Supporting businesses in the energy transition

The role of LPG and bioLPG in Europe

WLPGA

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World LPG Association (WLPGA)

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. This report was prepared with analysis and input from Ecuity Consulting LLP, a firm of energy policy experts based in the United Kingdom. We would also like to thank Liquid Gas Europe, Liquid Gas UK, Le Comité Français du Butane et du Propane (CFBP) and Assogasliquidi for their valuable contributions and support.

Contents

Introduction

"Summer 2019 saw record temperatures across Europe and stark warnings from scientists with **climate change** at the forefront of the public's mind. Teenage climate activists are garnering global attention, and the world is seemingly embarrassed by its ongoing oil and coal addiction."

Policymakers across the continent are catching up. The UK and France signed historic net zero emission targets into law during 2019 with other European countries and the EU itself moving in this direction. City leaders are reacting too, not just to greenhouse gases (GHG) but to air pollution with major cities from Madrid to Amsterdam and Paris developing low-emission zones to improve air quality.

These political trends will increasingly impact the competitiveness of energy technologies, products and indeed national economies over the coming years.

Despite the ambition, so much of our economic activity and productivity around the globe still depends on the availability and exploitation of reasonably priced energy. Whilst substitution away from fossil fuels is inevitable, the pace and direction of this change is a significant challenge for organisations operating at the sharp end of the economy. It could of course also provide opportunity.

This report focuses on an area of the economy where access to affordable, flexible and low-carbon fuel is at its most acute. It focuses on agriculture, commercial and industrial businesses located across Europe's vast rural areas. Focusing on companies located off the gas grid, the report demonstrates a cost-effective and low-hassle pathway away from high-carbon fossil fuels such as oil, to lower emission alternatives such as Liquid Petroleum Gas (LPG), and ultimately to renewable fuels such as bioLPG.

Unprecedented change: the energy transition in Europe

Europe's energy system is changing at an unprecedented rate. The energy technologies, fuels and products that underpinned European economies in the 20th century are being phased out an increasing pace. Instead, politicians, businesses and energy companies are looking to a range of new technologies to deliver affordable, secure and sustainable energy in the 21st century.

With wide political support at all levels of government and a thriving global green-tech market, this trend is here to stay. Businesses that understand the direction of travel, and are knowledgeable about the technology trends, will be able to make prudent and profitable investment decisions to help secure their future cost base and stay competitive as Europe's economies decarbonise. Companies that are unaware of these sustainability policy and technology trends and evolve with them over time, are at risk from becoming uncompetitive and potentially even unviable in strong regulatory environments.

But business action on climate change is not only about controlling costs and responding to climate risk, businesses increasingly see value in proactively setting their own targets from a corporate social responsibility (CSR) and ethical marketing perspective. Companies ranging from Coca-Cola to Schneider Electric have made net zero emission pledges over recent years.

Supply chain partners are demanding greater action on climate change as a response to growing interest in sustainability from regulators and their customers.

Indeed, for Europeans, climate change is a serious concern. According to an EU-wide survey published in 2017, more than nine in ten EU citizens (92%) consider climate change to be a serious issue[1]. The last 20 years have witnessed 18 of the warmest years on record, and an increase in the intensity and frequency of extreme weather events. In Europe, this has resulted in severe drought in large parts of Europe, flood events, with Central and Eastern Europe particularly affected, and extreme heatwaves in four of the last five years.

Policymakers are taking note. The impact of unabated action on climate change could have serious negative consequences on both the European and global economy, infrastructure, food production, public health, biodiversity, and political stability. It has been predicted, for example, that by 2100 the yearly damage from river floods in Europe could increase from €5 billion to €112 billion. Around 16% of the present Mediterranean climate zone may become arid[2], and in several Southern European countries outdoor labour productivity may decline by around 10-15% from present-day levels.

In November 2018, the European Commission presented its strategic long-term vision for a prosperous, modern, competitive and climate-neutral by 2050. Responsible for 10% of global GHG emissions, the EU's target of reducing emissions by 80-95% in 2050 (on 1990 levels) has expanded and the EU now aim to transition towards a net-zero GHG economy by 2050.

Transitioning towards a net-zero economy is a long-term trend that will define energy and product markets over the next 30 years. The regulation that is being developed now by European Governments will be in place and its impact will be felt in the near to medium term. Consumers, businesses, supply chains and Governments are all likely to be concerned by the change but motivated to conserve the planet and its resources.

This report provides a timely overview of the energy options that commercial, agricultural and industrial consumers have in three representative European markets. The challenge for businesses is to understand what the energy transition means for their

[1] *Special Eurobarometer (459) on climate change – European Commission*
[2] *Going climate-neutral by 2050 – European Commission*

existing business model. They will need to quickly understand how the transition could impact demand for their products and services and assess the potential opportunities from this transition to create new value by diversifying energy sources and transitioning to lower emission fuels that have a long-term role in Europe's energy mix.

Businesses with premises located off the gas grid could be targeted first by these changes. As typical consumers of the highest carbon fuels – such as heating oil and coal – these companies will be required to switch away from existing energy sources, to lower emission alternatives. Policymakers are targeting the highest carbon fuels first and developing policies to encourage switching today.

This report shows that this transition can be delivered cost-effectively for businesses which operate off the gas grid, and with minimal disruption. Many of these commercial and industrial companies use heating oil and coal to power their processes and provide heat to buildings. Switching fuels to LPG in the immediate-term, and progressively to bioLPG as a direct replacement fuel which can be used in existing appliances provides an easy, and often cost-effective route to deep emission reductions.

Reducing off-gas grid emissions

For industrial, agricultural and commercial businesses that fuel their processes, space heating and vehicles with oil or coal, switching to LPG can present an immediate win. LPG is a lower-carbon alternative to oil and coal, with an emission intensity approximately 20%[3] and 30-40% lower respectively. As well as lowering carbon emissions, LPG can improve local air pollution since it is a clean burning fuel that produces almost zero particulate matter (PM) when combusted.

LPG is a gaseous fuel, but it is often stored under pressure that turns it into a liquid. This makes it very easy to transport and to store, an advantage over other lower emission energy options. The fuel has therefore been used widely by businesses who value its flexibility and ease of use in a variety of processes and across urban and remote, rural areas.

Rural and intermediate areas account for 90% of the European Union's territory and are often located away from the natural gas-grid and at the extremities of the electricity grid. For commercial business (or industrial plants) that are situated in rural areas, switching to LPG can be economical and convenient due to its versatility and portability, and as such it is accessible to even the most remote parts of a region. This report includes several specific industry case studies which show the economic and environmental value of fuel switching away from heating oil to LPG.

Developing a robust LPG market can provide a platform to sustainably transition to bioLPG, a chemically indistinct yet renewable form of conventional LPG. BioLPG is increasingly coming to market across Europe as a direct renewable replacement for LPG in growing volumes, with several of the largest companies having defined 100% renewable targets. BioLPG has a carbon intensity that is around 70-80% lower than oil and can be used in existing LPG appliances and storage units, allowing for a cost-effective pathway to decarbonisation for industrial and commercial businesses.

> More than nine in ten EU citizens consider climate change to be a **serious issue**.

[3]*Greenhouse gas reporting: conversion factors 2019 - BEIS*

Business benefits from fuel switching

This report presents several reasons why industrial, agricultural and commercial businesses are currently taking the initiative to switch away from heating oil and coal to LPG – and bioLPG:

Cleaning the air

Europe has an air quality problem. Concentrations of particulate matter (PM) are thought to have been responsible for over 391,000 premature deaths across EU28 countries in 2015[4]. Nations, cities and towns are failing to meet European and World Health Organisation (WHO) standards, and as a result many commentators consider air quality to be Europe's biggest environmental risk.

Governments are responding with tighter standards and regulations, targeting air pollution generated from the combustion of fuel in vehicles, and stationary appliances – such as boilers. A range of European directives including Ecodesign, the Medium Combustion Plant Directive (MCPD) and the Industrial Emissions Directive (IED) are already acting to improve environmental standards of boilers and generators. This trend towards lower emission machinery is likely to continue in the future, as several European countries continue to struggle to tackle air pollution and lower measurements beneath EU and WHO guidelines.

Businesses are also taking a lead, acting responsibly to reduce their impact on local air pollution, which can otherwise harm the health of communities and employees. Many are switching to lower emission technologies and fuels to pre-empt tightening environmental standards.

Here LPG and bioLPG can play a role. LPG emits ~84% less Nitrogen Oxide (NOx) than oil and emits almost no particulate matter as it is a clean burning fuel. BioLPG is therefore a clean burning fuel with a negligible impact on air quality, and also a low-carbon alternative to oil and coal with a long-term role in the energy mix.

Operational benefits

Europe has an objective to provide sustainable, secure and affordable energy to every community and citizen. People live in diverse circumstances across the continent, across a variety of geographies and with variable access to infrastructure. Rural areas cover 75% of the EU populated mainland[6], and businesses that are located off the gas grid need secure, dependable and flexible energy resources to power their processes and heat their buildings.

LPG can provide a range of operational benefits for these businesses. The fuel can be easily stored and transported to remote parts of the continent, providing businesses with a flexible and dependable off-grid fuel. Businesses can save on space by installing LPG systems as they typically require less fuel-storage (than biomass for example) and are more compact than an oil boiler. Indeed, LPG storage vessels generally do not require a containment area, unlike oil tanks, and can be sheltered either above or below ground which increases the ease of storing LPG compared to oil.

LPG – and bioLPG a low-emission fuel – can be seamlessly used in existing heating systems, be those gas boilers, combined heat and power (CHP) units or even in renewable hybrid heat pumps. The fuel is compatible with a range of heating technologies and systems, and the transition from LPG to bioLPG is a seamless way to reduce emissions further today or in the future. This can all be delivered by a well-developed supply chain, with experienced installers, retailers and distributors providing businesses with security of supply and excellent service.

[4] *EEA (2018) Air quality in Europe – 2018 report*
[5] *European Commission (2018) Territorial Facts and Trends in the EU Rural Areas within 2015-2030*

Switching to LPG systems today also locks-in a seamless pathway to renewable energy use, as bioLPG can directly replace conventional LPG without any changes needed to equipment or infrastructure. This reduces costs and hassle for businesses by ensuring a smooth transition to renewable energy.
The fuel also has a wide range of use-cases and can be effectively used to meet diverse building and process heat requirements. Particularly for older, hard-to-treat buildings such as historic rural hotels in France, replacing existing oil-powered units with LPG / bioLPG heating systems, proves to be a straightforward way for these businesses to cut emissions. Whereas heat pumps and other low emission technologies might struggle to work effectively in older and less energy efficient buildings, LPG heating systems operate with no issues.

Driving decarbonisation

European Governments have established a set of challenging decarbonisation targets in response to growing climate change concerns. Policymakers will develop specific policies and strategies to enable these targets to be met. At a business level this will mean complying with new regulations. For example, policymakers in several European countries – including France and Belgium – have developed policies to phase out high-carbon fossil fuel heating (coal and oil).

Crucially the LPG industry has a credible pathway to delivering deep emission reductions that are aligned with the long-term direction of policy. This reduces the risk of investing in a technology that could become uneconomic or unviable under tighter regulations. Installing an LPG process or space heating system today ensures a seamless pathway to low emissions through transition to bioLPG which can be used as a direct replacement fuel in existing LPG appliances with no changes required to equipment or infrastructure.

Many businesses are also seeing the value in proactively decarbonising their operations. This report includes an example case study of a Scottish distillery which switches away from using heating oil to bioLPG to reduce emissions. Fuel switching creates business value by allowing companies to market the sustainability of their production process to consumers, creating a point of difference against other brands and additional value for customers. Indeed, consumers are often willing to pay a premium for sustainable or ethical products6. LPG and bioLPG technologies support this process, and for those companies currently using oil and coal off the gas-grid, fuel switching is often the simplest way to lower emissions from their processes, and this report shows it to be a cost-effective move in many situations.

[6]*Dangelico, R, M. & Vocalelli (2017) "Green marketing": An analysis of definitions, strategy steps, and tools through a systemic review of the literature. Available from: https://www.sciencedirect.com/science*

Report Overview

This report focuses on the opportunities for fuel-switching to drive decarbonisation of industrial, agricultural and commercial sectors. As Europe transitions to a climate-neutral economy, the challenge for these businesses is to understand what the transition means for them and their business model.

The report draws out the benefits and value to industrial and commercial business of switching away from oil to LPG – an immediate win in the short- to medium-term. Crucially the LPG industry has a credible path to decarbonisation that is seamless for the consumer. In the longer term switching to bioLPG will take precedent, and the benefits are compared against a range of other renewable heating technologies.

An important feature of this report is that it quantifies the cost to businesses of switching to a range of heating technologies. By performing a levelised cost (LC) analysis, a business manager reading this report can quickly and easily evaluate which heating system is best-suited to their needs – several case studies are considered. In the case studies considered, switching to LPG (in the short term) and bioLPG (in the longer term) proves to be the most cost-effective solution for the businesses covered.

The report outlines the benefit of switching to LPG and bioLPG across three European economies – the UK, France and Italy. Each economy is at different points in terms of their energy transition, mix of fuels in energy generation and their climate ambitions. The benefits of switching to LPG and bioLPG are succinctly described for each of these countries and highlights the versatility of LPG and bioLPG as a fuel source and decarbonisation driver.

United Kingdom

The UK is one of the first major economies in the world to develop a legally binding net zero emissions target. Reaching this target by 2050 will require substantial emission reduction efforts across the UK economy, in a limited timeframe.

Many businesses are proactively switching fuel away from oil to reduce operational emissions. This chapter includes an example of a Scottish distillery that switches to consuming bioLPG, reducing carbon emissions by 81% in the process. Businesses acting sustainably can unlock a number of significant benefits creating brand loyalty, a point of differentiation in a competitive market and the opportunities for premium pricing.

Decarbonisation can be achieved cost-effectively as well. The UK has thousands of rural pubs, restaurants and hotels that utilise high-carbon fuels to provide heating and hot water. Our analysis shows how LPG – and an increasing supply of bioLPG – can support the decarbonisation of sections of the industrial and commercial sector in the UK. In addition, the use of oil for low-temperature industrial processes (e.g. manufacture of vehicles, and the food and drink industry) can be cost-effectively substituted by LPG and bioLPG – delivering lasting emission savings.

The levelised cost of a typical rural pub using an LPG boiler is around 14% lower than an existing, oil boiler. In the longer term, switching to a bioLPG-fuelled system would generate a levelised cost of £86/MWh, this is around 30% lower compared to a biomass boiler and around 13% for a typical in-situ electric heat pump.

Italy

One of the ways in which Italy has looked to reduce GHG emissions, is by encouraging the use and combustion of solid biomass fuel. Whilst the burning of wood as a potentially renewable resource has reduced national carbon dioxide (CO_2) emissions, its combustion has worsened air quality in Italy.

In 2018, air pollution levels exceeded the European Union's (EU) legal limit in more than half of Italy's 107 provincial capitals with most of the breaches taking place in the industrialised North. The industrial and commercial sectors were one of the main sources of particulate (PM2.5 and PM10) and NOx emissions. The European Environment Agency (EEA) estimate that air pollution is responsible for over 81,000 premature deaths in Italy, the most for any European member state.

Regulations such as the MCPD are being developed and enacted to tackle such persistent air quality issues. Businesses need to be aware of this trend away from polluting technologies. For this reason, biomass boilers are shown to be potentially challenging given the high emissions of particulate matter.

Switching oil to conventional LPG represents an immediate win. LPG is a lower-carbon alternative that has desirable chemical properties, a mature and established supply chain in Italy, and is a clean-burning fuel that produces low levels of air pollution. For deeper decarbonisation Italy should look to support the commercialisation and uptake of bioLPG, which is lower than oil in both GHG and air pollutant emissions when combusted.

Switching from oil to LPG would drastically reduce the damage cost associated with carbon emission and air pollution by a sharp reduction (~70-80%) compared to biomass and oil (66%).

France

France recently committed itself to achieving net zero emissions by 2050. This could be a challenge given that fossil fuel consumption in the French energy mix is high and prevalent across a range of sectors.

