LPG HEATING INCENTIVE POLICIES

A Survey of Why and How Governments Can and Should Encourage Heating With LPG

AUGUST 2021

WLPGA

Liquid Gas Europe

LPG EXCEPTIONAL ENERGY

The World LPG Association

The World LPG Association (WLPGA) is the authoritative voice for the global LPG industry representing the full LPG value chain. The primary goal of the association is to add value to the sector by driving premium demand for LPG, while also promoting compliance to good business and safety practice. With over 300 members in 125 countries, the association brings together private and public companies involved in one, several or all activities of the industry, develops long-term partnerships with international organisations and implements projects on local and global scales. The Association was established in 1987 and granted Special Consultative Status with the United Nations Economic and Social Council in 1989.

The association's multi-faceted mission is to demonstrate the benefits of LPG and inform, educate and influence all stakeholders; to support the development of LPG markets; to promote compliance with standards, good business and safety practices; and to identify innovation and facilitate knowledge transfer.

The WLPGA is based in Paris, France.

For more information visit www.wlpga.org (@worldlpgassociation).

Liquid Gas Europe

Liquid Gas Europe is the sole representative of the LPG industry at the European level, representing national LPG associations as well as distributors and equipment manufacturers from across Europe.

Its mission is to engage with EU decision-makers and the wider policy community in order to optimise the contribution that LPG (and bioLPG) – as a cleaner and immediately available energy source – can make to meeting Europe's energy and environmental challenges.

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Glossary

CHP	Combined heat and power
CO2	Carbon dioxide
EU	European Union
GHP	Gas heat pump
GEHP	Gas engine heat pump
Gt	Gigatonne
HVO	Hydrogenated vegetable oil
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
Kg	Kilogramme
kWh	Kilowatt hour
LGE	Liquid Gas Europe
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
MEPS	Minimum energy performance standard
Mt	Million tonnes
Mtoe	Million tonnes of oil equivalent
NGL	Natural gas liquid
NOx	Nitrogen oxides
OECD	Organisation for Economic Co-operation and Development
R&D	Research and development
SCC	Social cost of carbon
VAT	Value-added tax
WHO	World Health Organisation
WLPGA	World LPG Association

Executive summary

The need to switch to clean fuels like LPG for heating has never been more urgent. About one-quarter of all the final energy used in the world is for space and water heating in buildings. Most heating needs are currently met by dirty fuels, such as heating oil, coal and traditional biomass, often in inefficient ways, or electricity produced largely from fossil fuels. As the world's population expands and people become richer, demand for heating services will continue to grow, threatening to worsen climate change and air quality. Switching to conventional LPG – the cleanest form of fossil energy – could play an important role as a bridging fuel for heating alongside natural gas and renewables in the energy transition to net-zero greenhouse-gas emissions. In the longer term, blending bioLPG into conventional LPG holds the potential to further reduce emissions from heating and provide a cost-effective pathway to full decarbonisation of the buildings sector.

Globally, LPG use for heating amounted to 34 million tonnes in 2019, or around 4% of total energy use for that purpose. The share is much higher in some countries, generally where natural gas grids are less developed (natural gas, where available, is normally preferred to LPG). Worldwide use of LPG for heating has been edging higher in recent years, thanks to growing demand in developing countries. Space heating makes up just under three-quarters of all heating uses of LPG in the buildings sector, almost all of which is in North America, Europe, China and Russia, and around 56% in residential buildings.

The environmental advantages of LPG provide a strong rationale for governments to support its use for heating. As a clean-burning and non-toxic fuel, it emits roughly 84% less nitrogen oxides – the principal precursors of ozone, which produces smog – than oil and almost no particulate matter. These two pollutants are the leading causes of poor air quality in most towns and cities around the world. Coal, biomass and heating oil are the primary sources of particulate emissions from the energy sector. LPG also emits much less unburned hydrocarbons, carbon monoxide, toxics and heavy metals than heating oil and coal.
Compared with other fossil fuels and some biofuels, LPG is also a low-carbon fuel, contributing less to climate change. Unlike natural gas, LPG is not a greenhouse gas. As a heating fuel, LPG can be far less carbon-intensive than electricity, even when the latter is used to power a heat pump, depending on the fuels used to generate power. In countries like China, India, Germany and the United States that rely heavily on coal-fired power stations, heating with electricity results in emissions at least three to four times higher than LPG in the case of electrical resistance-heaters and about twice as high in the case of conventional electrical heat pumps. On average worldwide, the carbon intensity of LPG is approximately 70% lower than that of electricity.

The lower carbon intensity of LPG means that switching to it from heating oil or electricity for space and water heating can result in significant reductions in CO2 emissions. In a high LPG case that simulates the impact of increasing the use of LPG for heating in buildings worldwide by 50% by 2025 and doubling it by 2030 compared with a baseline scenario, global energy-related CO2 emissions are cut by around 70 Mt in 2030 – an amount equal to close to 1.5% of all the CO2 emissions from space and water heating in buildings. The increase in LPG use, which reaches 33 Mt in 2030, could easily be met by a very modest increase in global LPG supply. The CO_2 savings could be even higher with the efficiency improvements that could result from replacing oil boilers with more efficient LPG heating systems, including condensing boilers, highly efficient gas heat pumps and micro combined heat and power units such as fuel cells.

Blending bioLPG, supplies of which are growing, into conventional LPG could significantly lower the carbon intensity of LPG for heating in the coming years, yielding even bigger CO_2 savings. BioLPG – LPG derived from production processes that use renewable biomass as the feedstock – has an identical molecular structure to that of conventional LPG so can be used as a "drop-in" fuel for all current LPG market applications, including heating. BioLPG emits around 70-80% less CO_2 than heating oil on a full life-cycle basis.

Government policies are critical to encouraging the use of LPG for heating in places not served by natural gas grids. There are several ways of doing so, the most important of which involve making LPG competitive with other fuels through fiscal and other incentives. Fuel-pricing strategies – including taxes and subsidies – need to ensure market equality for all technologies. The first step should be to remove subsidies that favour heating oil over LPG and natural gas. Fiscal incentives can be directed at LPG or the technologies that use it. The goal should be to tax all heating fuels according to their relative CO_2 and air pollutant emissions, which implies a lower tax on LPG than heating oil and coal (electricity prices should reflect appropriate taxes on the fuel inputs to power generation) and an exemption for bioLPG. Governments also need to consider the case for subsidising the replacement of existing dirty heating systems with clean technologies, including LPG-fuelled systems.

