010).

The transition to modern fuels is a gradual and uneven process. A complete shift to the patterns of energy use seen in the industrialised countries cannot be achieved overnight. Many households in relatively rich developing countries continue to use large quantities of biomass, especially in rural areas because modern fuels are not available or are too expensive. In the poorest developing countries, widening access to modern fuels is limited by extreme poverty, which keeps these countries in a vicious circle of under-development. Rising incomes will tend to expand access to LPG. Yet among the households that today continue to rely on solid fuels are many who are financially capable of paying the

US$ 15 to 20 a month needed to purchase LPG. Availability of LPG is a crucial factor: if a modern distribution system is not in place, households cannot obtain access to modern fuels, even if they can afford them. Several other factors determine the take-up of LPG, including the prices of other fuels, acquisition costs of LPG cylinders and stoves, fears about safety, unfamiliarity with cooking with LPG, lack of knowledge about the harm caused by smoke from solid fuels burned in traditional stoves (Kojima, 2011; WLPGA, 2005). Cultural preferences can also play a role: in India, for example, even very rich households keep a biomass stove to prepare traditional bread. There are also rural-urban differences in household fuel choice. In rural zones availability of fuels is the main determinant of the actual fuel mix, while in cities consumption patterns are more likely to be affected by relative fuel prices.

Switching to LPG can be sustained by government policies and programmes aimed at improving the affordability, availability and accessibility of the fuel as part of a broad policy of expanding the use of modern fuels generally. Active policy support can catalyse LPG market take-off in areas where availability is poor and establish a virtuous circle of growing market potential, increased investment and expanded availability. Appropriate laws and regulations, adequately enforced, are the single most critical factor in whether widespread access to, and use of, LPG by a country's households and businesses can be achieved in the near and medium term and sustained for the long term (WLPGA, 2013). Indonesia offers a good example of how governments can proactively drive switching to LPG and the benefits that can accrue. In 2007, the Indonesian government undertook a massive programme to convert the majority of households from using heavily subsidised kerosene as their primary cooking fuel to LPG – the most ambitious programme of its kind ever undertaken. The initial goal was to convert 42 million households and small-to-medium businesses nationally, though it was later increased to 54-58 million units (Pertamina/WLPGA, 2012). All citizens meeting the programme requirements had the right to receive the free "initial package", consisting of a 3kg LPG cylinder, a first gas-fill, and a one-burner stove, hose and regulator. The programme proved highly successful: within less than 6 years, Pertamina, the national oil and gas company, had distributed initial packages to almost 54 million households and enterprises. The effect was to withdraw 8.2 million kilolitres of kerosene from the market by 2012, replaced by 3.2 million tonnes of LPG. As that LPG is subsidised much less than kerosene, the government has made a large financial saving, amounting to almost US$ 7 billion in 2012. The government has since raised LPG prices, further reducing the burden of subsidy.

Chapter Seven

What will the Energy Transition Look Like?

Another major energy transition is inevitable. Indeed, it is already underway. But what will that transition involve and what part will LPG play? The simple answer is no-one knows for sure. The uncertainties surrounding the drivers of both economic growth and energy supply and demand are too great for us to be able to predict with confidence what the energy future will look like decades from now. The outlook for technological developments is particularly uncertain. Will nuclear power make a come-back? How soon will emerging renewable technologies become commercially viable without subsidy? Will carbon capture and storage prove the saviour of the fossil-fuel industry? While the future energy landscape is undoubtedly uncertain, it is, however, not completely unpredictable. It is possible to be confident about several broad developments, including the following:

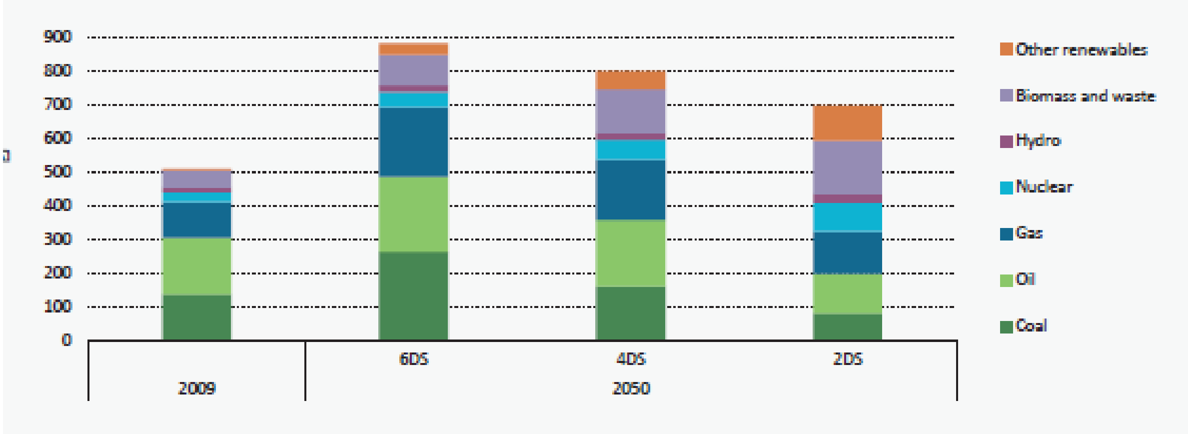
- On the reasonable premise that the world economy continues to expand over the long term, overall demand for energy will most likely to carry on growing, probably in almost linear fashion with incomes. While the efficiency of energy use will almost certainly continue to improve, those gains will most likely not be big enough to offset the underlying increase in demand for energy services – especially mobility and electrical services – that will result from rising population and household incomes, primarily in the emerging economies.
- The transition will be gradual, because it will take time to develop competitively-priced alternatives to fossil fuels. Some renewable technologies are reaching the stage where they are able to compete in the market without subsidy in some cases, but further improvements in operational performance and cost reductions will be needed for them to become competitive on a more widespread basis. Even when they do, they will not replace existing energy technologies overnight, as the rate of turnover of energy-related capital stock – both the equipment that uses energy and that involved in supplying it – is often very slow. Most cars and trucks last at least ten years, while heating and cooling systems and industrial boilers typically have working lives of 15-25 years. Power stations and refineries often last decades. But energy use is also affected by other types of infrastructure, such as buildings, roads, railways and airports, which can remain in use for much longer periods, sometimes centuries. Retiring these assets before the end of their normal lives is usually very costly, though refurbishment can have a significant impact on the types and amounts of energy used in some cases. In addition, the sheer scale of investment required to radically alter the way in which energy is provided is so large, that, even where market conditions and government incentives make investment in low-carbon energy economically viable today, investment in those energy sources will inevitably be spread over many years. Opportunities for investment in low-carbon energy will undoubtedly be much greater in the emerging economies, which will surely account for most of the increase in energy demand.
- Among the three principal fossil fuels, coal, oil and natural gas, the first – the most carbon-intensive – will be most affected initially by the shift towards low-carbon energy and the third – the least carbon-intensive – the least affected. Indeed, demand for LPG and natural gas may, in many cases, actually benefit, at least in the coming years and – depending on the pace the transition – decades to the extent that natural gas replaces coal in power generation and end-use applications, and that gas provides back-up for intermittent renewables. Increased demand for gas would go hand in hand with increased use LPG, which is increasingly sourced from natural gas processing: as natural gas production rises to meet increased demand, LPG supply will rise in parallel. In addition, in some regions, expanded use of LPG could pave the way for the introduction of natural gas, as users gain confidence and experience in using gaseous fuels.

In addition to economic and demographic factors, the prospects for LPG and all other types of energy hinge on energy prices, technological change and government policies, all of which are harder to predict. Clearly, the faster the cost of providing low-carbon energy falls, whether thanks to technological advances or government incentives, the faster the energy transition will occur. Equally, high fossil-energy prices will tend to speed up that process. Despite the recent drop in oil prices, which has dragged down gas and coal prices, most industry observers remain convinced that fossil-fuel prices will tend to rise over the longer term as the cheaper reserves are depleted and producers are obliged to turn to less accessible, higher-cost deposits, including shale, deepwater and arctic resources. But rare are those with a solid track record of forecasting oil prices. Similarly, it is hard to be confident about how determined governments will be to accelerate the transition through rigorous policy action, especially where this involves higher taxes, spending on subsidies or higher energy prices for end users. Worries about industrial competitiveness and household spending power are already affecting government attitudes to the pace of the energy transition given that the upfront costs are proving high in many cases. The climate summit in Paris in December 2015 will be yet another test of international resolve to face up to the challenge. But signing up to a deal to curb greenhouse gas emissions is one thing; it is quite another to follow through with tough measures to ensure that the commitments made in Paris and at subsequent climate meetings are adhered to and target met.