Any strategy to lower emissions should balance decarbonisation with consumer affordability, comfort and technical feasibility. For example, the upfront cost of an air source heat pump (ASHP) is over three times more expensive than a gas boiler. In an industrial setting, electric heat can be used as a pre-heating function only. Industrial processes requiring high-temperatures (for rolling or smelting) of 2000°C cannot be served by electric heat pumps. In a commercial setting, a heat pump installed in a heritage building would not operate at its claimed efficiency if the building does not have optimal thermal characteristics such as underfloor heating or thermal insulation.

Alternatives are therefore needed. LPG could replace high-carbon fossil fuels (oil and coal) in the industrial, agricultural and commercial sectors and this would represent an immediate win. With an established and mature supply network across France, switching to LPG could be done at little cost and minimal disruption in the industrial and commercial sectors.

LPG and bioLPG is a versatile fuel in a variety of settings. For old commercial buildings, economic analysis shows that the levelised cost of running a bioLPG boiler in an old building with poor thermal characteristics was €64.5/MWh, 4% less than an air-source heat pump and 17% lower than a biomass boiler.

The next 30 years will undoubtedly see radical changes to the way that Europe heats its buildings and powers its industries, as Governments strive to meet to ambitious climate change and air quality targets. The changes required are fundamental and increasingly demanded.

This report demonstrates that cleaner fuels such as LPG and bioLPG can support businesses in reducing emissions and complying with regulations. Particularly for commercial, agricultural and industrial companies that use high-carbon fossil fuels such as oil, LPG and bioLPG deliver lasting emission reductions. This can be achieved cost-effectively whilst supporting brand messaging.

> "The next 30 years will undoubtedly see **radical changes** to the way that Europe heats its buildings and powers it's industries."

Introduction

"France is home to numerous old and historic buildings that have huge cultural value and significance but are difficult to treat and hard-to-decarbonise."

France

Operational benefits: transitioning seamlessly to low-carbon energy use

LPG is the most credible lower-carbon and clean-burning fuel source in rural, off-grid areas. This chapter highlights some of the significant operational benefits that LPG can deliver for businesses and industry in France as they transition from high carbon fossil fuels to lower carbon options.

A key pillar of Europe's energy strategy is to provide each citizen with access to secure, sustainable and cost-effective energy. Rural areas cover 75% of the EU's populated mainland. It can be challenging and costly to supply the communities and businesses that are located in these sparsely populated areas, particularly with low-emission energy.

LPG has several characteristics that make it an excellent fuel for rural, off-grid areas, and bioLPG one of the most credible renewable options. Firstly, it is easy to transport and store. For larger industrial and commercial businesses, LPG can be stored in bulk storage vessels, either above or below ground. Businesses can save space, and the ease of storage supports security of supply for remote communities.

LPG and bioLPG can also be seamlessly used in existing heating systems – including gas boilers and CHP units. This compatibility with existing heating systems can lower investment costs for businesses and support a low-hassle transition from higher carbon fossil fuels, to LPG and Renewable-equivalent bioLPG. In industrial and commercial applications, LPG can also be used in cutting edge and state-of-the-art heating systems such as gas-driven heat pumps and hybrid heat pumps.

Switching to LPG also futureproofs rural businesses from the energy transition. As businesses are required to cut emissions further, in the longer term, a switch to bioLPG (renewable LPG) could be integrated seamlessly. No expensive retrofit or infrastructure changes are required ('lock-in' effect) as bioLPG can simply be used as a 'drop-in' fuel in an already existing LPG boiler.

The fuel also has a wide range of use-cases and can be effectively used to meet diverse building and process heat requirements. LPG can be deployed in old, historic buildings such as heritage buildings and museums. Whereas alternative solutions like heat pumps might struggle. Switching to LPG would also forego the extra cost of additional retrofits (e.g. insulation, larger radiators) in order to create the ideal environment for a heat pump to operate at its claimed efficiency.

The following chapter focuses on France, where these characteristics are particularly valuable. France is home to numerous old and historic buildings that have huge cultural value and significance but are difficult to treat and hard-to-decarbonise. Switching to LPG and bioLPG from heating oil is a straightforward way for businesses such as rural hotels and restaurants to lower their emissions without having to carry out substantial building works.

Additionally, the consumption of high-carbon fuels (oil and coal) is high in rural areas of France. Switching to LPG can enable industrial, commercial and agriculture businesses to reduce their carbon footprint. Developing and expanding the conventional LPG market will ensure that the transition to bioLPG can be undertaken sustainably and cost-effectively.

Opportunities for fuel switching to drive decarbonisation of industrial, commercial and agricultural sectors

To meet France's emission reduction target by 2050, the government has prioritised policies in the Multi Energy Action Plan (PPE), which include phasing out the use of coal and oil boilers. This policy will likely target sectors that are the largest users of coal and oil; the most carbon intensive fuels. These sectors range from large industrial plants, agricultural businesses, restaurants and hotels situated in rural, off-grid areas.

This will require businesses to switch their existing (old and inefficient) coal and oil boilers with lower-carbon alternatives. In doing so, businesses would reduce their carbon footprint (in industrial processes and space heating) and secure their long-term competitiveness as the energy transition in France intensifies.

Switching to LPG, a lower-carbon alternative to coal and oil, would enable businesses to lower their carbon footprint. Switching to LPG would also enable businesses to futureproof against the evolving energy transition as they could sustainably transition to bioLPG (renewable LPG) in the medium-to-longer term. This would help secure long-term competitiveness during the energy transition.

- **For commercial and agricultural businesses** currently using an old coal or oil boiler to provide space heating, switching to an LPG boiler would help decarbonise processes. Combustion of LPG emits 30-40% less carbon dioxide than coal and ~20% less than heating oil.
  In addition to the environmental benefits, installing an LPG boiler could be done quickly and seamlessly as the technology and installation is very similar to a gas boiler.
  A commercial business, in particular, could save on space by installing an LPG boiler as they are more compact than oil boilers. In a restaurant (or a hotel) where space is at a premium, an LPG boiler could be wall-mounted.
  Analysis: It could be cost-effective for an old, historic build (i.e. museum) to replace oil consumption with bioLPG. The levelised cost (LC) of owning and operating a bioLPG boiler is lower than an ASHP and a biomass boiler.

- **In the industrial sector**, coal and oil consumption could be replaced by LPG which would be suitable for processes that require high-temperature direct heating (heat pumps would be unsuitable for these applications). LPG could replace oil for key processes such as melting raw materials in a furnace, extrusion, moulding, forming, pressing and annealing.
  By switching to LPG, industrial processes would not be compromised, and the business will lower its carbon emissions.
  Analysis: A cheese production unit in France could benefit by switching oil consumption to LPG. We estimate a LC of €62/MWh of operating an LPG-fuelled system, a 21% reduction compared to an oil-fuelled system.

Achieving a net-zero carbon economy will require active policy. Deploying a macroeconomic fuel-switching policy – where oil and coal is replaced by a mix of renewable fuels – **could see carbon emissions reduce by over 93%** on 1990 levels in the I&C sectors.

France legislates to transition to a net-zero economy by 2050

In June 2019 French lawmakers voted into law the first article in a climate and energy package that sets goals for France to cut its GHG emissions and go carbon-neutral (zero net emissions) by 2050. To achieve this goal, it will be necessary to prioritise a reduction in the consumption of carbon-intensive fuels such as coal and oil, replacing them with lower-carbon alternatives. A reduction in the consumption of fossil fuels and a progression towards more sustainable options will reduce the overall environmental and health impact of fossil fuel combustion.

France's GHG emissions were 445 million tonnes of CO_2 ($MtCO_2$) in 2018, representing a 18.5% decrease on the level in 1990. Compared to the level in 2017, emissions fell sharply by 4.2%.

The industrial sector has contributed most to reducing French emissions since 1990. This has been driven mainly by improvements in the energy and environmental efficiency of industrial processes.

> "France's final energy mix is still dominated by oil."

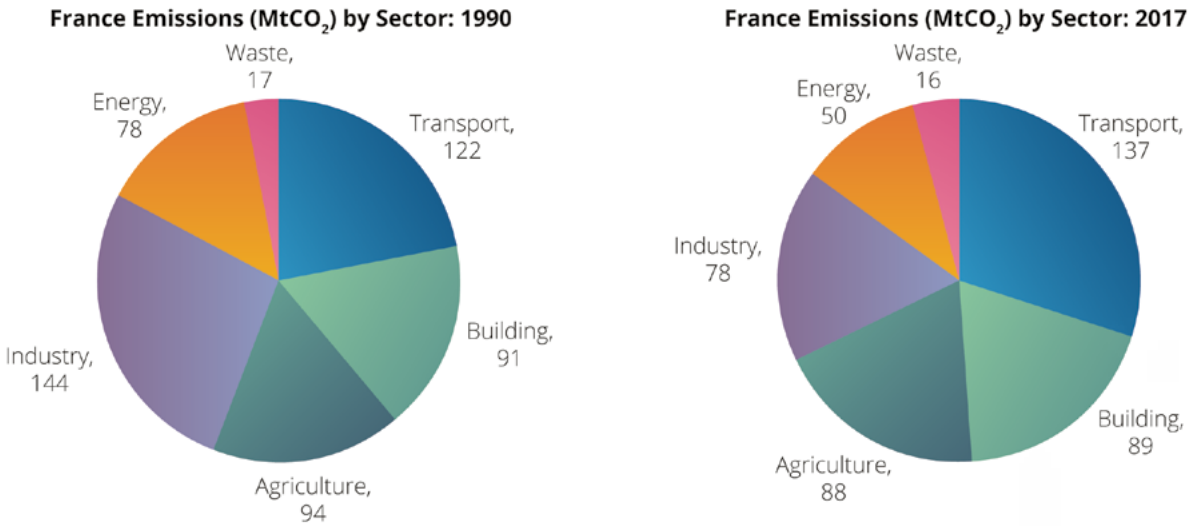


Figure 1: France emissions by sector – Ministère de la Transition Ecologique et Solidaire

Fossil fuel consumption prevalent across different sectors of the economy

France's energy mix is gradually changing and renewable energies are growing at the expense of oil and coal consumption[1]. However, this change is happening slowly.

In 2017, the primary consumption of mainland France amounted to 2,747 TWh (to satisfy final consumption of 1,641 TWh) which is a 0.7% increase compared to 2016.

France's final energy mix is still dominated by oil. In 2017, total final energy consumption of oil & petroleum products accounted for 39% (639 TWh) of end consumption for energy use. Industry in France consumed 1.62 million tonnes of oil equivalent (mtoe), equivalent to 18.8 TWh. Oil consumption is likely to be used for low and high-temperature industrial processes such rolling, melting, drying, separation and space heating. The commercial services sector consumed 2.37 mtoe, equivalent to 27.6 TWh. In the commercial sector, oil is likely to satisfy space heating demand.

Whilst modest as compared to oil consumption, coal still features in the French energy mix and will need to be transitioned away over the coming years. Figure 2 shows that over 90% (12.4 TWh) of all coal consumption is in the industrial sector (food and beverage, chemical and non-metallic mineral industries). The commercial and residential sector still have some coal-fired heating systems which account for 4% and 3% (respectively) of overall coal consumption in France. This is equivalent to 0.9 TWh of coal consumption per year in the building sector.

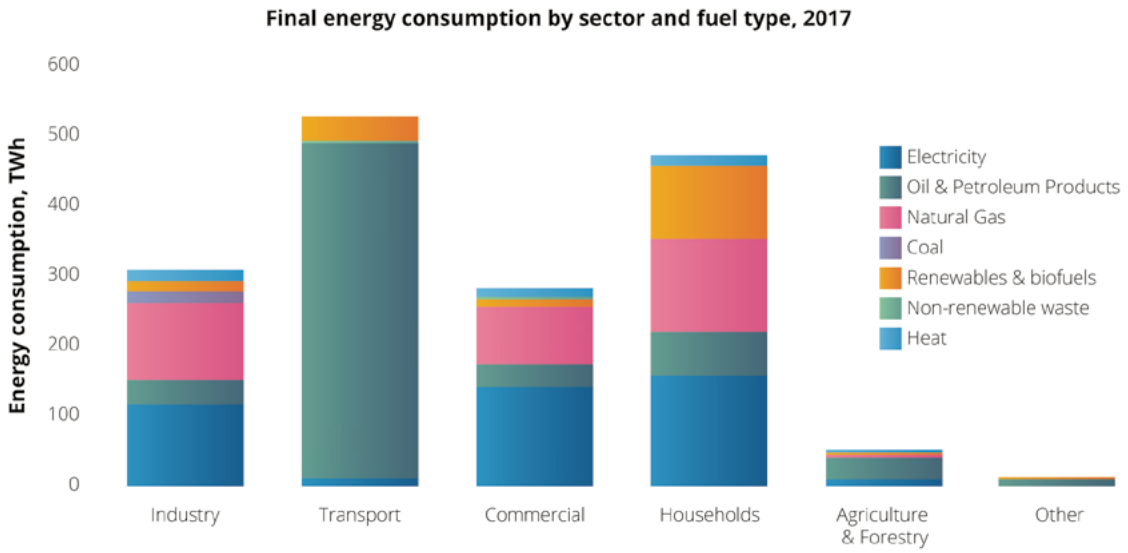


Figure 2: Final energy consumption by sector and fuel type in France, 2017 (Eurostat)

[1]*French Strategy for Energy & Climate: PPE – Ministère de la Transition Ecologique et Solidaire*

What does this mean for businesses in France?

France's Multi Energy Action Plan (PPE) describes the measures which will enable France to decarbonise its energy in order to become carbon neutral by 2050. The plan outlines that from 2023 onwards, France will replace 10,000 coal-fired heating systems (half of those remaining) and 1 million oil-fired boilers (out of 3.5 million remaining) with gas boilers with very high energy efficiency specifications[2].

These policies will likely target sectors and industries that are the most coal and oil intensive; from large industrial plants which use fuel and gas oil for industrial processes, to small rural hotels and restaurants that use oil for heating, to farms that use oil for space heating.

Companies in these sectors (and other industrial/commercial/agricultural users of oil) will have to switch away to lower-carbon fuels in order to be aligned with France's emission reduction ambitions. The transition to alternative fuels should be cost-effective, should reduce emissions and, should be a familiar technology to minimise disruption.

Industrial and commercial (I&C) businesses combined are the largest consumers of energy in France, accounting for 36% of total final energy consumption. These businesses also accounted for 11% of total coal and oil consumption in 2017.

The largest industrial consumers of oil include companies in the:

- Mining and quarrying sector – 173 thousand tonnes of oil equivalent (ktoe)
- Non-metallic minerals sector – 162 ktoe
- Food, beverages and tobacco sector – 102 ktoe

Total oil and coal consumption in the commercial services sector totalled 2,411 ktoe in 2017, accounting for around 10% of total final energy consumption in the commercial sector[3]. This sector consists of hotels, restaurants and offices.

The benefits of switching to LPG – a familiar and versatile lower-carbon alternative

An industrial business, a hotel or a poultry farm could benefit by replacing their consumption of oil with LPG. The switch could be done seamlessly and cost effectively whilst allowing the business to lower its carbon footprint.

Switching to LPG would enable businesses in the I&C sector to decarbonise. Combustion of LPG emits 30-40% less carbon dioxide than coal and ~20% less than heating oil[4]. The difference is even more important when looking at the emissions over the lifecycle of the heating system.

LPG emits no black carbon, a major contributor to climate change. Beyond the CO_2 benefits, LPG emits no particulate matter and is a clean-burning smoke-free fuel that supports cleaner air quality.

Consumers are already familiar with and widely use LPG in France. In 2016, total consumption of LPG was 4,208 ktoe, second to only Germany and accounting for 11% of total LPG consumption in the European Union. Close to half (48%) of total LPG consumption was in the industrial, residential and agriculture sectors. By switching to LPG, businesses would be tapping into a fuel that has a mature and wide supply network.
For commercial businesses already using a

[2] *French Strategy for Energy & Climate: PPE – Ministère de la Transition Ecologique et Solidaire*
[3] *Energy Balances (France) – Eurostat*
[4] *CoM Default Emission Factors for the Member States of the European Union – European Commission*

boiler to provide space heating, switching to an LPG boiler could be done relatively quickly and with little hassle or disruption. Installers will find LPG boilers familiar to install. In addition, installers do not have to worry about air in the system or connecting the filter. A commercial business, in particular, could save on space by installing an LPG boiler as they are more compact than an oil boiler. In a restaurant (or a hotel) where space is at a premium, an LPG boiler could be wall-mounted.