Governments can also strongly influence the choice of heating technology and fuel through the design of the regulatory framework, including restrictions on the deployment of specific technologies. In view of the urgent need to reduce urban air pollution and cut CO_2 emissions, all governments will need to consider whether to introduce a ban on the installation of heating oil and solid fuel heating systems, at a minimum for new buildings. Some countries have already done so. However, other countries, including the United Kingdom and France, and some US municipalities have also introduced, or plan to introduce, restrictions on the use of gaseous fossil fuels including LPG for heating: these moves threaten to slow the decarbonisation of the buildings sector and raise costs to consumers.

Energy and emissions standards are another crucial area of policy action. At the very least, governments everywhere need to implement and update minimum energy performance standards for heating equipment to steer markets towards clean-energy technologies, including LPG-fuelled boilers. Labelling is also an effective way of raising the awareness of the energy efficiency and emissions performance of alternative heating systems: many countries – including four of the five countries surveyed in this report – have already commenced labelling schemes for heating equipment, but these can be expanded and improved. Information dissemination and education can also form a key element of government-incentive programmes for clean technologies. And governments can support research and development, demonstration and deployment of clean heating technology, either through voluntary agreements with manufacturers and fuel providers or through direct funding of such activities.

It is also vitally important that policy makers recognise the environmental advantages of bioLPG. There may also be a case for explicit subsidies to the use and production of bioLPG, either sold as a pure renewable for of energy or blended into conventional LPG, as well as research and development, alongside other biofuels and renewable energy sources. Incentives for bioLPG will be critical to expanding supplies in the long-term.

There is no "one-size-fits-all" approach to formulating and implementing a government programme of incentives to promote the development of LPG and other clean heating systems. The appropriate strategy for each country depends on specific national circumstances, including budgetary considerations, which might limit available funds for subsidies, the seriousness of local pollution problems, fuel-supply and cost issues, the stage of development of the market and prevailing barriers to fuel switching. The starting point should be to set out a detailed roadmap in consultation with the industry and other stakeholders. Policy stability and a strong, long-term commitment by the government to achieving environmental-policy objectives are crucial to success in promoting switching to LPG.

The types of incentives that encourage LPG for heating use in the five countries surveyed in this report vary:

- In **Chile**, the main incentives include building codes, a sustainable heating programme and information campaigns to encourage switching from firewood to LPG and other clean fuels.
- **France** taxes LPG less than heating oil and electricity, and offers incentives for efficient boilers.
- In **Germany**, a tax rebate is available for LPG used for co-generation while the introduction of carbon pricing for heating fuels and the extension of a ban on the installation of heating oil systems from new to all buildings will increase opportunities for LPG.
- The **United Kingdom** encourages LPG for heating mainly through the absence of an excise tax that is applied to heating oil.
- In the **United States**, federal and state tax credits for efficient LPG boilers and an investment credit for co-generation are available. LPG is also encouraged through federal boiler standards and labelling schemes, research and development programmes and procurement rules

Introduction

Objectives and scope of the study

About one-quarter of all the final energy used in the world is for space and water heating in buildings. Most of those heating needs are met by fossil energy. A growing number of countries around the world are introducing restrictions on the use of certain types of fossil fuel for heating to lower emissions of climate-destabilising greenhouse gases as part of efforts to achieve net-zero emissions in the long term and reduce air pollution. Switching to conventional LPG – the cleanest of all forms of fossil energy – and emerging bioLPG can play an important role in meeting these goals.

The World LPG Association (WLPGA) and Liquid Gas Europe (LGE) engaged Menecon Consulting to conduct a study of government policies to incentivise switching to LPG as a clean fuel for heating in buildings. The study demonstrates why governments should encourage switching to LPG and how they can and should go about doing so. It reviews current policy developments in the field of heating and assesses the socioeconomic benefits of switching from coal and oil to conventional LPG and bioLPG, as well as other gaseous fuels, as part of the long-term transition to totally carbon-free energy use for space and water heating. It also looks at how LPG can be combined with new and innovative technologies such as solar thermal installations, micro combined heat-and-power (CHP), fuel cells or hybrid and gas heat pumps. Finally, it considers what types of policies, such as taxation and financial incentives for consumers, are most effective in encouraging switching and why, and presents a set of recommendations for policymakers.

The work involved a detailed survey of the heating market and government policies affecting fuel switching in five countries: Chile, France, Germany, the United Kingdom and the United States. This involved gathering detailed information on energy use for heating and the contribution of LPG, as well as on policies with respect to heating.

Structure of this report

Part A of this report presents the main findings of the study:

- Section 1 sets out the challenge facing policymakers in creating a sustainable heating market in the face of rising demand and a growing environmental imperative.
- Section 2 provides an overview of trends in the global heating market and the contribution of LPG.
- Section 3 assesses the socioeconomic and environmental benefits of switching to LPG and bioLPG for heating.
- Section 4 reviews the different LPG heating technologies commercially available or under development.
- Section 5 reviews the types of policies and measures at the disposal of governments to encourage switching to LPG for heating, reviews how those policies are deployed and affect LPG use in the countries surveyed, and sets out broad recommendations for policy action.

Part B presents the detailed results of the five surveys of the heating sector by country. References and a note on data sources are included in the annexes.

PART A: MAIN FINDINGS

1 The heating challenge

Heat is a basic human need and a gauge of comfort and well-being everywhere. As the world's population expands and people become richer, demand for heating services in buildings is rising – especially in the dynamic Asian economies, Africa and Latin America. Meeting those needs means installing more heating systems and procuring the raw energy to run them. Growing heating needs is a sign of greater prosperity, but they carry the risk of damaging our environment as increased use of traditional fuels, heating oil and coal contribute to local air pollution – the leading threat to public health worldwide – and climate change. The need to switch to cleaner fuels like LPG has never been more urgent.

1.1 Meeting the growing demand for heat

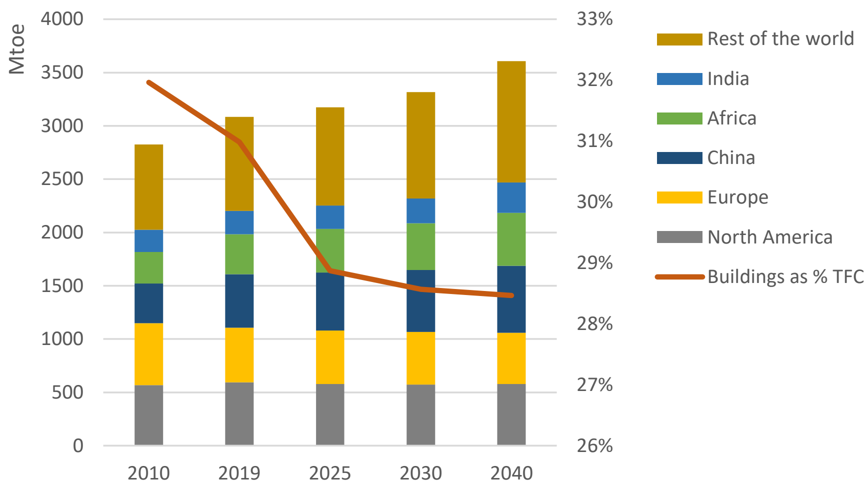
Despite long-standing and continuous efforts to improve the energy efficiency of space and water heating systems, the demand for energy for producing heat continues to rise steadily in most parts of the world in response to growing populations and economic activity. As the number of buildings[1] increases to house and cater for a growing population, and as people become wealthier, demand for hot water and space heating appliances – both individual units and integrated central heating systems – in homes and offices inevitably increases. The gradual increase in average global temperatures associated with climate change has, so far at least, had little impact on the growth in heating demand, though it is pushing up cooling demand.