Uncertainty about energy prices, technological developments and government policies translates into uncertainty about how soon emerging low-carbon technologies will be able to compete effectively with existing fuels and technologies. Renewables, especially wind and solar power, have been getting cheaper in recent years – both the result of and the reason for increased investment. But they are still generally more expensive than conventional power-supply options, especially when the additional costs of integrating them into the power grid, including the cost of back-up power, are taken into account. And the supply of wind and solar energy is inherently intermittent: the sun does not always shine and the wind does not always blow. Biofuels for transport also remain relatively expensive, notably those that are derived from non-crop biomass, and often bring only limited if any environmental benefits. Despite some important advances in battery technology, electric vehicles are still struggling to compete because of their high cost and limited range, and carry their own set of environmental problems. The costs of renewables are likely to continue to fall as they become more widely deployed, which will boost their attractiveness to investors and end-users. But the process will surely be a very gradual one.

The usual approach to looking at the long-term future of the energy system is to develop scenarios that make high-level assumptions about prices, technology and/or government policies. The idea is to demonstrate what is required in terms of energy pricing and taxation, technological development and broader public measures to achieve a particular outcome, such as a given reduction in energy-related CO_2 emissions. A prominent example of this approach is the IEA study, Energy Technology Perspectives, which regularly presents a set of long-term scenarios that correspond to different climate change outcomes. The most recent scenarios, published in 2012, involve limiting the global temperature increase to two, four and six degrees. The first corresponds to the internationally agreed goal, the second broadly to the outcome that would be achieved were current government policy commitments to be fully implemented and the third to what would happen if governments do nothing more than what they have already done to address climate change, i.e. a "business-as-usual" case. At the global level, the resulting level of energy demand and the fuel mix are, unsurprisingly, very different: In the 6-degree scenario (6DS), primary energy demand increases by 85% and the share of fossil fuels remains broadly unchanged; the share of renewables remains at about one-tenth (Figure 8). By contrast, demand rises by only 35% in the two-degree scenario (2DS) and the share of fossil fuels drops to 60%, with the share of renewables increasing to well over a third.

Figure 8: World primary energy consumption by ETP climate scenario

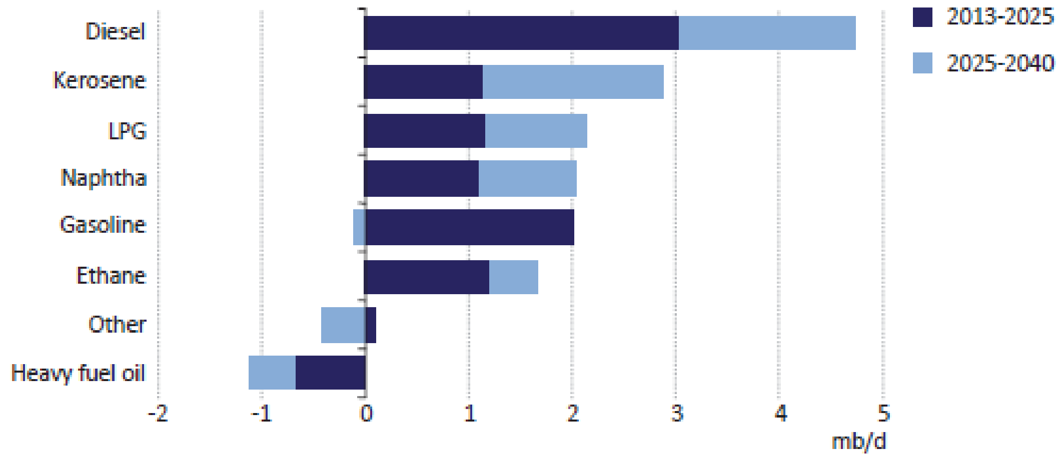


Note: 2DS = two degrees scenario; 3DS = three degrees scenario; 4DS = four degrees scenario.
Source: Energy Technology Perspectives (IEA, 2012).

The clear message that emerges from this analysis is that meeting the two-degree target will call for a lot more renewables and/or nuclear, a lot less fossil energy and a massive effort to use energy more efficiently. But another revealing message is that the overall use of oil and gas need not be much lower, on condition that coal use is greatly reduced. In fact, in the 2DS, the consumption of natural gas actually increases slightly, while oil use falls. This points to LPG more-or-less retaining its overall market share, given that the decline in output from oil refineries would probably be almost entirely offset by an increase in the supply of LPG extracted from natural gas (ETP includes no explicit projections of LPG supply). In the 4DS, which is arguably a more likely outcome given the lack of progress to date in curbing greenhouse gas emissions, oil use actually increases slightly while natural gas consumption grows strongly, pointing to a big increase in LPG use. Of course, in reality, there are an infinite number of combinations of coal, oil and gas that would result in an emissions trajectory consistent with each climate goal. A faster phase-out of coal would make it possible to carry on using larger amounts of LPG as well as other oil products and natural gas for longer. Halting the burning of coal almost entirely would allow for higher LPG use even in meeting the two-degree goal, though consumption would probably need to peak by the early 2030s and be falling steadily by 2050 for that to be happen.