In the industrial sector, coal and oil consumption could be replaced by LPG which would be suitable for processes that require high-temperature direct heating. In these high-temperature processes, the combustion gas comes into direct contact with a solid material[5]. In the non-metallic minerals sector (such as glass and ceramic manufacturing), LPG could replace oil for key processes such as melting raw materials in a furnace, extrusion, moulding, forming, pressing and annealing.

While other low-carbon heating technologies are available, there can be challenges including with storage space for fuel (e.g. biomass pellets), and the need for new radiators and heat emitters given a low-temperature heating system (e.g. heat pumps) which might not be right for each business. LPG boilers are in relation, familiar and dependable.

> "Switching to an LPG boiler could be done quickly and with little hassle or disruption."

A robust LPG market can allow a sustainable transition to bioLPG in the medium and longer term

An initial transition to LPG would see businesses in the I&C sector lower their emissions. However, progressing towards a net-zero target would require switching sustainably to bioLPG (renewable LPG). France's energy action plan PPE recognises the role of biofuels and mentions that LPG of biological origin (i.e. bioLPG) obtained from different biomasses should become a viable technology in the medium-term. One of the priorities of the plan is to develop so-called "advanced" second-generation fuels produced from waste and residues.

The benefits of bioLPG include it being chemically indistinct from conventional LPG. This means it has the same attractive physiochemical properties – bioLPG can be compressed, stored and transported cost-effectively. BioLPG can also be used as a 'drop-in' fuel which can be combusted in existing LPG boilers. This would avoid the cost of retrofit and reduce the disruption to a business.

The environmental benefits of bioLPG are a carbon intensity that is around 70-80% lower than gas/fuel oil and around 80%-90 lower than coal[6]. Using data from Bilans-GES's resource centre for greenhouse gas accounting, they estimate a carbon intensity of bioLPG that is around 0.0603 $kgCO_2/kWh$[7].

[5] *Industrial Fuel Switching Market Engagement Study – Element Energy*
[6] *The Emission Factors – Covenant of Mayors*
[7] *Resource centre for greenhouse gas accounting (biopropane) – Bilans-GES*

Benefits of switching to LPG and bioLPG: Cheese production unit

In France, dairy products are the second largest agrifood industry after meat. France has 700 processing establishments that produce 24 billion litres of milk annually. France ranks second in Europe for producing milk, cheese and butter. The milk industry produces around 1.9 million tonnes of cheese, more than 760,000 tonnes of butter & cream and 2.4 million tonnes of yogurt and desserts (France Agroalimentaire).

Energy consumption in cheese production is needed for:

- Cheese reception (thermization)
- Processing, treatment/storage
- Cooling
- Pressurised air to cleaning

Many of these processes use fuels such as oil in order to perform mid-temperature requirements (75-85°C) for milk pasteurisation and low-temperature requirements for cheese treatment.

Performing these functions can be done at a lower cost if oil is replaced by LPG or bioLPG. We estimate that the levelised cost (LC) of using LPG to fuel these processes is €62/MWh, a 21% reduction compared to using oil. Using bioLPG to fuel these processes would marginally raise the LC (higher price premium for bioLPG over LPG) however, the economics are still favourable – LC of using bioLPG is estimated to be 15% lower than oil.

Electrification solutions could be challenging and technically unfeasible

For industrial and commercial businesses that are heavy consumers of oil, switching to LPG (and bioLPG) is cost-effective, less disruptive and environmentally-compliant.

However, much of France's decarbonisation strategy is geared towards electrification (namely heat pumps). While heat pumps may be a suitable option for modern buildings that are on-the-gas-grid, they could be a less effective solution for buildings and industrial plants located in rural areas that are off-the-gas grid. Their effectiveness is considered below in terms of cost, practicality and technical feasibility.

The major barrier for switching to a heat pump is cost – upfront cost is much higher than an LPG boiler. Data from a European Commission report on space and combination heaters shows that the specific cost (€/kW) of an air-source heat pump (>20kW) was around seven times more expensive than a condensing gas boiler (>100kW)[8]. The price differential nearly doubles when considering a ground-source heat pump for a poultry farm – extra cost of the horizontal or vertical heat exchanger (almost doubles the investment cost).

In addition to the upfront cost, additional storage space may be required to host the heat pump. This can be problematic for commercial businesses where space is at a premium. The opportunity cost to a commercial business could be to use existing space (which originally may have been used for productive purposes) or to build additional storage – an additional cost. Maintaining a heat pump can be costly too, with annual servicing costs around double the cost of maintaining an LPG boiler.

Whilst the French government has tried to counter the high upfront cost of heat pumps with financial support such as tax credits and loans, the question remains whether these support schemes target the right technologies and are cost-effective.

The French government will also have some challenges in ensuring that electricity remains low-emission and prices do not rise as some nuclear plants are phased out in the coming years. Around 75% of electricity in France is generated from nuclear energy[9]. Current government policy is to reduce this share to 50% by 2035 which would require closing up to 14 of the 58 reactors by the same time period.

The replacement of nuclear with (intermittent) renewables could raise system costs. In the UK, empirical research has found that the annual cost of balancing the electricity grid increased from £692m (€761m) in 2006 to £1,207m (€1,328m) in 2016[10]. This increase was accompanied by huge growth in the share of renewable generation as a proportion of total electricity supply. The deployment of renewables relies upon balancing services whose costs are borne by consumers via higher network chargers as well as levies built into electricity prices.

[8] *Mapping & analyses of the current and future heating/cooling fuel deployment – European Commission*
[9] *Nuclear Power in France – World Nuclear Association*
[10] *Renewable generation, constraints and the cost of balancing the electricity system – University of Edinburgh*

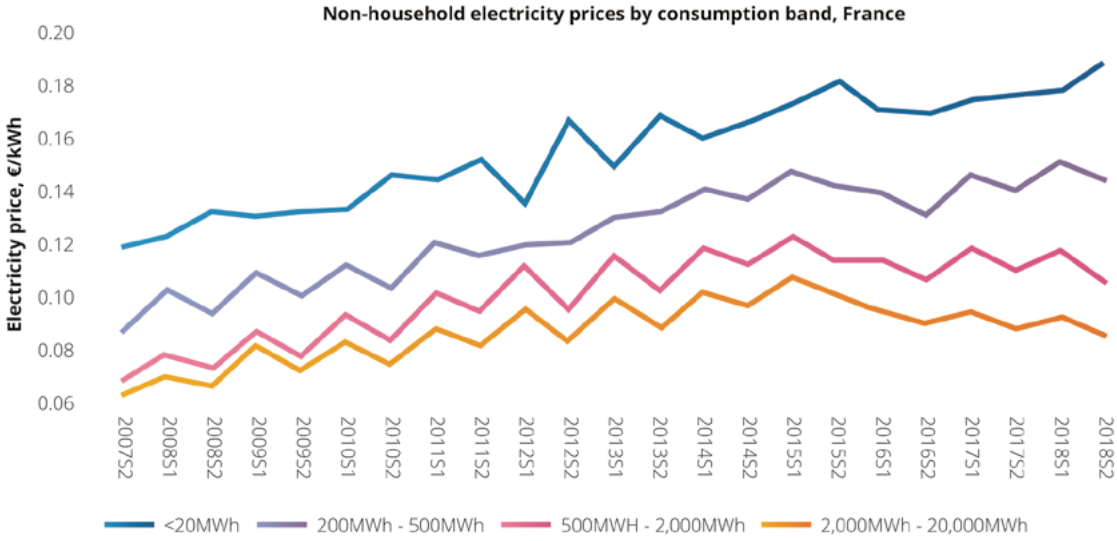


Figure 3: Non-household electricity prices by energy consumption band (taxes and levies included) - Eurostat

Figure 3 shows that electricity prices have generally been rising for commercial and industrial users over the last decade. For a commercial business, typical annual energy consumption would be in the 20MWh – 500MWh band and prices have risen 66% since the second half of 2007. For small industrial businesses, typical annual energy consumption would be in the 2,000MWh – 20,000MWh band. While prices in this band have fallen about 20% since the first half of 2015 they are however, still around 40% higher compared to the second half of 2007.

Replacing an industrial process entirely with heat pumps could potentially be unfeasible and expensive. Heat pumps, in industrial processes, can replace some fossil fuel consumption to perform pre-heating functions only. They become redundant for processes that then require high-temperature direct heating (such as melting and rolling). To reach these high temperatures, often up to 2000°C, a gaseous fuel is required.

In the context of decarbonisation, LPG stands out as an ideal fuel to replace coal or oil and which can be used for high-temperature industrial processes. These processes usually involve heating a solid material (e.g. melting, kiln firing or metal shaping processes) at high temperatures of between 240°C and 2000°C.

Heat pumps may be unsuitable for old (or historic) buildings that are hard-to-decarbonise. These buildings are built of traditional construction techniques, using bricks, stone or timber framing. These buildings are more than likely to have solid wall insulation which increases the rate of heat loss. As a result, these buildings would not be suited to low-temperature heating from a heat pump and, direct electric heating would be an expensive option given rising electricity prices (see figure 3).

Switching to LPG can be cost-effective in niche applications – old and historic buildings

Historic buildings shape European cities; they are part of a country's culture. They also represent a significant part of the European building stock and have an important role to play in improving energy efficiency in cities. In France specifically, there are over 40,000 officially classified historic monuments[11], giving it one of the densest concentrations of historic buildings and other monuments of any country in Europe. These buildings and monuments range from great palaces and cathedrals to small medieval chapels, Roman remains, museums and, vestiges from the time of the Industrial Revolution. In addition to the 40,000 officially designated sites, there are many thousands more bridges, barns, houses, chapels, villages and private residencies that are historic monuments in all but official designation.

Historic and old buildings are typically built using traditional construction methods. They are often located in rural, off-grid areas and can be characterised by solid stone walls, high vaulted roofs, single-glazing, poor wall and floor insulation, poorly draught-proofed doors and low-occupancy levels. These buildings are highly thermally inefficient and heat loss is very high.

Existing heating systems in these buildings can range from old and inefficient oil boilers to convector radiators. Switching to an LPG heating system may be a much more cost-effective solution compared to switching to an ASHP or a GSHP. An LPG boiler can provide instant heating whereas the performance of a heat pump can depend on various factors. Heat pumps are ideally suited to buildings which are well insulated, are draught-proof, have underfloor heating and a designated space to house the heat pump (less important for an LPG boiler). Having these thermal characteristics enables a lower supply temperature compared to systems based on radiators in older buildings. Lower supply temperatures contribute significantly to higher efficiency (coefficient of performance or 'COP') of heat pumps[12]. The quality of installation and dimensioning can also impact the performance and efficiency of a heat pump. A poorly designed and installed heat pump can lead to the heat pump performing sub-optimally and operating at a much lower COP.

In rural areas particularly, the electricity grid is less developed, and it can be expensive to reinforce the network. This cost is avoided if commercial businesses in rural areas switch to LPG. LPG is a flexible and versatile fuel that can be transported and stored in locations that are hard to reach. LPG can be supplied in bulk, which can then be stored in a large over-ground or underground tanks. This ensures commercial businesses have a secure and steady supply of LPG.

A levelised cost analysis has been undertaken in order to quantify the cost-effectiveness of replacing an old and inefficient heating system in an old building (such as a rural hotel) with a bioLPG boiler, a biomass boiler or an air source heat pump. The LC of a particular generation technology is the ratio of the total costs of a heating system (capital, maintenance and operating), to the total amount of energy consumption over the heating system's lifetime. The LC is discounted (giving the net present value) and expressed in €/MWh in order to enable a comparison across technologies.

The thermal characteristics for a typical old building have been considered – poor thermal insulation, single-glazing and low draught-proofing. Data for France shows that specific energy demand for existing older buildings is around 230 – 330 kWh/m^2. We assume the size of this building is around 500 square meters.

The coefficient of performance and maximum output of a heat pump depend on the operating conditions. These conditions include the external air temperature, the temperature of the return flow from the heating system (return temperature), and the

[11] *Historic monuments in France – About France*
[12] *Efficiency of Heat Pumps in Real Operating Conditions – REHVA*

relative humidity (which affects the frequency at which defrost cycles are required). Furthermore, retrofitting wall insulation after the dimensioning process and installation of the heat pump can impact the life cycle of the heat pump which could impact the annual fuel bill. This process is less important for an LPG boiler.

Statistical analysis by the University of Strathclyde showed a negative relationship[13] between the COP and temperature difference (return temperature less external temperature) – as the temperature difference increases the lower the COP. We estimate that the sub-optimal thermal characteristics of an old, historic building could reduce the COP of the heat pump to as low 200%.

Figure 4 shows that the levelised cost of operating a bioLPG boiler in an old building with typical sub-optimal thermal characteristics is €64.5/MWh. If an air-source heat pump was installed, instead, then the levelised cost would increase to €65.2/MWh. The levelised cost of a biomass boiler is calculated at €99.8/MWh.

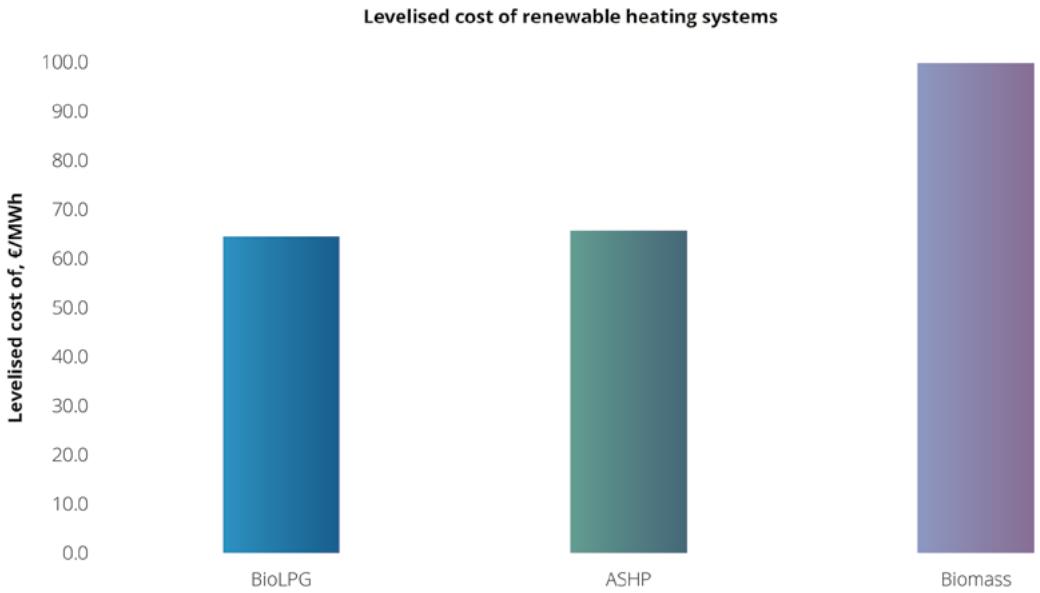


Figure 4: Levelised costs of a bioLPG, biomass boiler and an air-source heat pump in a heritage building (Analysis from Ecuity Economics, supported by data from CFBP and European Commission).

The upfront cost of an LPG and bioLPG boiler is much lower compared to an electric heat pump or an automatic-fed biomass boiler. The installation cost of an electric heat pump can be prohibitive, even before any requirements to carry out insulation and radiator upgrades in older buildings. New, automatic biomass boilers while efficient, require additional space on-site to store wood pellets or chips. In addition, the storage space should have minimum ventilation standards to prevent significant build-up of toxic gases (i.e. off-gassing) during wood pellet and wood chip fuel storage[14]. Biomass combustions is also inherently dirtier in terms of particulate emissions and C02 than gas, thus potentially exacerbating existing air quality issues.