Demand for heat will almost certainly keep on rising for the foreseeable future in view of the close and relatively stable correlation that exists between the size of the global economy and the underlying demand for heating services. Rising heating needs is an inevitable consequence of rising building floor space and comfort levels. Official projections bear this out. In the baseline scenario of the International Energy Agency's (IEA) latest World Energy Outlook, which takes account of stated government policies including official targets and plans, total energy use worldwide in buildings – the bulk of which is for space and water heating – is projected to grow by 21% between 2018 and 2040 (Figure A1.1). Most of the increase in those energy needs continues to come from the emerging economies of Asia, Africa and Latin America, where population and economic activity are expanding most rapidly.

Energy use in buildings in North America and Europe is projected to stagnate, largely due to their slower rates of population growth, saturation effects and continuous investment in more energy-efficient buildings and heating systems. The share of buildings in total final energy use worldwide is projected to level off at around 30% over the next two decades – only slightly lower than at present.

[1] The buildings sector in this report refers to residential, public and commercial properties.

Figure A1.1: Buildings final energy consumption by region in the IEA Stated Policies Scenario[1]



TFC = total final consumption.

1.2 Tackling air pollution

The choice of fuels to meet rising demand for heat in the coming decades will have far-reaching consequences for air quality. At present, the bulk of the world's heating needs are met by fossil fuels – mainly natural gas and heating oil (kerosene) – and, in poorer countries, traditional biomass (see the next section). In some countries, notably China, coal is still an important fuel for household heating, especially in rural areas close to coal mines. With the exception of natural gas, these fuels are highly polluting.

Air pollution has a devastating impact on public health. The World Health Organization (WHO) estimates that nine out of ten people around the world breathe polluted air every day, causing around seven million premature deaths each year[2] – more than twice the death toll from COVID-19 to June 2021. This shocking mortality is largely due to exposure to fine particles in polluted air – mainly from the burning of dirty fossil fuels – that penetrate deep into the lungs and cardiovascular system, causing diseases such as stroke, heart disease, lung cancer, chronic obstructive pulmonary diseases and respiratory infections, including pneumonia. Outdoor air pollution alone caused 4.2 million deaths in 2016, while indoor pollution from burning dirty fuels and technologies caused an estimated 3.8 million deaths in the same period. According to new research from Harvard University, in collaboration with the University of Birmingham, the University of Leicester and University College London, air pollution caused solely by pollution from coal and oil was responsible for 8.7 million deaths globally in 2018, a staggering one in five of all people who died that year; the share is highest in Asia, at 30%.[3] Air pollution also causes ill-health and the loss of productivity among millions more.

[1] IEA (2020a)
[2] https://www.who.int/news/item/02-05-2018-9-out-of-10-people-worldwide-breathe-polluted-air-but-more-countries-are-taking-action
[3] https://www.seas.harvard.edu/news/2021/02/deaths-fossil-fuel-emissions-higher-previously-thought

Burning dirty fuels for space and water heating is a major contributor to both outdoor and indoor pollution. The former is particularly prevalent in urban areas, while indoor pollution is more of a problem in rural settings. The biggest burden is in developing economies, where more than 2.6 billion people still do not have access to clean fuels for cooking and heating (IEA, 2020), while the rate of access to clean fuels and technologies is increasing everywhere, improvements are not even keeping pace with population growth in many parts of the world, particularly in sub-Saharan Africa. Air pollution is not just a poor-country problem: according to the WHO, air pollution has been shown to lower average life expectancy by anywhere between two and 24 months, depending on pollution levels in cities of high-income countries in Europe. Road traffic is the leading source of air pollution in these cities, but dirty heating fuels burned in homes and offices often make a significant contribution.

The use of dirty fuels for heating can also give rise to other forms of environmental degradation. Demand for biomass can lead to deforestation, while the use of animal waste degrades soil quality. Burning heating fuel and coal can give rise to a phenomenon known as acid rain, whereby emissions of sulphur dioxide and nitrogen oxide react with the water molecules in the atmosphere to produce acids. Acid rain has been shown to have adverse impacts on forests, freshwaters and soils, killing insect and aquatic life-forms, damaging infrastructure such as bridges through corrosion of steel and accentuating the weathering stone buildings and statues.

1.3 Addressing climate change

There is also an urgent need to step up efforts to curb emissions of greenhouse gases associated with energy use in buildings. Climate scientists agree that there is a strong and incontrovertible link between global emissions of greenhouse gases caused by human activity, the concentration of those gases in the atmosphere and average global temperatures of the air, land and sea. The bulk of CO2 and other greenhouse gas emissions come from the production and use of fossil energy. According to the Inter-governmental Panel on Climate Change (IPCC), global net emissions of greenhouse gases including CO2 would need to fall by 45% between 2010 and 2030 and to zero by around 2050 to be on track to meet the long-term goal of limiting the temperature increase to 1.5 degrees under the 2015 Paris Agreement (IPCC, 2018).

The decarbonisation of energy use in buildings will be vital to achieving climate goals. Buildings contribute around 30% of global energy-related CO2 emissions – 8% directly from the burning of fossil fuels indoors and the remaining 22% indirectly from producing the electricity used in buildings using fossil fuels. Reducing buildings-related emissions will, therefore, need to involve a shift to less carbon-intensive fuels alongside the decarbonisation of power generation.

There is increasing recognition of the need for stronger action to address climate change across all sectors. A growing number of countries and regional jurisdictions have adopted targets for achieving net-zero emissions of greenhouse gases. For example, in 2019, the European Union agreed to adopt a net-zero target for 2050; China adopted a similar target in October 2020 for 2060. In addition, more than 1,100 businesses and 45 of the world's biggest investors have already set net-zero targets. Yet these moves still fall well short of what is required collectively to reach global net-zero emissions by the middle of this century. In the IEA's baseline scenario, which takes account of nationally determined contributions under the Paris Agreement, global energy-related CO2 emissions are projected to remain flat through to 2040 at around 33 gigatonnes, implying a temperature increase of around 2.7 degrees Celsius by 2100 (IEA, 2020a). This is in spite of a marginal 1% fall in buildings-related emissions over the same period.