A similar message emerges from the projections of the IEA’s latest World Energy Outlook, which currently provides projections of energy use and production out to 2040, including projections of LPG use in its central scenario (New Policies Scenario) which takes into account both government policies already adopted and commitments yet to be implemented. That scenario is broadly equivalent to the 4DS of the ETP. Overall world LPG demand grows from 7.4 mb/d in 2013 to 9.5 mb/d in 2040, largely due to increased use in transport – consumption doubles from 0.7 mb/d in 2013 – and as a petrochemical feedstock; use in other sectors including industry, residential and services is projected to be either flat or to decline gradually (Figure 9). The pace of demand growth is faster than that of any other product bar kerosene. So, again, even allowing for the possibility that governments may follow through on all their commitments to tackle climate change, LPG demand would still grow over the next two-and-half decades at least.

Figure 9: Projected world oil demand growth by product



Note: Projections from the New Policies Scenario.
Source: World Energy Outlook (IEA, 2014b).

Chapter Eight

Intelligent Policy Making to Support LPG

Government policies will be crucial to the pace and nature of the energy transition. There seems to be a growing determination on the part of governments around the world to step up efforts to curb emissions of greenhouse gases to limit global warming. But this goal has to be reconciled with broader environmental, economic and social objectives. There are potential trade-offs between them: climate policies that lead to higher energy costs can hold back economic growth and the fight against poverty. They may also bring environmental problems of a different kind. For example, hydroelectric facilities can cause enormous damage to eco-systems and wind turbines can disfigure the landscape. Yet some types of climate measure can complement other socioeconomic goals. For example, measures aimed at reducing the use of coal can lower air pollution and, through lower production, can reduce fatalities in coal mining, as well as cutting emissions. Similarly, measures that lead to more natural gas and LPG being used can reduce greenhouse gas emissions, reduce air pollution and help alleviate energy poverty. The aim is to seek to balance the different objectives through policies that are both effective and keep costs to a minimum. For the developing countries, in particular, national climate plans need to be affordable, cost-effective and compatible with and supportive of their national development goals (UNEP, 2012).

In practice, the design of climate policies can involve a number of different approaches, including market-based measures such as taxes and subsidies, regulatory measures, such as energy-efficiency standards, public investment in supply infrastructure, information, awareness and training programmes, and public support for research and development of clean energy technologies. In principle, a strong reliance on the market-based approach can help to minimise the overall economic cost. The provision of energy services should be competitive and, where possible, prices should be set by the market rather than by the public authorities. The structure of taxes on energy should take into account the specific environmental effects of using each fuel, including their emissions of CO2 and other greenhouse gases, as well as noxious and toxic air pollutants. That would undoubtedly favour gaseous fuels over coal and oil in the medium term. Given the benefits of LPG over traditional fuels and kerosene, taxes on LPG in poorer countries should be kept to a minimum so as not to harm its competitiveness and discourage its use. In short, policymakers need to treat LPG in the same way as natural gas. In some cases, subsidies can be an effective approach, where market barriers – including high initial costs when production is starting to scale up – prevent the take-up of specific emerging low-carbon technologies. But they need to be applied carefully, in a targeted and transparent manner, to prevent them from creating unwanted market distortions and becoming too large a burden on the public purse.

There is a strong case for targeted policies to facilitate the expanded use of LPG by households in developing regions through actions both within and outside the LPG sector, in order to establish a virtuous circle of growing demand, increased investment and expanded availability of the fuel. Over time, rising incomes will tend to boost the proportion of poor people using modern fuels such as LPG for cooking in developing countries. Yet that process will remain unacceptably slow unless governments intervene – in part because incomes are held back by the very fact that households do not have access to modern energy. Within the LPG sector, support can take various forms, including measures to make the general regulatory and business environment more favourable to private investment in distribution facilities, “smart” subsidies to the equipment needed to use LPG to make it more affordable while avoiding waste or corruption, and assistance in setting up micro-credit programmes. Outside the sector, the government needs to ensure that the transport infrastructure is built to enable the fuel to be delivered to local communities, including roads that can cope with heavy trucks and adequate port facilities.

Appendix One

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