[13] *Modelling the performance of air source heat pump systems – University of Strathclyde*
[14] *Safe storage of wood pellet and wood chip fuel – Health and Safety Executive*

Benefits of switching to LPG: Rural hotel – 'Gite'

A 'Gite' is a holiday house in France, typically in a rural district, that is available to rent. Today there are over 450,000 gites or holiday rental properties in France, over ten times the number available back in 2011 (About France). There are around 27,000 municipalities in France that are not connected to the natural gas line. As a substitute, heating oil is widely consumed for heating purposes in these off the gas-grid areas.

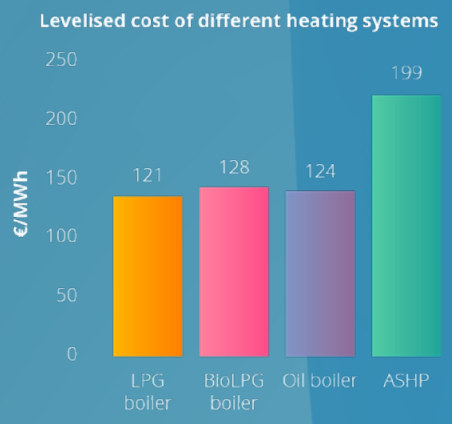
It could be cost-effective for a typical gite in rural France, that currently consumes oil, to switch to LPG. LPG is a lower-carbon alternative to oil and is a cleaner burning fuel as it contains no sulphur. LPG performs particularly well in off the gas-grid areas due to its versatility, flexibility and portability. The fuel can be easily transported in cylinders or in bulk, and a storage tank can be bought to ensure you never run out of supply.

We estimate that the LC of running an LPG system in a rural 'Gite' is €121/MWh, around 3% less than an oil-fuelled hot water and heating system. The initial capital cost of an LPG heating and hot water system is estimated to be around ~20% less than an oil heating and hot water system.

The LC of installing a heat pump is over 60% higher than an LPG boiler. This is because the initial capital cost of a heat pump is much higher than an LPG boiler.

Compared to a heat pump, an LPG heating system can provide instantaneous hot water. This is important for a hotel where paying guests demand a seamless shower experience and are unlikely to wait long for the water to reach an optimal temperature. Using a heat pump to produce hot water can take time and detract from the customers staying experience.

Switching to a bioLPG-fuelled heating system would raise the LC to €128/MWh (higher price premium over conventional LPG) however, this is still much lower than the LC for a heat pump, around ~40% lower.



(Analysis from Ecuity Economics, supported by data from CFBP).

Impact of phasing out high-carbon fossil fuels in the I&C sectors – aligning with climate change targets

The industrial and commercial (I&C) sector, combined, account for the largest share of energy consumption in France (36%). The I&C sector also account for 11% of total coal and oil consumption. For France to achieve net zero emissions by 2050, policies will be required to switch current consumption of coal and oil to lower-carbon alternatives.

In 2017, total consumption of oil and coal in the I&C sectors was 5.1 million tonnes of oil equivalent (59 TWh). The construction, mining and quarrying and non-metallic minerals industries were the largest consumers of oil. The non-metallic mineral industry comprises of the production of cement, glass and lime. These manufacturing sectors are characterised by the transformation of naturally occurring minerals such as limestone, silica and clays through an energy-intensive process. The use of oil is used in the glass sector for melting and annealing (direct high temperature process). The ceramics sector uses oil for kiln firing.

Utilising projected consumption growth rates of oil and coal[15], the estimated level of oil and coal consumption in the I&C can be estimated. By 2050, it is estimated that the consumption of coal and oil would fall from 5.1 mtoe to 3.7 mtoe, a 27% reduction in energy consumption. Carbon emissions would fall to 11.7 million tonnes of CO_2 ($mtCO_2$), a reduction of 71% against 1990 levels. Given that France has recently committed to net-zero ambitions, this reduction is not enough for France to meet its aspirations and therefore more needs to be done to decarbonise the industrial and commercial sectors.

An oil and coal transition (OCT) scenario is developed to consider the transition needed in the I&C sectors. In 2027, and in line with ambitions in the PPE, the consumption of coal and oil is replaced by a mix of heating technologies including bioLPG, biomass and electric heat pumps.

Figure 5 shows that by switching from oil and coal to mix of different renewable technologies, energy consumption could fall by 15%. This is driven by the fact that the replacement technologies have higher operating efficiencies than existing and outdated coal and oil boilers.

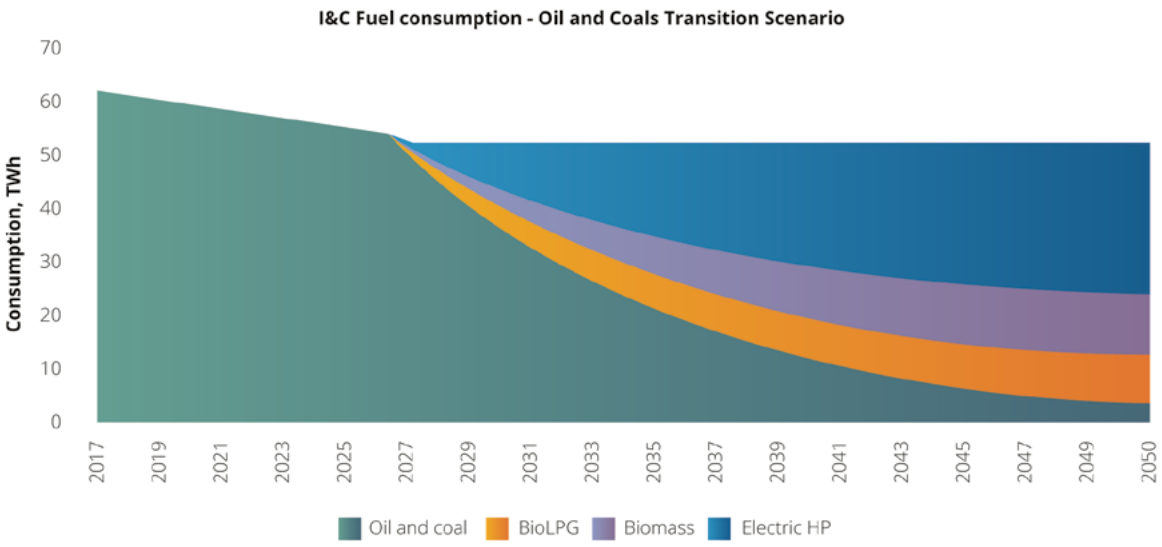


Figure 5: Energy consumption in the I&C sectors (TWh) - Oil and Coal Transition (OCT) scenario (Ecuity Economics)

[15]*EU Reference Scenario (2016) – European Commission*

The impact of this transition is to lower annual carbon emissions from 17.8 $mtCO_2$ to 2.4 $mtCO_2$ by 2050, a reduction of 87% on 2017 levels. Compared to the level of I&C emissions in 1990, this represents **a reduction over 93%** – in line with France's net-zero carbon emissions.

In the business-as-usual scenario, the consumption of coal and oil reduces but at a very slow rate. As a result, the cumulative damage cost associated with carbon emissions would amount to €37.4bn by 2050. Deploying an OCT scenario would see the damage cost from carbon emissions fall to €21.8bn, a 42% reduction on the level in the business-as-usual scenario.

The consumption of coal and oil can worsen air quality because these fuels produce high levels of nitrogen oxide (NOx) and particulate matter (PM). It is estimated that the damage cost associated with air quality (both NOx and PM) amounts to €40.6bn in the business-as-usual scenario. In the OCT scenario, the damage cost associated with air quality (both NOx and PM) is estimated to reduce by 20% against the level in the business-as-usual scenario.

Damage cost by scenario	Carbon emissions (CO_2)	Air quality (NOx)
Business-as-usual, £m	37,434	40,596
Oil transition, £m	21,846	32,326
Saving, £m	**15,588**	**8,270**

Figure 6: Industrial & Commercial cumulative damage costs by 2050 (Ecuity Economics)

What is bioLPG?

- Renewable form of LPG that is made from a blend of waste and residues.
- Chemically indistinct from LPG, has same attractive physiochemical properties – can be compressed, stored and transport cost-effectively.
- Can be used as a "drop-in" fuel – can be combusted in existing heating systems and foregoes the need for expensive retrofits and disruption.
- Attractive and cost-effective option for businesses and industries located in rural areas that are not connected to the natural gas lines.
- Has a carbon intensity that is around 80% lower than oil.
- Can improve air quality – emits 27% less Nitrogen Oxide (NOx) and 43% less Particulate Matter (PM).

"Air pollution is a leading cause of premature deaths and is considered by the World Health Organisation as the single largest environmental health risk in Europe."

Italy

Cleaning the air

LPG is a clean-burning alternative to heating oil and biomass that reduces the air quality impact of businesses and industries that switch to it. This chapter includes details of the benefits that LPG can deliver for businesses in Italy that want to comply with environmental regulations by cutting their air quality impact as responsible corporate citizens.

Air pollution is a global threat that impacts human health and ecosystems. These impacts have economic costs, cut lives short, increase medical costs, reduce productivity through lost working days and damage vegetation and the quality of water.

Air pollution is a leading cause of premature deaths and is considered by the World Health Organisation as the single largest environmental health risk in Europe. Heart disease and stroke are the most common reasons for premature deaths attributable to air pollution, followed by lung diseases and lung cancer. In the EU28, around 391,000 premature deaths were attributed to exposure from particulate matter (PM) concentrations in 2015.

This cannot continue unabated. Europeans expect the authorities to implement effective measures to reduce air pollution and its damaging impact. To curb the effects of air pollution, coordinated action at national and local levels will be required and must be supported by other relevant sectors.

Given that these businesses are among the largest contributors to overall PM emissions (EEA, 2018), EU policymakers are likely to target these sectors for reductions. For businesses this could mean having to replace old, inefficient and highly polluting boilers with modern, lower-pollutant alternatives. This would be in line with existing regulation such as the Medium Combustion Plant Directive (MCPD) which limits pollutant emission from the combustion of fuels in medium-sized plants. Policymakers are likely to continue to tighten such standards over time.

LPG is the primary low-pollutant fuel alternative for off-grid plants that use oil or coal to fuel process and space heating. LPG is a clean-burning smoke-free fuel that supports cleaner air quality. In commercial and industrial boilers, LPG emits over 90% less PM than oil and over 99% less PM than coal[1].

In Italy, where air quality has reached crisis levels, switching to LPG in off-grid rural areas can significantly improve air pollution and reduce the number of premature deaths associated with poor air quality. As well as lowering air pollution, LPG is a versatile and flexible fuel that has multiple applications in industrial and commercial settings. These range from performing direct heat high-temperature processes to satisfying space heating in commercial offices.

[1] *EMEP/EEA air pollutant emission inventory guidebook 2016 (updated July 2017) - EEA*

Opportunities for fuel switching to drive decarbonisation of industrial, commercial and agricultural sectors

Businesses in Italy have reduced GHG emissions by switching to solid biomass fuel. Whilst the burning of wood as a potentially renewable resource has reduced national CO_2 emissions, its combustion has worsened air quality in Italy.

Air quality is an increasing concern across the EU. As policy is devised at EU level to tackle poor air quality, this will also impact Italy who will be required to employ these measures or implement their own national air quality standards. Indeed, air quality in Italy reached crisis levels in 2018. The EEA estimate that air pollution is responsible for over 81,000 premature deaths in Italy, the most for any EU state.
As Italy's policymakers consider measures that tackle both CO_2 and air pollution, businesses will need to actively consider what this means for them. Switching to a lower-carbon heating technology now, rather than later, could be less disruptive and cost-effective. This would help secure the businesses long-term competitiveness as it futureproofs itself from an evolving energy transition.

The most cost-effective, versatile and environmentally-compliant solution could be for businesses to switch to LPG. As the conventional LPG market expands in industry, commercial businesses and farms, this would enable a sustainable transition to bioLPG in the medium term to deliver deep decarbonisation.

Switching oil to conventional LPG represents an immediate win. LPG is a lower-carbon alternative that has desirable chemical properties, a mature and established supply chain in Italy, and is a clean-burning fuel that produces low levels of air pollution. For future deeper decarbonisation Italy should look to support the commercialisation and uptake of bioLPG, which is lower than oil in both GHG and air pollutant emissions when combusted.

1. LPG is a good direct replacement to oil heating in commercial buildings and is particularly suited to off-gas grid applications. In industrial applications, LPG could replace oil consumption for direct heating at high-temperature and performing other industrial processes such as drying and pasteurising in the food & drink manufacturing sector.

2. Switching from oil to LPG would drastically reduce the impact associated with carbon emission and air pollution. The total damage cost from LPG combustion is estimated to total €28.5/MWh - a sharp reduction (~70-80%) compared to biomass and oil (66%).

   Meanwhile, switching to biomass instead of LPG can lead to spikes in localised air pollution:

3. Switching from oil to biomass in the commercial sector would lower carbon emissions but significantly worsen air quality. We estimate that substituting oil with biomass (wood pellets) would raise total damage costs from €84.5/MWh to €97.4/MWh. This would be largely driven by the emission of PM, where the associated damage costs would increase by 266% compared to oil.


Italy

Europe tackling GHG emissions but need an integrated approach to tackle air pollution

The European Commission in 2018 presented its long-term vision for a prosperous, modern, competitive and climate-neutral economy by 2050. This vision is line with the Paris Agreement objective to keep global temperature increases to well below 2°C and pursue efforts to keep it to 1.5°C. As part of this transition to a climate-neutral economy, the EU aims to reduce emissions (relative to 1990 levels) in 2020 by 20%, by 40% in 2030 and by 80%-95% in 2050.

Italy aims to reduce GHG by 39% by 2030 (on 1990 levels) and by 63% by 2050 compared to emissions in 1990.

While the EU is focused on reducing carbon emissions, it also needs to tackle air pollution more effectively. Air pollution is a global threat leading to large impacts on health and ecosystems. When it comes to Europe, air quality remains poor in many areas, despite reductions in emissions. Energy consumption links both air pollution and climate change and, therefore, energy policy should consider how both environmental challenges can be met. Addressing one without considering the impact on the other can lead to sub-optimal outcomes.

Air pollution is perceived as the second biggest environmental concern for Europeans after climate change[2] and people expect the authorities to implement effective measures to reduce air pollution and its effects. Across the EU-28 a little over 391,000 premature death were attributed to particulate matter exposure and 76,000 to NOx exposure[3] in 2015 (latest year data).

The EU will need to devise directives and measures that tackle poor air quality. This will impact Italy where air quality has deteriorated to reach crisis levels.

[2] *Clean air for all – European Commission*
[3] *Air quality in Europe: 2018 report – European Environment Agency*

The health impact of air pollution: a global perspective

Air pollution is a major cause of death and disease globally. An estimated 4.2 million premature deaths globally are linked to air pollution, mainly from heart disease, stroke, lung cancer and acute respiratory infections in children (World Health Organisation).

Air pollution globally accounts for:

- **29%** of all deaths and disease from lung cancer
- **17%** of all deaths and disease from acute lower respiratory infection
- **24%** of all deaths from stroke.

Pollutants with the strongest link to public health concerns include particulate matter (PM), nitrogen oxide (NOx), Ozone (O^3) and sulphur dioxide (SO^2).

PM
Includes any solid or liquid particle that is suspended in the air. PM pollution is classified by size – with $PM_{2.5}$ relating to particles with a diameter less than 2.5µm. PM_{10} relates to particles with a diameter smaller than 10µm.

NOx
Is a grouping of seven gases and compounds composed of nitrogen and oxygen. The two most common and hazardous are nitric oxide (NO) and nitrogen dioxide (NO^2). NOx is emitted from vehicle exhausts, and the combustion of fossil fuels – especially from the burning of coal, oil and diesel.

Italy making progress to reduce CO_2 emissions but need to tackle deteriorating air quality

Italy's total CO_2 emissions were 426 $MtCO_2e$ in 2017, a reduction of 18% on 1990 levels. This reduction has been driven mainly by emission reductions from industry, buildings and the transport sector. The European Environment Agency projects that carbon emissions will fall a further 8% to 392 $MtCO_2e$ by 2030[4] – based on existing adopted and implemented measures.

One of the ways in which the Italian government has looked to reduce emissions, is to encourage fuel switching to biomass. This has helped Italy to reach its 2020 target, of 17% renewable energy share (as a proportion of gross final energy consumption), four years earlier in 2016[5].