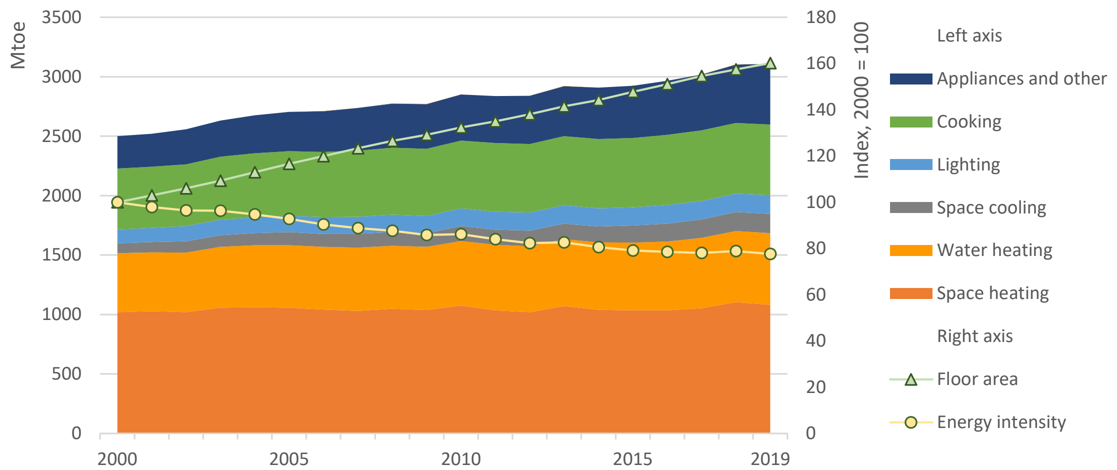
2 LPG and the global heating market

LPG is one of several fuels that can be used for providing space and water heating – the single largest energy end-use category in buildings worldwide. Globally, LPG accounts for around 4% of total energy use for heating, but the share is much higher in some countries. Worldwide use of LPG for heating has been edging higher in recent years, thanks to growing demand in developing countries, especially for hot water.

2.1 Heating market trends

The buildings sector – households and commercial and public offices – consumed around 3,080 million tonnes of oil equivalent (Mtoe) worldwide in 2019, accounting for 31% of all the final energy consumed and almost 53% of global electricity consumption. Residential buildings make up about 70% of total energy use in buildings. Buildings sector energy demand rose by nearly one-quarter between 2000 and 2019, as energy intensity reductions (due largely to efficiency gains) were insufficient to fully offset rapidly growing floor area and rising demand for energy services. (Figure A2.1). This trend is expected to continue as the number of buildings grows: building floor area is expected to double by 2070 – the equivalent of adding the built surface of Paris to the buildings stock every week (IEA, 2020a).

Figure A2.1: Global buildings sector energy use by end-use, floor area and energy intensity[1]



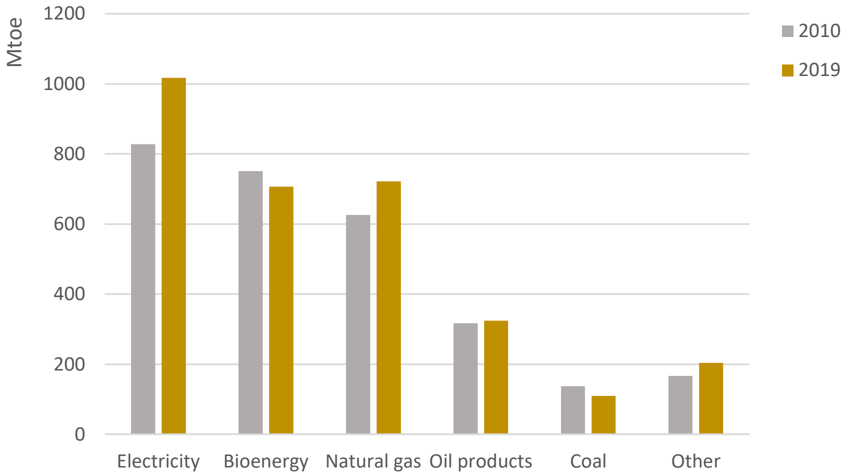
Note: "Appliances and other" includes major household appliances such as refrigerators, clothes washers and dryers, dishwashers and televisions as well as small plug-loads and energy use related to other electrical equipment (e.g. printers, computers and network servers).

Building energy needs are currently met by a variety of fuels and forms of energy. Electricity is the leading fuel, used mainly for appliances, electrical equipment and, in some cases, space and water heating. Bioenergy – mainly traditional biomass – and natural gas, used for both heating and cooking, make up the bulk of the rest of buildings energy use. Oil products, including LPG, accounted for 11% of total buildings energy use worldwide in 2019. Heating

[1] IEA (2020b), adapted from "Energy Technology Perspectives 2020", https://www.iea.org/reports/energy-technology-perspectives-2020. All rights reserved.

oil[1] is used mainly for heating and, in poorer countries, for cooking. Coal accounted for just 4% and district heating for most of the remaining sources of heat. Fuel shares vary widely across regions: the share of bioenergy is generally much higher in developing countries, while the share of electricity is highest in the most advanced economies. Generally, the share of natural gas is highest in the northern hemisphere countries with cold winters.

Figure A2.2: Buildings final energy consumption by fuel[2]



Space heating is the single largest energy end-use category in buildings, followed by cooking and water heating. Space and water heating combined consumed 1,685 Mtoe in 2019, of which space heating made up 1,082 Mtoe, according to data provided by the IEA (Box A1.1). Energy use for space heating has been broadly flat in recent years, while that for water heating has been growing steadily. This mainly reflects the considerable investment that has been made, mainly in northern hemisphere countries, in thermal insulation of existing buildings, which has cut energy needs, offsetting the increase in the stock of buildings and total floor space. Around three-quarters of all the energy used for heating worldwide is consumed in the United States, the European Union, China and Russia.

Heating is the most carbon-intensive building end-use and the single largest source of buildings CO2 emissions. Building operations account for around 30% of global energy-related CO2 emissions (including indirect emissions from power and heat generation); heating is responsible for around 45% of building emissions. Around 4.3 Gt of CO2 were released to the atmosphere in 2019 for heating in buildings (including indirect emissions). This represents nearly 13% of global energy-related CO2 emissions.

Box A1.1: Data on energy use for heating

Comprehensive annual data covering residential and services sector energy consumption by fuel is available online from the IEA (for a fee) for all countries up to 2018.[3] Regional and world totals for major fuel

[1] There are several different types of oil products used for space and water heating, most of which are middle distillates. Precise specifications and names vary by country and region. They include paraffin, domestic oil, kerosene, burning oil and light fuel oil. For the purposes of this report, they are referred to generically as heating oil.

[2] IEA (2020a).

[3] Details about the IEA databases can be found at https://www.iea.org/subscribe-to-data-services.

categories (including oil but not LPG alone) for total buildings energy use are available for 2019 from the IEA's World Energy Outlook 2020, published in November 2020. Data for space and water heating for major fuel categories (but not LPG) for 2018 are also available online from the IEA (in a separate database) for several countries (mainly advanced economies), but not for the world as a whole (the IEA has nonetheless published some global totals up to 2017 for heating). In some cases, there are inconsistencies between the data contained in the two datasets.

Data on LPG consumption up to 2019 is available from the 2020 edition of the annual statistical review published jointly by the WLPGA and Petroleum Argus for LPG consumption by sector, but not for specific end-use applications such as heating or cooking. There are some minor discrepancies between the IEA and WLPGA/Argus data, in part due to methodological differences. For Chile, detailed official data on the use of LPG for heating is available for 2018 only. For the other countries surveyed in this report and for the world, Menecon Consulting has estimated LPG use for heating using bottom-up assumptions and indicative estimates of the breakdown of oil use by product and shares of heating and cooking in total LPG consumption.

Major technology advances and policy initiatives have generally helped to stabilise global CO2 emissions related to space heating over the past decade, despite a 20% growth in heated floor area. More stringent building energy codes reduced thermal energy demand per square meter for new buildings by an estimated 30% in Europe, 35% in Japan and 20% in the United States between 2000 and 2019. In addition, the deployment of more efficient heating technologies, including condensing boilers and heat pumps, has reduced the energy needed to heat a given amount of space or volume of water.[1] However, low-efficiency heating technologies, including conventional coal, oil and gas boilers, as well as basic electric resistance heaters, still dominate heat production in most buildings.

2.2 Use of LPG as a heating fuel

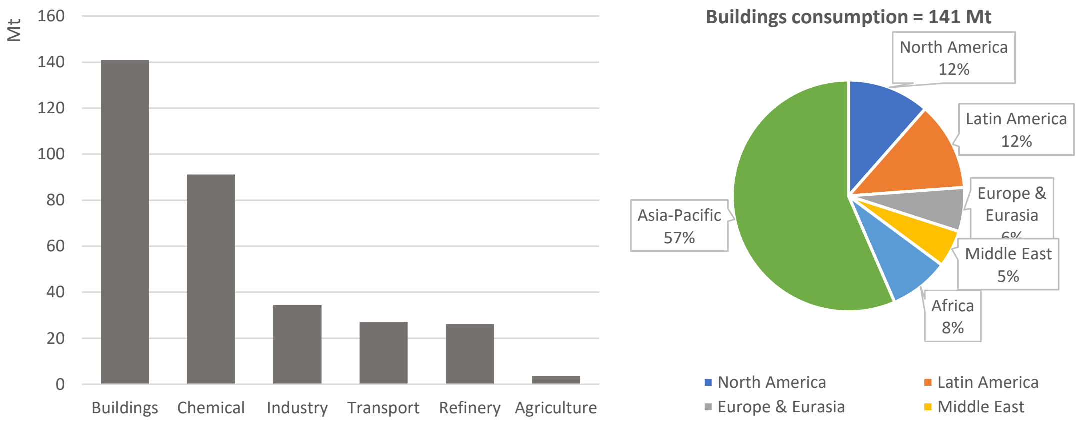
Heating is a leading use of LPG worldwide. Global consumption of LPG amounted to 323 million tonnes (around 370 Mtoe) in 2019, of which 141 Mt (161 Mtoe), or 44%, was consumed in buildings (

Figure A2.3). The Asia-Pacific region is by far the biggest consumer of LPG in buildings, accounting for 57% of the world total. Of that consumption, an estimated 34 Mt (39 Mtoe) or one-quarter of all the LPG consumed in the buildings sector, was used to provide space and

[1] https://www.iea.org/commentaries/is-cooling-the-future-of-heating

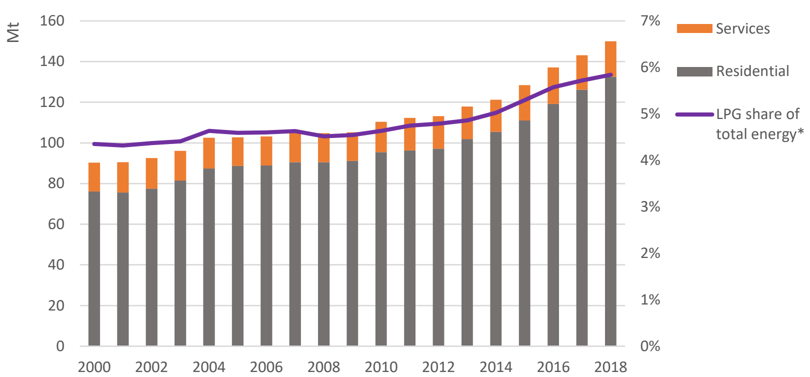
water heating – an amount exceeding all the LPG used in industry or as a transport fuel (Autogas), but much less than that used for cooking.[1]

Figure A2.3: World final energy consumption of LPG by sector and buildings use by region, 2019[2]



The use of LPG in buildings – and the share of LPG in total energy use in that sector – has been rising steadily over the last two decades (
Figure A2.4). The rate of growth in consumption has been fastest in the residential sector, which accounted for close to 90% of total LPG use in buildings in 2018.[3] Since 2000, the share of LPG in total buildings energy use has risen from 4.4% to 5.8%, exceeding that of heating oil (4%), but much less than that of electricity (32%) and natural gas (24%).

Figure A2.4: World final energy consumption of LPG in buildings by sector[4]



* Based on energy content.

Note: IEA data shows higher LPG consumption in buildings than WLPGA/Argus data.

[1] LPG used for cooking worldwide is estimated to have totalled around 115 Mt (130 Mtoe) in 2018, up from just 53 Mt (60 Mtoe) in 2000.
[2] WLPGA/Argus Media (2020).
[3] The breakdown of buildings LPG use by residential and services is not available in the WLPGA/Argus data.
[4] IEA databases; Menecon Consulting analysis.

Box A1.2: What is LPG and what is it used for?