Italy's share of renewable energy was 17.4% in 2016, surpassing the 2020 target. The renewable energy share in heating and cooling was 18.9% (2020 target is 17.09%) and, in electricity the share was 34% (2020 target is 26.39%).

Whilst increased biomass consumption has helped reduce GHG emissions, the fuel's combustion can generate dangerous air pollution. Air quality is a serious concern in Italy, particularly in areas where orography (mountain landscape) does not allow a good dilution of air pollutants.

According to the European Environment Agency Italy ranked first in the EU for the total number of premature deaths attributed to air pollution – 81,100 premature deaths in 2015 (see figure 7). Italy was ahead of second place Germany by nearly 6,000 premature deaths, a sizeable margin. Exposure to particulate matter and nitrogen oxides were the main reasons for the large number of premature deaths in Italy.

In 2018, air pollution was above EU legal limits in more than half of Italy's 107 provincial capitals in 2018[6]. The cities with the most polluted air last year were all located in the country's industrialised north, led by Brescia and followed by Lodi, Monza and Venice – areas with the highest consumption of biomass for heating appliances.

The leading sources of air pollution in Italy were road traffic, domestic heating, industry and agriculture. Together, they caused PM_{10} and ozone levels to rise above the daily legal limit in 55 out of 107 major cities.

Air pollutants (in particular nitrogen oxides and particulate matter) are linked to higher rates of infant mortality, increased frequencies of low birth weight, greater risk of asthma attacks and other forms of respiratory sickness. The incidence of low birth weight has been associated with higher health costs and reduced earnings later in life. Empirical research suggests that birth weight has a significant effect on longer-run outcomes such as height, IQ at 18, earnings and education[7].

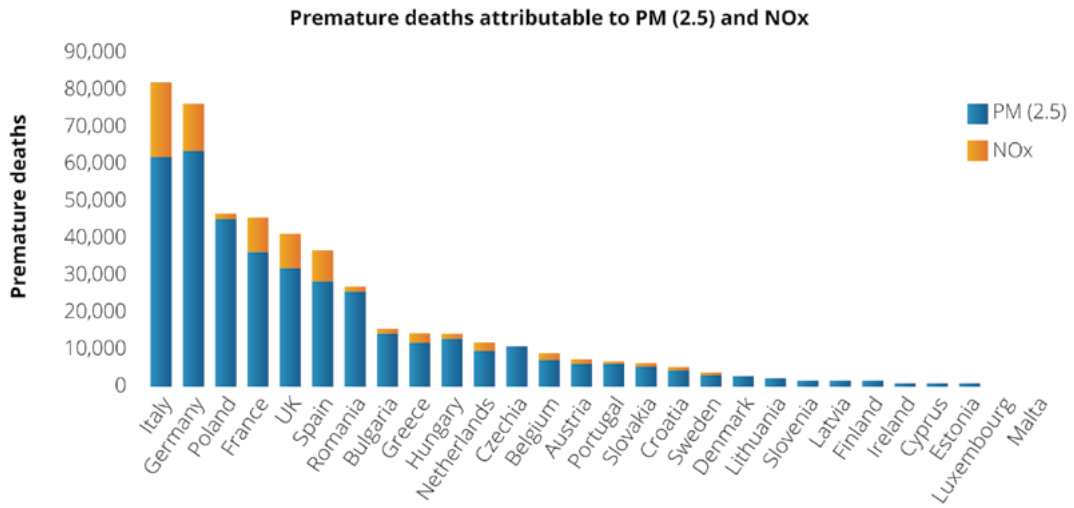


Figure 7: Premature deaths attributable to $PM_{2.5}$. and NOx across EU member states – European Environment Agency (EEA)

[4]*Trends and projections in Europe 2018 – European Environment Agency*
[5]*Italy – 2018 update: Bioenergy policies and status of implementation – International Energy Agency (IEA)*
[6]*Mal'Aria 2019, the annual report on air pollution in Italian cities - Legambiente*
[7]*From the cradle to the labor market? The effect of birth weight on adult outcomes – Quarterly Journal of Economics*

Industry, commercial services and agriculture are major polluters of air pollutants in Italy

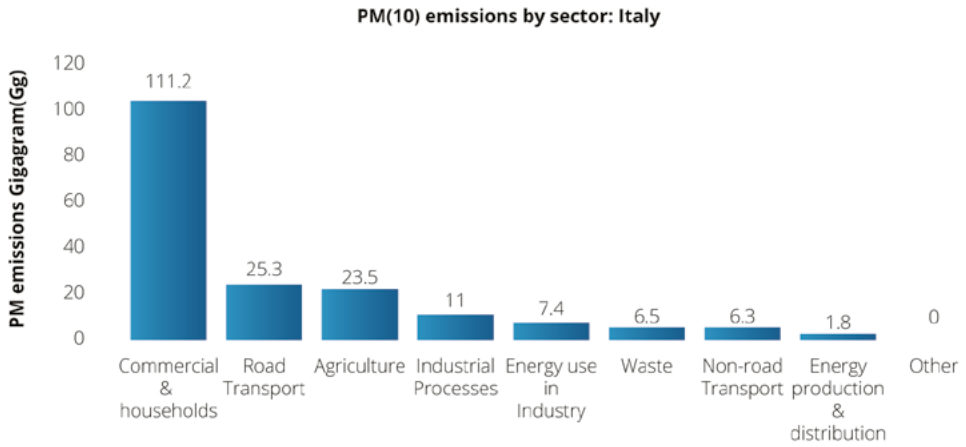
It is clear that Italian policymakers will need to tackle air pollution produced by businesses. Commercial services, agriculture and industrial processes were among the top sources of PM_{10}. Together these sectors emitted 145.7 Giga grams (Gg) of PM emissions, 76% of total PM_{10} emissions in 2016.

Road transport accounts for the overwhelming majority of NOx emissions in Italy (49%), followed by emissions from the commercial sector & households (16%). The industrial sector accounts for 10% of total NOx emissions.

Italy is bound by EU legislation, which establishes standards and objectives for a number of air pollutants. The EU's air quality directives[8] set pollutant concentrations thresholds that shall not be exceeded in a given period of time.

Italy has been referred to the EU's Court of Justice for persistent breaches of air quality limits[9]. It is important to consider the way in which energy policy decisions can impact air quality, as Italy's energy transition continues over the coming years.

Policymakers need to consider (both at a national and local level) that the uptake of biomass technologies is not environmentally-sustainable. Both air pollution and climate change are intertwined and therefore policymakers should propose policies and measures that address both issues – lowering carbon emissions and limiting air pollution, as LPG does.



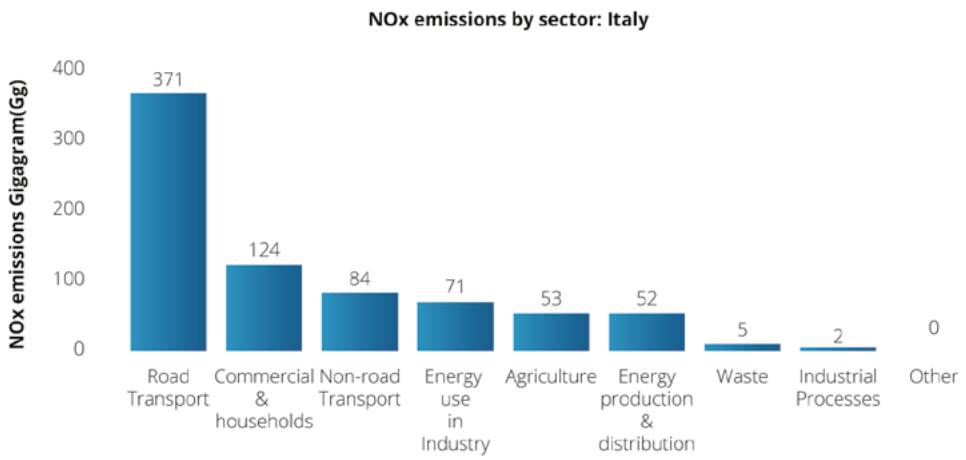


Figure 8: PM_{10} emissions by sector – European Environment Agency (EEA)
Figure 9: NOx emissions by sector – European Environment Agency (EEA)

[8]*Air quality standards – European Environment Agency*
[9]*Commission takes Italy to Court over air pollution and failure to properly treat urban waste water – EC*

What does this mean for businesses in Italy?

Under tighter environmental regulations, industrial, commercial and agriculture businesses will need to implement measures that lowers their carbon footprint while also limiting pollutant emissions to remain competitive and compliant. Delaying the switch to a lower-carbon heating system could be costly, disruptive and would see businesses misaligned with national climate objectives. In addition, delaying the switch could also hamper an industrial or commercial businesses' long-term competitiveness as the energy transition evolves.

To futureproof against this, an industrial, commercial or agricultural business could act now and switch to a lower-carbon heating system that also produces little pollutant emissions. Switching to LPG would enable these businesses to reduce their CO_2 emissions from process and space heating. In addition to lowering carbon emissions, switching to LPG would significantly lower pollutant emissions compared to combustion from oil and biomass. In the medium and longer term, a switch to bioLPG would see carbon emissions fall even further given its renewable credentials.

In Italy's industrial sector, the largest consumers of oil in 2017 were:

- Non-metallic minerals sector – 217 thousand tonnes of oil equivalent (ktoe)
- Machinery manufacturers – 185 thousand tonnes of oil equivalent (ktoe)
- Transformation sector – 175 thousand tonnes of oil equivalent (ktoe)

Many commercial businesses in Italy's rural, off-grid locations currently use oil to satisfy heat and hot water demand. These businesses include rural hotels, restaurants and offices.

Popular agritourism farms (farms licensed to provide accommodation) in Italy are situated mainly in mountainous and hilly areas[10]. These farms are off the gas grid and typical heating sources include oil and biomass.

While national policy has advocated and encouraged replacing the most carbon-intensive fuels (oil and coal) with biomass, this has on one hand helped to reduce carbon emissions, but it has also acted to contribute to air quality problems. A decade of this policy has culminated in Italy's air quality reaching crisis levels in 2018.

Businesses will need to look to alternative lower-carbon fuels that can lower carbon emissions as well as significantly reducing pollutant emissions.

The next section looks at how LPG could be an ideal solution for industrial and commercial businesses in rural, off-grid areas to lower carbon emissions and significantly lower pollutant emissions.

[10] *Agritourism farms in Italy - Istat*

Gaining an environmental edge – benefits to business of switching to LPG

Switching to LPG would enable businesses across industry, commercial sector and farms to decarbonise heat – an immediate win. LPG boasts a carbon intensity that is around ~20% less than oil[11]. In addition to being a lower-carbon alternative to oil, LPG also provides a considerable air quality advantage over oil. According to data from the EEA, LPG emits ~84% less NOx than oil. LPG emits almost no particulate matter as it is a clean-burning fuel (with almost no sulphur content) that supports cleaner air quality.

Figure 10 compares the air quality performance of LPG and a variety of different alternative fuels. While LPG performs well across the board, it is clear to see combusting the other fuels considered and biomass in particular can be problematic. Using emission data from the EEA and the ISPRA[12], LPG's NOx intensity is around 20% lower than wood logs, and its PM intensity is 99% lower.

Scientific studies and empirical research have shown that wood combustion was the main source of Benzo[a]pyrene (BaP)[13] emissions, this is particularly evident in some Italian areas where the consumption of biomass is very high. In 2017, the annual level of mean BaP emission was above the EU target value (1.0 ng/m3) in around 30 reporting stations in Italy[14]. The highest reported emissions of BaP were in the regions of Veneto, Lombardy and Torino.

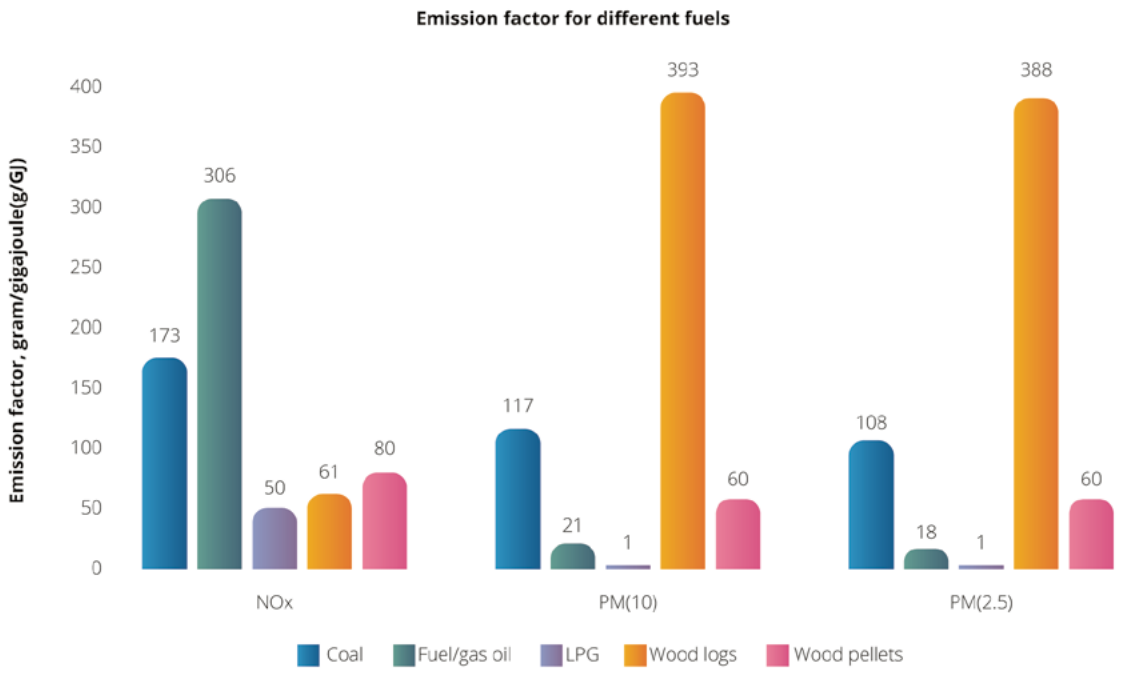


Figure 10: Emission factors (inclusive of country-specific limits where relevant) of different air pollutants by fuel type (commercial/industry) – European Environment Agency (EEA) and Istituto Superiore per la Protezione e la Ricerca Ambientale (ISPRA)

[11] *CoM Default Emission Factors for the Member States of the European Union – European Commission*
[12] *EEA and ISPRA - EEA and ISPRA*
[13] *Aside from producing particulate emissions, polycyclic aromatic hydrocarbons (PAHs) are known to be carcinogenic constituents of such fine particles. They are produced from the incomplete combustion of biomass and other heating fuels. Benzo[a]pyrene (BaP) has been regarded as a marker for both the total and carcinogenic PAHs. Silibello et al. (2012) modelled the BaP concentrations in Italy. Their analysis revealed a significant influence of certain national sources on BaP concentrations; the most important emission sector was non-industrial combustion in wood-burning devices. ACP*
[14] *Key air quality statistics for the main air pollutants - EEA*

LPG – a familiar and dependable off-grid fuel source

LPG is a flexible and versatile source of energy with many applications that span a range of sectors including transport & mobility, domestic and non-domestic sectors, industry and agriculture. In the industrial sector, LPG can be used in many processes such as rolling, melting, drying etc. In the commercial service sector, LPG can be used to satisfy space heating and hot water demand.

The market and supply infrastructure for LPG is well established in Italy. Consumption of LPG amounted to 4.15 million tonnes of oil equivalent (48.2 TWh) in 2016 and has been fairly stable over the last few years. The transport sector accounted for the highest share of LPG consumption (47%), followed by the domestic sector (38%). Industry accounted for 5.5% of LPG consumption in 2016.

Many buildings in rural Italy do not have access to the mains gas network (off-grid) and, as a result, in these areas rely heavily on off-grid fuels such as oil or biomass to satisfy space heating and hot water demand. For example, in popular agriturismi[15] areas, many of the farms are not on the gas network and therefore rely on oil or biomass for heating. For small businesses, such as the farmers who convert their farm into 'hotels', it makes sense to switch to LPG since this fuel has a higher calorific value per unit than other commonly used fuels. It is also an extremely versatile and portable fuel, and as such it is accessible to even the most remote parts of the country. A business that switches to LPG can easily ensure they are never without fuel since LPG offers safe and flexible storage options – it can be stored in cylinders or in a bulk tank which can be located above-ground or underground.