LPG is the generic name for mixtures of hydrocarbons that change from a gaseous to liquid state when compressed at moderate pressure or chilled. The chemical composition of LPG can vary but is usually made up of predominantly propane and butane (normal butane and iso-butane). In some countries, the mix varies according to the season as the physical characteristics of the two gases differ slightly according to ambient temperatures.

LPG is obtained either as a product from crude-oil refining or from natural-gas or oil production. At present, more than 60% of global LPG supply comes from natural gas processing plants (WLPGA/Argus, 2020), but the share varies markedly among regions and countries. With both processes, LPG must be separated out from the oil-product or natural gas liquid (NGL) streams. LPG is generally refrigerated for large-scale bulk storage and seaborne transportation as a liquid, while it is transported and stored locally in pressurised tanks or bottles (cylinders). LPG can also be obtained from production processes using renewable feedstock, in which case it is known as bioLPG (see Section 4).

LPG has high energy content per tonne compared with most other oil products and burns readily in the presence of air, making it a highly versatile fuel that can be used in a wide range of applications, from water and space heating, to cooking and to use as an alternative transport fuel. LPG is used in all the major energy end-use sectors:
Residential sector: LPG is well suited for cooking, and space and water heating. In some developing countries, it is also used for lighting where electricity is not available. In developed countries, it may be used for outdoor activities such as barbecues and camping.

Agriculture: LPG is used to increase the production and the quality of farm products through weed flaming, crop harvesting and crop drying. It is also used to heat breeding houses for pigs and poultry and power farm equipment such as irrigation pump engines.

Commercial sector: Applications include commercial cooking (restaurants and small and large-scale catering), and water and space heating in offices and other commercial premises.

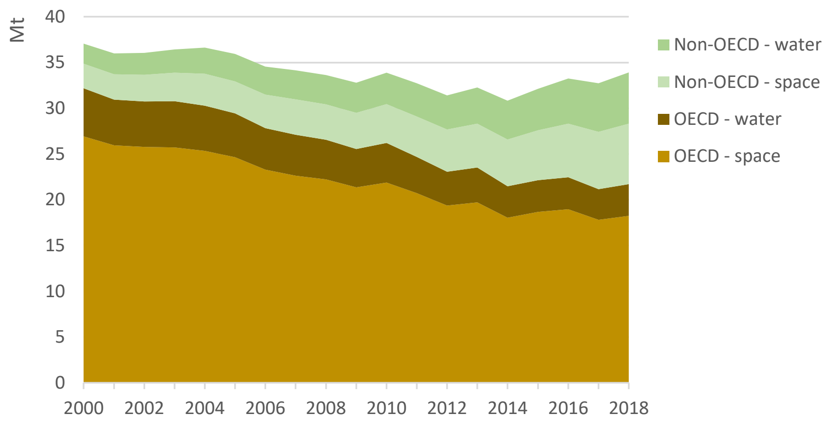
Industry: LPG is used in a wide range of industrial processes and activities, notably where a high degree of precision and flexibility in process temperatures – as well as a strong flame – are required. Common applications include heat treatment furnaces, direct firing of ceramic kilns, glass working, textile and paper processing, and paint drying. LPG can also be used as back-up fuel for electricity generators, including hybrid renewable energy systems in remote locations.

Transport: LPG is increasingly used as a low-emission alternative to gasoline and diesel for taxis, buses and private cars.

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

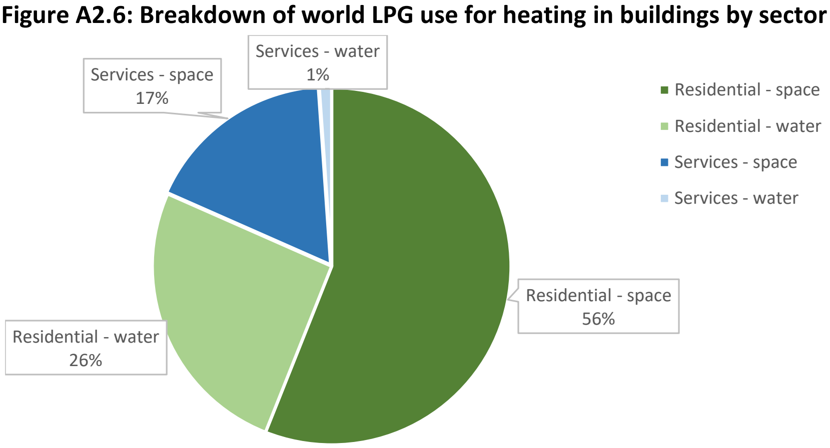
Worldwide use of LPG for space and water heating in buildings has been edging higher in recent years, after several years of decline. Regional trends differ markedly, with consumption declining steadily in Organisation for Economic Co-operation and Development (OECD) countries over the last two decades but rising in the rest of the world (
Figure **A2.5**). Globally, LPG accounted for around 4% of total energy use for heating in 2018.

Figure A2.5: World final energy consumption of LPG for heating in buildings use by region[1]



Space heating in residential buildings is the single largest category of LPG use for heating, accounting for 56% of the total worldwide (Figure A2.6). Space heating accounts for almost all of the LPG used for heating in the services sector. In the buildings sector as a whole, space heating makes up just under three-quarters of all heating uses, almost all of which is in North America, Europe, China and Russia.

Figure A2.6: Breakdown of world LPG use for heating in buildings by sector and type, 2018[2]



[1] Menecon Consulting analysis.
[2] Menecon Consulting analysis.

3 The rationale for heating with LPG

As a clean-burning, low-carbon gas, LPG from conventional sources can play an important role as a bridging fuel for heating alongside natural gas and renewables in the energy transition to net-zero greenhouse-gas emissions. Blending bioLPG, supplies of which are growing, into conventional LPG holds the potential to further reduce emissions from heating in the coming years and provide a cost-effective pathway to full decarbonisation in the buildings sector. Thanks to its portability and highly flexible distribution network, LPG is readily available and, with supplies set to expand further, will remain so well into the future.

3.1 A clean fuel

The main rationale for governments to support the use of LPG for heating, as with other end-uses, is the environment. LPG is a clean-burning fuel, emitting fewer emissions of noxious pollutants and CO2 than most other fossil fuels. Because LPG is made up of chemically simple and pure hydrocarbons, it mixes easily with air allowing almost complete combustion. It emits roughly 84% less nitrogen oxides (NOx) – the principal precursors of ozone, which produces smog – than oil and emits almost no particulate matter, or soot – the leading causes of poor air quality in most towns and cities around the world. Coal, biomass and heating oil are the primary sources of particulate emissions from the energy sector. LPG also emits much less unburned hydrocarbons, carbon monoxide, toxics and heavy metals than heating oil and coal. LPG gives rise to negligible emissions of toxic gases that can cause serious health problems if breathed in close to the point of combustion. LPG is non-toxic, so it cannot contaminate soils or aquifers.

Compared with other fossil fuels and some biofuels, LPG is also a low-carbon fuel, contributing less to climate change. LPG from conventional sources (oil refining and natural gas processing) has a CO2 emissions factor (tonnes of CO2 emitted per unit of energy contained in the fuel) about 16% lower than that of heating oil and over one-third lower than that of coal.[1] Although the factor is slightly higher than for natural gas, emissions are often similar and can be lower due to the higher efficiency of some LPG-fired heating technologies. In addition, emissions caused by accidental leakages of natural gas – an extremely powerful greenhouse gas – can be significant; by contrast, LPG is not a greenhouse gas if accidentally released, which is in any case rare. LPG also emits much less black carbon – a component of fine particulate matter formed through incomplete fuel combustion that contributes to global warming – than non-gaseous fossil fuels.[2]

As a heating fuel, LPG can be far less carbon-intensive than electricity, even when the latter is used to power a heat pump. The relative carbon intensity depends mainly on the thermal efficiency of power generating plant, transmission and distribution losses, and the fuel mix. In countries like China, India, Germany and the United States that rely heavily on coal for power, heating with electricity results in emissions at least three to four times higher than

[1] Based on US Environmental Protection Agency data (https://www.epa.gov/sites/production/files/2015-07/documents/emission-factors_2014.pdf).
[2] Black carbon warms the Earth by absorbing sunlight and heating the atmosphere, as well as by reducing the albedo effect directly when deposited on snow and ice and indirectly by interacting with clouds.

LPG in the case of electrical resistance-heaters and about twice as high in the case of conventional electrical heat pumps. On average worldwide, the carbon intensity of LPG is approximately 70% lower than that of electricity.

The lower carbon intensity of LPG means that switching to it from heating oil or electricity for space and/or water heating can result in significant reductions in CO2 emissions in the near to medium term. In this sense, LPG may be seen as a bridging fuel in the energy transition. In the longer term, electricity is expected to be largely generated using renewable energy sources. But there will probably still be a need for some fossil energy both for direct uses for heating and for generating electricity (possibly in conjunction with carbon capture and storage), due to constraints on the availability of renewables in some regions and the need for back-up capacity for variable renewables like solar and wind power (IEA, 2020b).[1]

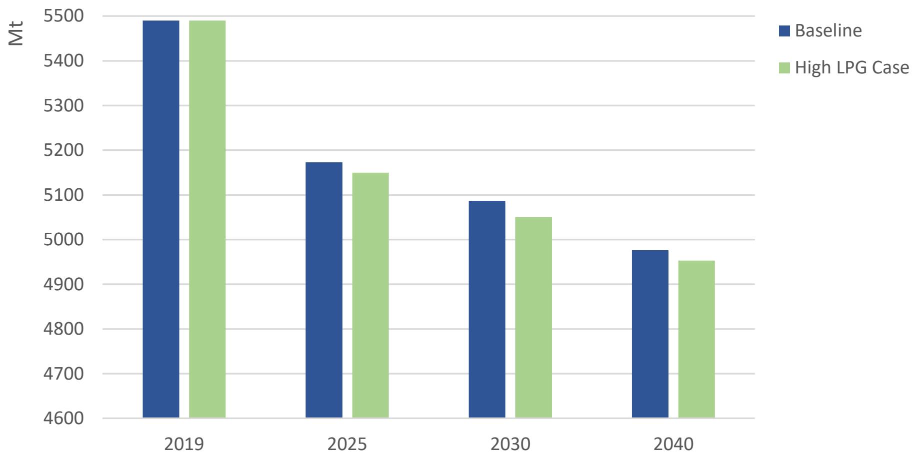
We devised a High LPG Case to test the impact of increasing the use of LPG for heating in buildings worldwide by 50% by 2025 and doubling it by 2030 compared with the IEA's baseline scenario (Stated Policies Scenario) in its latest World Energy Outlook (IEA, 2020b). That scenario takes account of current and planned policies, including nationally determined commitments under the Paris Agreement. It was assumed that half of the additional use of LPG would displace heating oil (which is widely used for heating in developing countries) and the other half electricity (which is a common source of heat in areas off the natural gas grid in the advanced economies). The total use of energy for heating is assumed to be unchanged.

In that Case, we project that worldwide energy-related CO2 emissions would be cut by around 70 Mt in 2030 relative to the baseline scenario – an amount equal to close to 1.5% of all the CO2 emissions from space and water heating in buildings (Figure A3.1). The savings fall to just over 40 Mt in 2040, because electricity becomes progressively less carbon-intensive as the global share of renewables in the power generation fuel mix expands. The increase in LPG use in the High LPG Case, which reaches 33 Mt in 2030, could easily be met by a very modest increase in global LPG supply, equal to just 8% of that projected by the IEA (see below).[2]

[1] In recognition of the need for low-carbon fossil fuels to provide backup power, the European Commission is reportedly considering a change in the rules that would classify electricity generated using LPG or natural gas as eligible for green finance under certain conditions (https://www.euractiv.com/section/energy-environment/news/leak-eu-considers-expanding-role-of-gas-in-green-finance/).

[2] An increase in global LPG supply could be achieved by faster growth in natural gas production, as the bulk of LPG today comes from NGLs. If the additional gas supply were also to be used entirely to displace heating oil and electricity in the buildings sector, the overall CO2 emissions savings would be much higher.

Figure A3.1: World CO2 emissions from space and water heating in buildings in the High LPG Case[1]



Note: Emissions include indirect emissions from power generation. The baseline scenario is the IEA's Stated Policies Scenario.

The CO2 savings could be even higher than those projected in the High LPG Case. Our analysis does not take account of the efficiency improvements that would result from replacing less efficient oil boilers with more efficient LPG heating systems, including condensing boilers, highly efficient gas heat pumps (GHPs) and micro combined heat and power (CHP) units such as fuel cells (see the next section). In Germany, a recent study suggests that significant additional savings could be achieved there through efficiency improvements by replacing inefficient existing heating oil boilers with highly condensing boilers fuelled by LPG in off-grid locations (DBI, 2020).

Blending bioLPG, supplies of which are growing, into conventional LPG holds the potential to significantly lower the carbon intensity of LPG for heating in the coming years, yielding even bigger CO2 savings. BioLPG – sometimes called biopropane – refers to LPG derived from production processes that use biomass as the feedstock, usually as a co-product. The molecular structure of pure biopropane is identical to that of conventional pure propane produced from hydrocarbons, so can be blended into LPG or sold in a pure form. As a genuine "drop-in" fuel, it can be used in all current LPG market applications, including for heating. BioLPG emits around 70-80% less CO2 than heating oil on a full life-cycle basis, depending on the extent to which the biomass feedstock comes from renewable sources, providing a cost-effective pathway to decarbonisation for commercial businesses and the residential sector (WLPGA, 2019). The emission savings can be even bigger when bioLPG is consumed in a GHP or micro-CHP and when energy efficiency measures are undertaken.