LPG is used in the industrial sector (accounting for ~6% of total LPG consumption in 2016) and there is huge potential for this share to increase. LPG can be used in many applications in the industrial sector namely in space and process heating, powering industrial-scale ovens, producing food as well as packing material. For example, LPG is extensively used in many food processing systems because of its clean burning properties. Bakeries and manufacturers of various confectionaries (biscuits, chocolate) are motivated to choose LPG as their favoured energy option as their products will not be exposed to the risk of contamination. The poultry industry use LPG as well as the bovine and pork breeding industries. The dairy industry utilises LPG for processes involving pasteurisation[16].

> "For small businesses, such as farmers who convert their farm into 'hotels', it makes sense to **switch to LPG.**"

[15] *Agriturismo translates (loosely) to "farm-stay". It is an independently-owned farm that the owners have decided to use partially for accommodation purposes. Walks of Italy*
[16] *Uses for LPG: Industrial – Total*

Benefits of switching to LPG: Bottle manufacturing in Italy

Bottled water is a global business and Italy is one of the most important producer and consumer countries (IBWA). Italian bottled water consumption was over 12 billion litres in 2013, the seventh highest in the world. In terms of annual per capita consumption, Italy ranks first in Europe and third in the world after Mexico and Thailand. According to Bevitalia's annual report (2015), the Italian bottled water industry included 143 companies of different sizes with gross sales of €2.4 billion annually.

According to Italy's energy balance (2019 edition), consumption of oil in the food, beverage and tobacco sector was 1.8 TWh, 16% of overall oil consumption in the industrial sector. Oil is likely to be used to sterilise plastic and glass bottles during the manufacturing process of packaging. This process could be done by using LPG, a lower-carbon alternative than oil.

We estimate that a typical bottle manufacturer in Italy could reduce its annual energy consumption by 17% if it were to use LPG to sterilise plastic and glass bottles instead of oil. With more and more manufacturing companies looking to reduce their environmental footprint throughout the product lifecycle, switching to LPG could enable this. We estimate that by switching to LPG annual carbon emissions would fall by 30%. If the bottle manufacturer were to switch bioLPG, annual carbon emissions would fall by more than 80%.

Developing the LPG supply chain can ultimately prepare the market to switch to bioLPG

While LPG can deliver immediate carbon savings and an improvement in air quality, for deeper decarbonisation of the industrial, agricultural and commercial sectors, an eventual switch to bioLPG will have to be made. BioLPG is the renewable equivalent to conventional LPG and has appealing characteristics such as being chemically indistinct from conventional LPG. The carbon footprint of bioLPG is around 80% lower compared to oil.

For businesses already using LPG, the transition from LPG to bioLPG could be done seamlessly since bioLPG can be used as a 'drop-in' fuel in existing LPG boilers. A large proportion of bioLPG can be blended with conventional LPG without causing any disruption to the boiler. This can be problematic for users of oil that switch to bio-oil – many of the feedstocks for bio-oil have relatively high cold filter plugging points and this makes them problematic in cold weather. Another problem with using bio-oil is that it can oxidise and turn sour if stored for too long. BioLPG can be produced from many processes that do not violate EU sustainability criteria. Some of these processes include from hydrotreating of oil and fats, and from the fermentation of glucose by bacteria, yeasts or other microorganisms[17].

Developing strong demand for LPG in industrial and commercial applications today would enable a strong platform for a sustainable switch to bioLPG in the future. The Italian distribution chain is already well developed and is able to support the distribution of bioLPG in due course. There are currently two oil refineries in Italy (Porto Marghera and Sicily) where biofuels are produced[18]. This suggests that there is significant scope for deploying biofuels (such as bioLPG) in the future. In addition, Europe is increasing its production of bio-based fuels such as bioLPG. Finland-based Neste is the largest producer of bioLPG, making about 90 kilotonnes/year at three locations.

Damage cost analysis – switching to LPG and bioLPG can lower the cost to society

To better understand the options an industrial, commercial or agriculture business may have for reducing emissions, the following section of this chapter compares and contrasts the social 'damage' associated with combusting a range of different fuels.

When an industrial plant emits CO_2 or NOx into the atmosphere, the pollution it creates is not accounted for by the owner of the plant and therefore the negative impacts are borne by society. Air pollution can have damaging impacts on human health, productivity, amenity and health of the environment. These impacts have an associated economic cost to society.

This social 'damage' can be monetised (known as a 'damage cost') and enables quantification of the inferred cost to society (social cost) from industrial plants and commercial buildings emitting CO_2 or air pollutants into the atmosphere. The damage cost can be measured in euros per unit of combustion (€/MWh) and this enables a consistent comparison across a range of fuels.

Monetising the social cost of carbon emissions requires an associated CO_2 damage cost, expressed in €/tonne. Due to a lack of Italy-specific carbon prices, European-wide carbon prices (expressed in €/tonne) were used instead. This was sourced from the European Bank for Reconstruction & Development (EBRD) who estimate that the average cost of emitting one tonne of CO_2 (non-traded) is €79 between 2020 and 2050[19].

[17] *Annual Review 2018 – Liquid Gas Europe*
[18] *Process Technologies and Projects for bioLPG – MDPI*
[19] *Methodology for the economic assessment of EBRD projects with high greenhouse gas emissions - EBRD*

The EEA produce country-specific damage costs associated with emissions of NOx, $PM_{2.5}$ and PM_{10}. The EEA apply a simplified modelling approach to assess the damage costs to health and the environment, caused by pollutant emissions from industrial facilities. Damage estimates (€/tonne) for Italy were applied to NOx and PM emissions[20].

Figure 11 shows the annual damage costs associated with combusting different types of fuel. The damage costs are expressed in euros per MWh (€/MWh) and reveals the cost to society per unit of fuel combustion. This enables a consistent comparison across a range of fuels.

The analysis shows that the damage cost from oil combustion in the I&C sectors is €84.5/MWh. Simply put, this states the cost to society for every megawatt/hour of oil combusted is ~€85. NOx emissions from oil produces the largest damage cost, accounting for ~40% of total damage costs from oil combustion. Around one-third of the total damage cost can be attributed to CO_2 emissions.

Switching from oil to LPG reduces the total damage costs by 66%. This is mainly driven by a sharp decrease in PM emissions from the combustion of LPG (a clean burning fuel). We estimate that the total damage cost associated with combusting bioLPG is just €10.4/MWh. The main driver for this is the decrease in carbon emissions, compared to oil, the damage cost associated with CO_2 emission from combusting bioLPG would be over 80% lower.

Switching from oil to biomass would lower the damage cost associated with CO_2 emission (~90% reduction). However, air quality is a challenge with biomass consumption. The combustion of wood pellets by businesses would raise damage costs associated with PM emission by 266% compared to oil. The increase in PM-related damage costs is more than enough to offset the decrease in CO_2-related damage costs. Overall, the total damage cost from biomass consumption would rise by 15% relative to oil consumption.

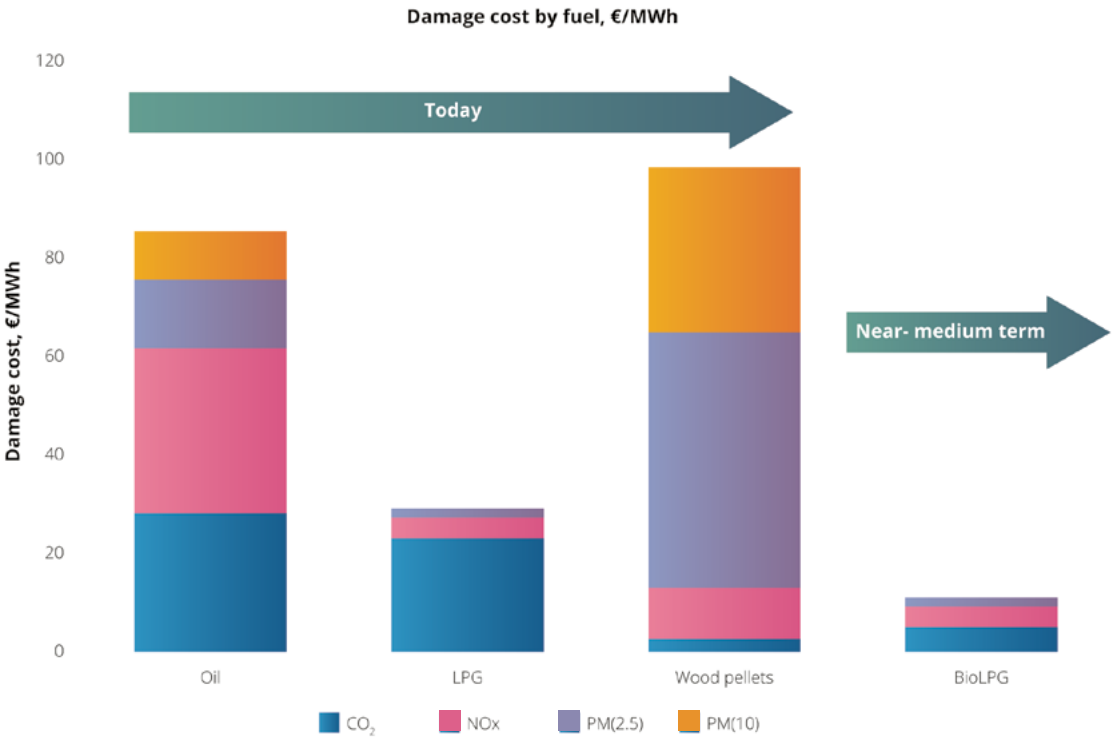


Figure 11: Annual damage cost from various heating fuels (€/MWh) – Ecuity Economics

[20]The underlying methodology to calculate the damage costs was based on the Value of Statistical Life (VSL). This is an estimate of damage costs based on how much people are willing to pay for a reduction in their risk of dying from adverse health conditions (EEA). The VSL methodology has been established as a standard method for measuring the cost of mortalities since the 1960s. Recently the UK and the European Commission have begun to conduct calculations using the Value of a Life Year (VOLY) methodology, although without abandoning VSLs altogether. VOLY estimates the damage cost based upon the loss of life expectancy. This measures considers the age at which deaths occur by giving greater weight to deaths at younger age and lower weight to deaths at older age.

Benefits of switching to LPG: Agriturismi's in rural Italy

Agriturismo is a combination of agricoltura (agriculture) and turismo (tourism) and covers any agriculturally-based operation or activity that brings visitors to a farm. An agriturismo is effectively a farm licensed to provide accommodation. There were 23,406 agritourism farms in 2017, 745 more than the previous year (Istat).

In Italy the term agriturismo refers only to farms. Popular destinations include Tuscany, Sicily, Sardinia and Puglia. Over 84% of agritourism farms are located in mountain and hill areas.

Oil consumption, to satisfy heating and hot water demand, is a popular heating fuel in many agritourism farms. Heat pumps could be used in some agriturismi however, this is an expensive option and its use is likely to be limited.

We estimate that a typical agriturismi with around ten rooms could reduce its energy consumption by ~20% if it were to switch from using oil to LPG. Annual carbon emissions are estimated to fall by 33% after the switch to LPG and this is something the agriturismi's could market to customers, with bioLPG able to drive emissions lower.

LPG has desirable characteristics relevant to agriturismi's. LPG is perfect for those who do not have access to natural gas lines. Since it is easily transported and even able to be stored underground with little danger, many agriturismi's would benefit. LPG can be delivered in bulk or in cylinders, making it a versatile and flexible fuel. It also offers safe and flexible storage options with regular top ups to help ensure that the farm is never without fuel.

"The UK Government, in 2019, legislated to achieving **net-zero greenhouse gas emissions by 2050**."

United Kingdom

Driving Decarbonisation

LPG is lower-carbon than heating oil and coal. An eventual transition to bioLPG can almost completely decarbonise a businesses' operations. This chapter shows how companies in the UK can use LPG to meet their decarbonisation obligations cost effectively and without operation hassle.

The European Commission in 2018 presented its strategic long-term vision for a prosperous, modern, competitive and climate-neutral economy by 2050. Many European countries, including the UK and France, have set their own legally binding net-zero emission target. Action on climate change is considered to be a global megatrend and will be a feature of policy development of the coming years. Such action is supported by EU citizens, of which more than nine in ten (92%) consider climate change to be a serious issue.

In rural Europe, the share of solid and liquid fuels (i.e. coal, heating oil and solid biomass) represents around two-thirds of the energy mix. For European countries to meet their climate ambitions, they need to reduce and eventually eliminate fossil fuel consumption in rural areas. This means transitioning away from high carbon fuels to lower-emission alternatives. For industrial and commercial businesses, it is increasingly challenging to meet emission control standards with oil unabated (e.g. MCPD). Businesses that invest prudently given the direction of the energy transition can support their long-term competitiveness as environmental policies are tightened.

LPG is today, an excellent lower-carbon alternative for businesses in rural, off-grid areas. LPG reduces carbon by around 20% compared to oil and around 30-40% compared to coal[1]. In addition, switching away from an old and inefficient high-carbon heating system to a modern, lower-carbon LPG system would reduce a businesses' energy consumption – further lowering carbon emissions.

Crucially the LPG industry has presented a credible pathway to low-emission fuels which is backed by public commitments made by several of the largest companies in the sector. Businesses switching to LPG today will lock-in and benefit from a gradual and seamless transition to bioLPG over time. BioLPG boasts a carbon intensity that is around 70-80% lower than oil. The gradual increase of bioLPG in the fuel mix will have no impact on the end-user (industrial, commercial or agriculture business) experience and require no change to existing LPG systems.

The following chapter considers how LPG and bioLPG can drive decarbonisation of businesses in the UK, as the first major economy to legislate for a net-zero carbon economy by 2050. Many industrial, commercial and agriculture businesses in rural areas use high-carbon fossil fuels (namely oil and coal) to satisfy process and space heating demand. These businesses will need to switch to a lower-carbon alternative fuel or face becoming uncompetitive in an evolving and intensifying energy transition.

The chapter demonstrates that off-grid businesses in the UK currently using oil, from rural pubs and hotels, to food processing facilities and warehouses can reduce their emissions immediately by switching to LPG and bioLPG. Businesses can benefit from this drive to decarbonise. Indeed, the chapter develops a Scottish distillery case study which illustrates how companies can market sustainability initiatives to drive business value. The analysis shows that LPG and bioLPG systems can support a cost-effective transition to lower emission heating.

[1] *Greenhouse gas reporting: conversion factors 2019 - BEIS*

Opportunities for fuel switching to drive decarbonisation of industrial, commercial and agricultural sectors

The UK is one of the first major economies in the world to target net zero emissions by 2050. Reaching this target will require substantial emission reduction efforts across the UK economy, in a limited timeframe.

Parts of the industrial, agricultural and commercial sector can be seen as an area of immediate opportunity for fuel switching, with large heat demands and older heating systems that can be cost-effectively switched. This chapter focusses on the opportunities available for switching away from oil consumption in these sectors.

LPG and bioLPG can play a crucial role in driving heat decarbonisation across the industrial, agricultural and commercial sector, particularly for sites that are off-the gas grid and for applications that are not suited to an electrical solution.

1. Commercial, industrial and agricultural businesses in the UK will be required to reduce their emissions over the coming years. One of the ways in which this can be achieved is by switching away from the use of high-carbon fuels such as oil and coal to lower emission alternatives. LPG – and an increasing supply of bioLPG – can support the decarbonisation of sections of the industrial and commercial sector in the UK particularly in off-gas grid applications. Particularly commercial businesses located off-grid such as restaurants, pubs and warehouses, farms which use oil and also industrial sites that require low-temperature process heat such as food and drink production plants.

2. Many businesses in the UK are taking a lead in proactively reducing emissions. This chapter includes a case study of a Scottish distillery which reduces its direct emissions from the combustion of oil in its production process by 81% by switching to bioLPG. Businesses like this distillery have the opportunity to publicise their sustainability credentials to create brand loyalty, establish a point of differentiation against competitors, and develop the conditions for premium pricing. Increasingly customers, employees and supply chain partners are putting pressure on businesses to reduce their emissions and switch away from the use of high-carbon fuels like oil.

3. Switching can be achieved cost-effectively. For a commercial business looking to replace their existing oil boiler, switching to LPG could be the most cost-effective option from a resource cost basis. For example, analysis for a rural pub shows that the levelised cost of switching to a new LPG boiler is £78.6/MWh, 15% lower than an in-situ oil heating system. The UK has thousands of rural pubs and restaurants that need cost-effective routes to decarbonisation.

UK

UK reconsiders long-term decarbonisation strategy

The UK Government, in 2008, legislated to commit the country to reduce its greenhouse gas emissions (GHG) by at least 80% compared to 1990 levels. As of June 2019, the UK has revised the 2050 target down to net zero emissions (100% emission reduction on 1990 levels). This strengthens the need to reduce emissions from all sectors of the economy – including industrial and agricultural processes and commercial heating.

Provisional estimates by the UK's Business, Energy and Industrial Strategy (BEIS) department suggest that in 2018, total UK GHG emissions were 43.5% lower than in 1990[2]. Sectoral analysis shows that the energy supply sector and business sector have experienced the largest reductions (59% and 41% respectively) in CO_2 emissions between 1990 and 2018.

The required emission reductions will only be possible if clear, stable and well-designed policies are introduced. According to the Committee on Climate Change (CCC) current policy is insufficient to even meet existing targets.

A key consideration for policymakers will be how the UK can transition away from consuming high-carbon fossil fuels. Total oil consumption in the commercial sector currently stands at 15.8 TWh, with space heating and hot water loads accounting for around two-thirds of total oil consumption[3]. Over the last few years, the median growth in oil consumption has been 2.7% each year. To represent business as usual and using this historic growth rate to project forward to 2050, oil consumption (space heating and hot water) could reach 32.7 TWh. As a result, emissions would increase from 3.6 million tonnes of CO_2 ($MtCO_2$) to 8.7 $MTCO_2$.

Total oil consumption in the industrial sector currently stands at 43.3 TWh, with process and space heating accounting for around 89% of oil consumption. Industrial consumption of oil has been steadily declining with industrial companies switching to natural gas, electricity and bioenergy. As a result, if this downward trend were to continue, by 2050 the level of oil consumption is around 41.2 TWh. As a result, carbon emissions would fall from 13.3 $MtCO_2$ to 10.7 $MtCO_2$.

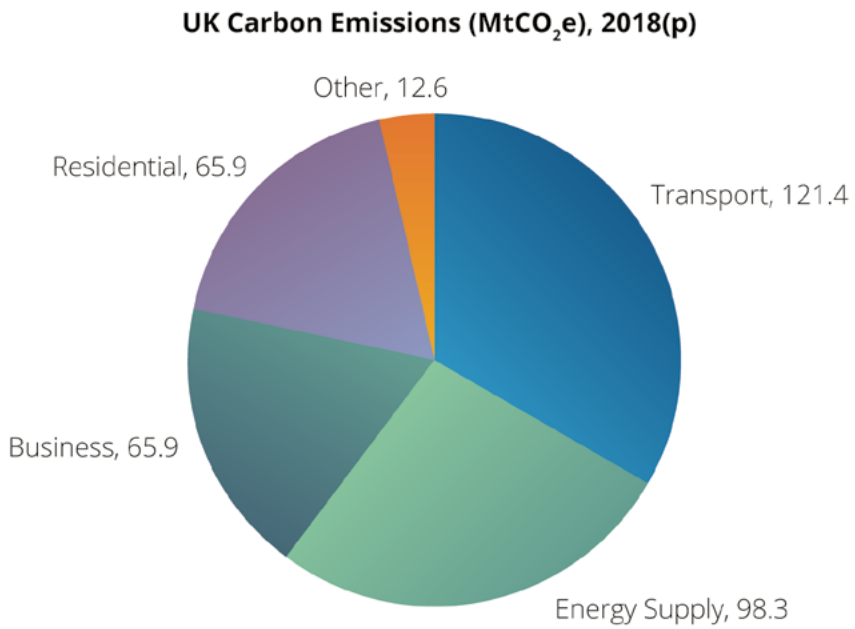


Figure 12 - UK Carbon Emissions ($MtCO_2e$) in 2018 (provisional) (BEIS)

[2] *2018 UK Greenhouse Gas Emissions, Provisional Figures (Department for Business, Energy & Industrial Strategy)*
[3] *Energy Consumption in the UK (2018) – Business, Energy & Industrial Strategy (BEIS)*

Figure 13 illustrates that more needs to be done to transition such businesses away from consuming oil. Policymakers recognise this and will be developing legislation which supports UK decarbonisation in the coming years.

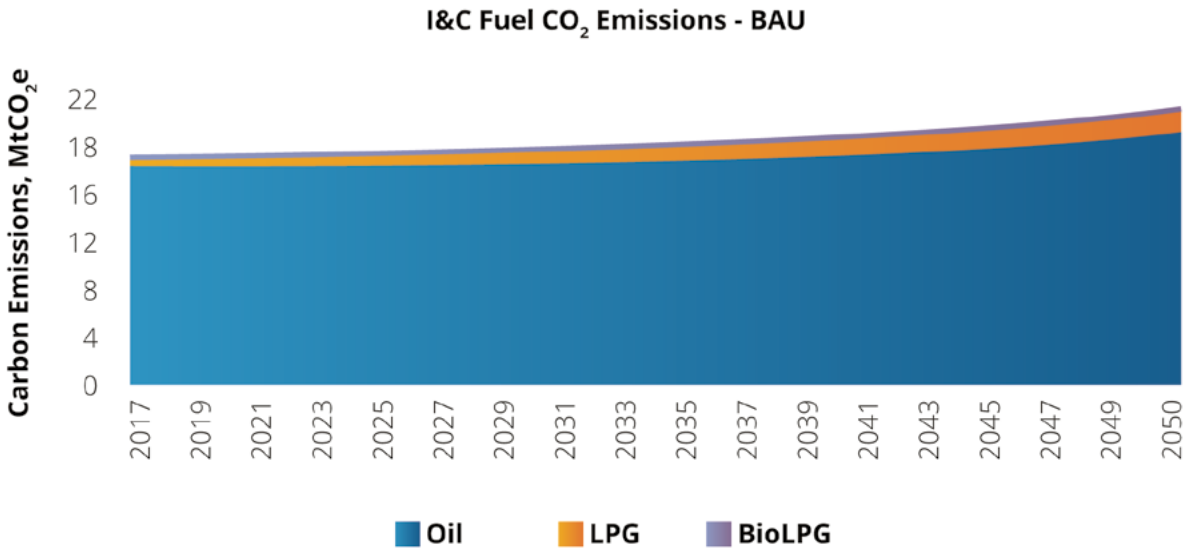


Figure 13 - Industrial & Commercial carbon emissions from oil consumption ($MtCO_2$) – business as usual scenario (Ecuity Economics)

What does this mean for UK business?

The net zero target has focused policymakers' minds and sets a direction of travel for future changes to regulation. This will impact UK business, from large plants which use heavy fuel oil for industrial processes, to small rural pubs and hotels that use kerosene for heating – such high-carbon energy use is inconsistent with the UK's net zero target.

Businesses that use coal and oil – the highest carbon fossil fuels – will be particularly targeted by Government policy. Many of these companies are located off the gas grid and include food and drink processing companies which consumed over 1,400 GWh of oil equivalent (toe) of coal and oil in 2016, and motor vehicle manufacturers who consumed 700 GWh.

Driving business value: reputational advantage of switching away from oil

UK consumers are concerned about climate change. 80% of respondents surveyed by the UK Government in March 2019 reported that they were fairly or very concerned about climate change. This is up from 65% in a similar survey carried out in June 2012, showing that this is a growing issue for the public.

Many consumer-facing businesses have taken the lead by committing to carbon-neutral operations targets, with Jaguar-Land Rover, John Lewis and Marks and Spencer developing notable targets. Indeed, many companies have recognised the benefit from aligning their brand principles with the values of their customers. Climate change is increasingly a significant issue for many consumers and has become a key business target.

Box 1 provides a concrete example of a Scottish distillery that switched away from using heating oil in the whiskey production process, to LPG and its direct renewable replacement, bioLPG. The transition from oil to LPG heating is straightforward, and businesses can immediately benefit from marketing their emission reductions to consumers. This has the potential to support brand loyalty, create a point of differentiation against competitors and create the conditions for premium pricing. For UK businesses currently using oil, a switch to LPG can support a sustainable response to climate change.

> The industrial, agricultural and commercial sectors can utilise bioLPG to achieve **deeper decarbonisation**

Indeed, the LPG industry has a credible pathway to deep decarbonisation through its development and increasing supply of bioLPG. This pathway to renewable fuel supply is supported by notable public commitments made by the largest companies in the industry – with 2040 targeted as a date to achieve 100% renewable energy supply.

The industrial, agricultural and commercial sectors can utilise bioLPG to achieve deeper decarbonisation, and as a renewable and sustainable form of conventional LPG. BioLPG benefits from being chemically indistinct to LPG and is therefore compatible with all existing LPG products, and the supply chain. Compared to heating oil, the carbon emission factor of bioLPG is around ~80% lower – though this varies depending on production process and feedstock.

BioLPG supply to the UK is in its infancy, but volumes are increasing across Europe. In March 2018, Finland-based oil refiner and renewable fuel producer Neste commenced production of the world's first large-scale renewable LPG (bioLPG) production facility in Rotterdam[4]. Neste's new facility has an annual production capacity of 40,000 tonnes, supplying 160,000 tonnes over four years.

A year later SkyNRG, a global market leader, for sustainable aviation fuel (SAF), announced it will develop Europe's first dedicated plant for the production of SAF in Delfzijl, Netherlands[5]. The production facility is scheduled to open in 2022 and will specialise in producing 100,000 tonnes/year of SAF (100,000 tonnes/year) and 15,000/tonnes of bioLPG. KLM has committed itself for a ten-year period to the development of purchase of 75,000 tonnes of sustainable aviation fuel a year.

[4]Neste delivers first batch of 100% renewable propane to European market (Neste)
[5]KLM, SkyNRG & SHV Energy announced project first European plant for sustainable for aviation fuel (SkyNRG)

Benefits of switching to LPG: Distillery in Scotland

There are over 120 active distilleries spread across Scotland, which are split into five whisky-producing regions; Campbelltown, Highland, Islay, Lowland and Speyside. Scotland's brewing and distilling sector plays a vital role in the Scottish economy. It contributes approximately 3% to total Scottish GDP. The economic contribution from the 'spirits and wines' industry was £3.9bn in 2015.

Many distillers and brewers are based in rural communities and most remote distilleries use fuel oil to provide energy for steam, which drives the distillation process. Islay, an island located on the west coast of Scotland, has nine distilleries which burn through 15 million litres of fuel oil every year, costing £8 million per year (Pale Blue Dot Energy).

Switching to LPG can result in running cost and carbon emission savings. LPG is a lower-carbon alternative to fuel oil with a carbon footprint that is around 20% lower than fuel oil.

If a distillery in Scotland were to replace their existing oil boilers with a modern condensing LPG boiler, annual running costs would fall by 2.5% per annum, rising to 3% after accounting for servicing and maintenance costs. This annual saving would enable the distillery to payback the capital cost of the new LPG boiler in under five years which is highly appealing.

Furthermore, if the distillery were to utilise bioLPG from 2030 onwards, then annual carbon emissions fall by 81% lower compared to fuel oil. Air quality would also significantly improve as emissions of NOx would fall by 80%.

Switching to bioLPG could bring additional financial and commercial value to the distillery. The distillery could market and advertise that it is using bioLPG in its production process. Consumers, who are increasingly climate-conscious, are likely to react positively to this and this could increase demand for the product, raising revenues. In addition, moving to a lower-carbon production process (by switching to bioLPG) could encourage suppliers to partner with the distillery, boosting financial performance and clout.

Supporting the cost-effective decarbonisation of businesses located in rural areas of the UK

Whilst there are clear reputational benefits for companies acting more sustainably and the long-term investment case is compelling, the costs of decarbonisation need to be managed carefully to maintain short-term competitiveness. Businesses operating in off-gas-grid areas will be required to transition away from high-carbon fossil fuels like oil but need to do so cost-effectively.

In the commercial sector, there are around 545,000 businesses registered in rural areas, accounting for 24% of all registered businesses in England. There are more registered businesses per head of the population in predominantly rural areas than in predominantly urban areas (excluding London). The main commercial sectors account for around 40% of all businesses in rural areas – accommodation and food services, professional services, transport and storage and wholesale businesses. These businesses are likely to be off-the-gas grid and therefore alternative lower-carbon fuels will have to be sourced to facilitate decarbonisation.

The service sector predominantly consumes oil for heat in buildings, such as workplaces, warehouses, libraries, pubs and hospitals. Hot water use is particularly significant in the health, hospitality emergency services and education sectors, driven by demand for washing facilities. Cooking and catering require heat and are important for many businesses especially those in the hospitality sector.

The commercial sector is a part of the main services sector which consists of hospitality services, storage, offices and retail businesses. The hospitality and storage sectors are the two largest commercial sub-sector that consume oil, accounting for 76% of all oil consumption in the commercial sector. In the hospitality sector (i.e. pubs, restaurants) this is mainly for catering with some use for heating and hot water requirements. In the storage sub-sector (i.e. warehouses) oil is consumed almost entirely for heating purposes.

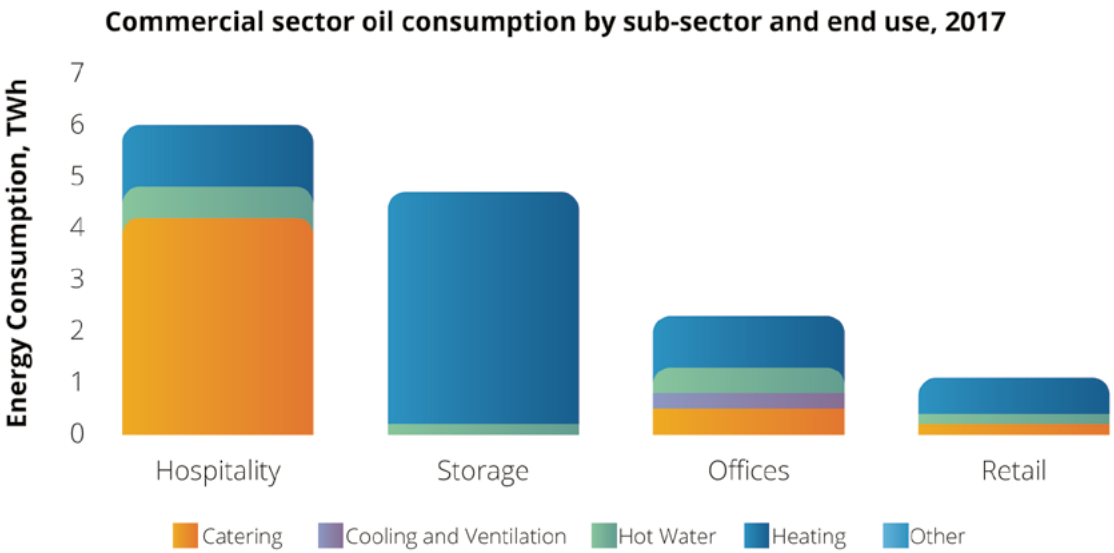


Figure 14 - Commercial sector oil consumption by sub-sector and end use, 2017 (BEIS)

[6] *Rural business statistics (Department for Environment, Food & Rural Affairs)*

Benefits of switching to LPG: Pub in England

The beer and pub industry in Britain contributes £23.1 billion to the economy. Investment in the industry has increased 40%, up from £1.2 billion in 2015 to £2 billion in 2016, and over 49,000 pubs across Britain support nearly 900,000 jobs.

Many rural pubs are not connected to the mains gas grid, so they rely on fuels such as oil to provide hot water, heating, cooking and lighting requirements. There are thousands of pubs in rural England that use heating oil to satisfy heating and cooking requirements.

Switching to a lower-carbon alternative, such as LPG, could hugely benefit pubs in rural locations. These benefits would come in the form of lower running costs and lower carbon emissions.

Savings are possible as the existing old oil boiler (with a lower thermal efficiency) is replaced with a new LPG boiler that operates at a higher thermal efficiency. Given these assumptions, a typical rural pub in England could save around £146/year in fuel bill costs.

This would enable the pub owners to payback the new LPG boiler in 13 years, well within the 20-year lifetime of an LPG boiler.

There are also strong environmental benefits to be achieved with annual carbon emissions falling by 81%, and annual NOx emissions by 80%

To encourage businesses to switch to alternative lower-carbon technologies the economic and financial case must be appealing. Below a social levelised cost is presented for a range of different technologies. A levelised cost of generation shows the lifetime cost of ownership of using a generation asset converted into an equivalent unit cost of generation (£/MWh). We go a step further by monetising the carbon emissions from each generation asset – acting effectively as a carbon price. The impact of this is to value carbon emissions which are not otherwise internalised in market prices.

We assume that a rural pub in England is currently operating an oil boiler and is considering a replacement heating system. There are a number of reasons why a business could be thinking of switching. There could be pressure from the supply chain to reduce emissions, environmental regulation might be getting tighter and more stringent or the existing heating system could be coming to the end of its life.

The business has a number of options and these are modelled below (figure 15). It can opt to replace the old boiler with a new oil boiler, or it can switch to a range of lower-carbon technologies – LPG, bioLPG, heat pumps and biomass.

The most cost-effective option for the rural pub is switching to a conventional LPG heating system. Compared to the in-situ oil boiler, the levelised cost of switching to LPG would be 15% lower (£78.6/MWh). The social levelised cost would fall by over 21% to £108/MWh.

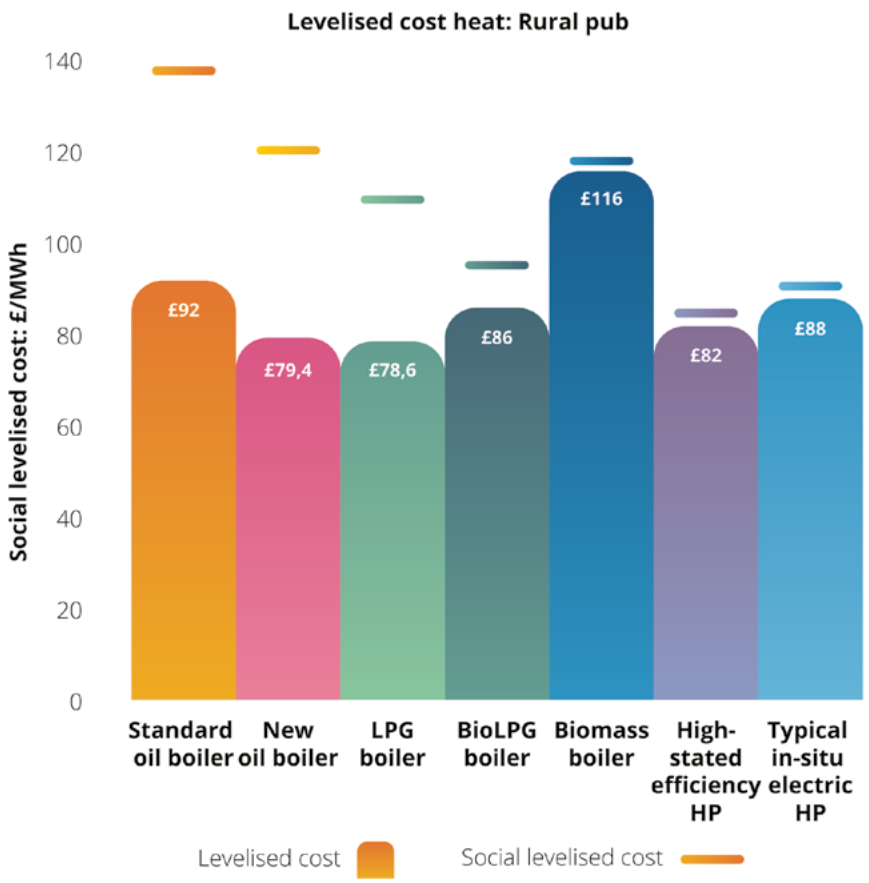


Figure 15 - Levelised and 'social' levelised cost of different heating technologies (£/MWh) (Ecuity Economics)

Replacing the old oil boiler with a new oil boiler would see the levelised cost fall from £92/MWh to £79.4/MWh. The social levelised cost will not fall by as much as the LPG boiler, and this is because oil has a higher carbon intensity than LPG (around 24% higher).

In the longer term, the rural pub can go truly renewable by fuelling the LPG boiler with bioLPG, instead of conventional LPG. The levelised cost of doing this is estimated to be £86/MWh and is cost-competitive against other renewable heating technologies modelled such as heat pumps and biomass boilers. The main benefits from switching to bioLPG is the lower carbon intensity (around 70-80% against oil) and the lower capital cost compared to a biomass boiler and a heat pump.

The electric heat pump has the lowest levelised cost amongst the renewable heating options (£82/MWh), under targeted product efficiency levels – a seasonal performance factor (SPF) of 3. Operating the heat pump in a setting which is less suited to constant, low-temperature heating can result in lower efficiencies – the typical in-situ electric HP figure represents this scenario (SPF 2.65) with a levelised cost of £88/MWh. A rural pub is a good example of where a heat pump may not be able to reach the claimed SPF value, because the building is likely be of old construction with solid walls and low levels of thermal insulation.

	Old oil boiler	New oil boiler	LPG boiler	BioLPG boiler	Biomass boiler	High-efficiency heat pump	Typical in-situ efficiency heat pump
Capex*, £	5,717 (BEIS)	4,900 (BEIS)	4,000 (BEIS)	4,000 (BEIS)	39,235 (BEIS)	27,300 (BEIS)	27,300 (BEIS)
System efficiency, %	75 (BRE/OF-GEM)	88 (BRE/OF-GEM)	92 (BRE/OF-GEM)	92 (BRE/OF-GEM)	80 (Assump-tion)	300 (BEIS)	265 (RHPP/UCL)
Fuel cost, £/kWh	0.063 (BEIS)	0.063 (BEIS)	0.067 (Assump-tion)	0.073 (Assump-tion)	0.055 (SAP)	0.144 (BEIS)	0.144 (BEIS)
CO_2 emis-sion factor, $kgCO_2/kWh$	0.26627 (BEIS)	0.26627 (BEIS)	0.21447 (BEIS)	0.06 (Bilans-GES)	0.01506 (BEIS)	0.06809 (BEIS)	0.06809 (BEIS)
Energy demand, kWh	76,650 (Calc)	76,650 (Calc)	76,650 (Calc)	76,650 (Calc)	76,650 (Calc)	76,650 (Calc)	76,650 (Calc)

Figure 16 - Data table for figure 15
**Include cost of installation. Assume capex of gas boiler similar to LPG boiler.*

Industrial sector: need for high temperature heating

In the industrial sector there is a diverse range of heat requirements and processes – production of iron normally uses coal, whereas high quantities of electricity are needed for aluminium smelting. The mining and quarrying sector is the largest consumer of oil followed by motor vehicles and chemicals sector.

Oil consumption is used mainly for low-temperature processes (39%), which include those that require temperatures of 30-80°C for indirect heating (drying, separation etc), and 80-240°C for direct heating (melting, rolling and kiln firing etc). Oil is also consumed in lower volumes to provide space heating (19%) and to power high-temperature processes (18%). High temperature corresponds to processes requiring temperatures of up to 600°C for indirect heating, and up to 2,000°C for direct heating.

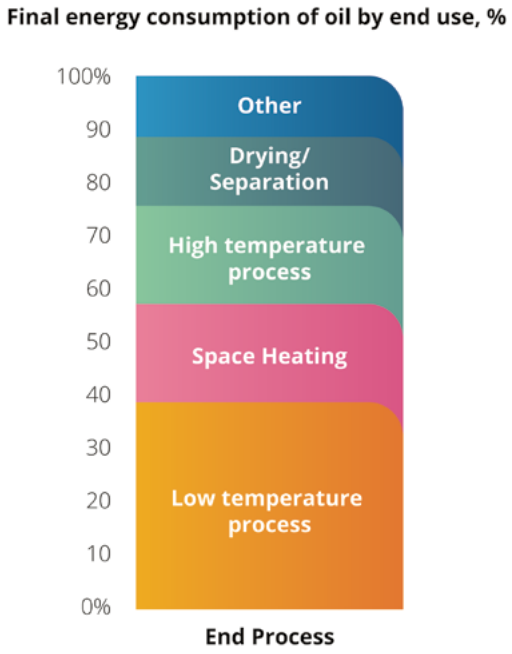


Figure 17 - Industrial final oil consumption by end process, 2017 (BEIS)

The motor vehicles and other industrial sectors typically rely on low temperature processes whereas high temperature processes are prevalent in the glass, ceramics and cement sectors where melting, rolling and kiln firing are more common.

A range of technology solutions will be needed to decarbonise the industrial sector in the UK owing to the diversity of process and building requirements, and the variety of fuel and technology solution characteristics. There is no one silver bullet.

LPG most immediately, and bioLPG over the coming years will play an important role as part of this mix, particularly in off-grid areas, where the supply and storage of fuel is most challenging and a key consideration.

Fuel switching away from heating oil and coal will be needed, and several solutions exist. Electric heat pumps will likely play a role in providing some space heat and very low indirect heating – which is where the technology works best and is most cost-effective – but will be unable to power high temperature processes and can be an expensive option.

Biomass boilers have been identified as one of several technologies which can play a role in the decarbonisation of industrial-sector energy[7]. Whilst some commentators have questioned the use of scarce feedstocks as a source of energy for industrial and commercial heat[8], it is likely that biomass heat will play a role in the decarbonisation mix.

There are certain challenges with the burning of biomass in boilers. BEIS have recognised the air quality implications and challenges created by combusting biomass in populated areas[9]. Additionally, biomass is unsuitable for several direct heating industrial processes, for which a biogas solution would be better suited to the manufacture of glass, ceramics and non-metallic minerals[10].

[7] *Discussion of the Evidence Base: Characteristics of Low Carbon Options (BEIS)*
[8] *Biomass in a low-carbon economy (CCC)*
[9] *Renewable Heat Incentive: biomass combustion in urban areas (BEIS)*
[10] *Industrial Fuel Switching Market Engagement Study (Element Energy and Jacobs)*

Whilst hydrogen is a potential solution for on-gas grid energy users, the impracticability and resulting cost of compressing the gas, distributing it to off-gas grid areas, and storage makes it unsuitable for off-grid sites. Instead, bioLPG – as a low-emission gas – can play a similar role in meeting commercial heating requirements and reducing the emissions from carbon intensive industrial processes. BioLPG is easily transported and stored by an existing supply chain.

BioLPG therefore has an important role to play in offering a long-term and flexible route to decarbonisation for many UK industries, particularly the food and drink, chemicals and vehicle manufacturing sectors that have low temperature indirect heating processes that need to be powered off the gas grid.

> BioLPG has an important role to play in offering a long-term and flexible route to **decarbonization** for many UK industries.

Fuel switching scenario

An Oil Transition Scenario (OTS) is modelled from 2027 onwards to estimate how carbon emissions and air pollution from the I&C sectors could reduce by 2050. In this scenario current oil consumption, that is used to satisfy space heating and hot water demand in commercial applications and process heating in industrial applications, is switched to a mix of lower-carbon technologies. This mix of technologies includes switching to conventional LPG and bioLPG boilers, and electric heat pumps.

The analysis uses a typical annual switching rate away from oil to mix of lower emissions technologies. This assumption was informed by an industrial fuel switching market study by Element Energy and Jacobs[11]. This market engagement study considers the technical potential of industrial fuel switching to hydrogen, biomass and electrification.

The study finds that out of 320 TWh of fuel consumption across energy intensive industries in the UK, the technical potential for fuel switching is found to be 89 TWh in 2040. If industries were to switch to only biomass and electrification, then the technical potential would be 57.9 TWh of replaced fuel consumption each year.

The proportion uptake to each mix of technologies is informed by the Element Energy study on industrial fuel switching. This study highlights the technical potential of switching to biomass/waste or electrification only. The report isolates the switching potential of each individual fuel, and this allows estimation of the proportion of consumption going to the mix of technologies modelled.

For modelling purposes, the uptake of bioLPG has been informed by communications from major LPG players in the UK on their ambitions to be 100% renewable by 2040. We assume that by 2040, at least two-thirds of the LPG market is supplied by bioLPG.

[11] *Industrial Fuel Switching Market Engagement Study (Element Energy and Jacobs)*

It should be highlighted that this is a scenario (for modelling purposes) which is highly dependent on a supportive policy and legislative framework. Policy should be developed which encourages a switch from oil to conventional LPG in the short and medium term. The decarbonisation benefits would be immediate. As LPG volumes increase in the non-domestic sector, this would then enable a sustainable transition to bioLPG over the longer term, driving further and deeper decarbonisation. LPG suppliers would therefore have ample time to sustainably increase bioLPG volumes to cover market demand and, avoid the problems with over-committing and under-supplying.

As noted in the previous section Europe has an initial supply of bioLPG however, this is not mainstream. We assume for modelling purposes that the current bioLPG production for heating (non-transport) is 0.137 TWh. We estimate that 50% is utilised by the industrial and commercial sectors in equal shares, the remaining 50% of consumption is absorbed by the domestic sector.

This fuel-switching policy could see emissions from the I&C sector fall from 18.6 $MtCO_2$ to 3.4$MtCO_2$ by 2050, a reduction of 82% on the level in 2017. Compared to the estimated level of (oil and LPG) emissions in 1990, this represents a reduction of 89% - in line with the UK's net zero ambitions.

By undertaking an active fuel-switching policy, the cumulative damage cost (CO_2) by 2050 is estimated to be around 60% lower against the business-as-usual scenario.

Switching consumption from oil to a range of technologies would improve the air quality situation significantly. Cumulative NOx emissions by 2050 from the mix of technologies would be over 370,000 thousand tonnes lower (43% reduction) compared to the business-as-usual scenario. As a result, the associated damage cost (NOx) would fall by £3,208m cumulatively by 2050.

Damage cost by scenario	Carbon emissions (CO_2)	Air quality (NOx)
Business-as-usual, £m	78,405	7,194
Oil transition, £m	31,638	3,986
Saving, £m	**46,767**	**3,208**

Figure 18 - Industrial & Commercial cumulative damage costs (Ecuity Economics)

From record temperatures across Europe to stark warnings from scientists, climate change is now at the forefront of the public's mind. Policymakers are starting to react to these warnings and are considering policies and solutions that will avert a climate catastrophe. The UK and France were the first to sign into law net-zero emission targets. Other EU countries, and the EU itself, are also moving to this target.

As Europe transitions to a climate-neutral economy, the challenge for commercial, industrial and agricultural businesses is to understand what the transition means for them and their existing business model. Rapid changes to legislation could impact demand for their products and services, and it could create new value in transitioning to lower-emission fuels that have a long-term role in Europe's energy mix.

LPG use supports a move to cleaner air, as the fuel emits almost no particulate matter when combusted securing compliance with regulations and allowing businesses to act as responsible corporate citizens. As the EU and national governments tighten environmental standards and target reductions in air pollution, switching to LPG enables businesses to get ahead of the curve and lock in to a low-emission pathway today that enables seamless bioLPG uptake and renewables integration tomorrow.

As a lower-carbon alternative to oil and coal, switching to LPG (in the short term) and bioLPG (in the longer term) can help businesses decarbonise their operations. Particularly for commercial, agricultural and industrial companies that use high-carbon fossil fuels such as oil, LPG and bioLPG deliver lasting emission reductions. This can be achieved cost-effectively whilst supporting brand messaging.

This switch to LPG can also deliver significant operational benefits for businesses. LPG is a cost-effective solution to satisfy process and space heating demand. It can be easily stored and transported to the most remote parts of Europe, providing flexibility and dependability as an off-grid fuel.

This report shows how switching to LPG can present an immediate win for these businesses. LPG is a lower-carbon alternative to high-carbon fossil fuels such as oil and coal, it is an exceptional energy with exceptional benefits and is an available solution to many of the pressing issues today.

LPG
EXCEPTIONAL
ENERGY

WLPGA