The prospects for using bioLPG for heating depend critically on investment in production facilities and supply chains. Global production of bioLPG increased by half between 2014 and 2018 to around 200,000 tonnes and could rise to 300,000 tonnes in 2022 (Atlantic Consulting, 2018). The bulk of the recent increase in bioLPG supply has come from hydrogenated vegetable oil (HVO) plants, which produce bioLPG as a by-product of renewable diesel production. Global bioLPG supply from such plants is expected to triple between 2018 and

[1] Menecon Consulting analysis based on IEA (2020a).

2025 (NNFCC, 2019). SHV Energy already blends bioLPG obtained from Neste's Rotterdam plants into LPG and sells it in cylinders and in bulk for heating in several countries in Europe. Alternative bioLPG pathways are also being investigated which might deliver a high potential in the future. In order to increase fuel availability, it is possible to blend bioLPG with bio-dimethyl ether (bioDME) and bio-isobutene, which have similar properties. In Europe, LPG demand of 8 -12 million tonnes in 2050 could be met entirely by bioLPG produced in Europe using a mix of technologies, including biorefining (such as HVO), pyrolysis, gasification, power-to-X and conversion of biogas, though stronger policy incentives will be needed (LGE, 2021).

3.2 A practical and economic fuel

LPG – like natural gas – has several practical as well as environmental advantages over liquid and solid fuels that can also be used for heating. LPG has been used for more than a century for heating homes and offices around the world, so suppliers and consumers are well-educated in how to handle the fuel safely and effectively. The physical properties of LPG enable significant amounts of energy to be transported easily as a liquid under moderate pressure in specially designed bottles or in tanker cars and trucks. This portability makes it particularly suitable for applications in remote locations that cannot economically be supplied with natural gas via a pipeline network. Its high calorific value in liquid form reduces transportation costs and makes it easier to handle than other fuels. For example, a 13 kg bottle provides around 180 kWh of energy; 25 kg of coal and 91 kg of wood would be needed for the same amount of energy. This also means that LPG tends to burn more efficiently than other fuels, such that more of the energy contained in the fuel is effectively transferred to hot water and/or the air for heating. On an equal energy basis, LPG also takes up much less space than other liquid or solid fuels, reducing storage costs.

LPG is particularly well-suited to space and water heating systems for several reasons:

- As a gaseous fuel, LPG is highly adjustable with a much higher turndown ratio (the ratio of the maximum capacity to minimum capacity) than heating oil or electric systems. This improves operating efficiency at reduced loads.
- As LPG has a higher-octane rating and has higher energy density than heating oil, it can offer much better heating performance compared to other fuel sources. LPG is particularly effective at heating water: an electric boiler may take nearly an hour to heat an entire hot water tank compared with as little as 20 minutes with LPG.
- LPG-based heating systems are easy to use, reliable and relatively inexpensive to maintain.
- LPG-fuelled boilers and furnaces are compact, quiet and aesthetically attractive – important considerations in the choice of heating system. There is no need for noisy and unsightly units installed alongside the building as is required for air source electric heat pumps. Although a fuel tank may be needed, it can be installed underground.
- Remote monitoring of the tanks can ensure that supplies are topped up when needed, giving householders reassurance that they will always have access to fuel for heat and hot water.
- LPG used in a hybrid system with solar energy offers a flexible and complementary low-carbon fuel source to power these homes when solar output is insufficient or unavailable at night, during winter or at times of cloudy weather.

- In the future, the development of bioLPG will provide a renewable fuel that can be added directly into the supply chain, avoiding the need for consumers to replace their existing LPG-based heating system.
- LPG heating systems work in an emergency. In the event of a natural disaster or other type of emergency causing disruption to power supplies, electric heating is no longer possible. LPG played an important role as a backup fuel in response to the power disruptions across the United States caused by severe weather in February 2021.
- LPG also has a very long life-span. Unlike heating oil, LPG does not deteriorate over time when held in storage.
- LPG is safe. Storage tanks buried underground are extremely resistant to puncturing, leakage and corrosion. LPG produces very little carbon monoxide, reducing the risk to health in the event of a leak. Because it is transported and stored in sealed containers, there are virtually no evaporative emissions – a major problem with heating oil. If spilt, it evaporates quickly and disperses into the atmosphere with little risk of igniting unless trapped in a confined space. This is a significant advantage compared to heating oil (kerosene) – a popular household fuel in many developing countries and one of the principal causes of destruction of property by fire in urban areas (WLPGA, 2011).
- LPG is a competitive solution for heating homes and offices in off-grid locations, taking account of the upfront cost of installing the heating system and the ongoing cost of the fuel. Bulk LPG prices, which fluctuate broadly in line with international oil markets, have fallen relative to heating oil prices on an energy basis in recent years because of a rapid expansion in supply, a trend that is expected to continue in the years to come (see below). This provides an assurance to homeowners and the owners of commercial premises investing in a new heating system that LPG will not become uncompetitive in the future. Relative fuel prices for consumers vary widely across countries and regions according to local market conditions, supply constraints and tax/subsidy policies. Natural gas is normally the preferred option for heating for buildings connected to the grid, but in many cases, LPG is the least-cost option in off-grid areas.

3.3 A secure fuel

LPG is a widely available and secure fuel. It is traded freely on international markets and widely distributed throughout the world through well-established supply chains. The portability of the fuel means that availability is rarely a barrier to its use, bar in remote underdeveloped regions. The global LPG market is essentially supply-driven, as production is primarily determined by oil-refinery throughputs and flows to upstream gas-processing plants. LPG consumption has been growing steadily in recent years, at a faster rate than that of oil generally on the back of strong growth in supply from gas-processing plants – in part driven by increased production of natural gas and its increased NGL content – and the increased price-competitiveness of the fuel, which has driven increased demand in all major end-use categories, including for heating in buildings.

The global LPG market is likely to continue to grow steadily in the medium term driven by increased upstream supply. NGLs are likely to provide most of the increase in LPG supply, because natural gas demand will most likely grow faster than oil demand. In its latest World Energy Outlook, the IEA projects the global supply of natural gas in its baseline scenario to grow at an average annual rate of 1.2% from 2019 to 2040, compared with just 0.3% for oil; the supply of NGLs is projected to grow by 0.8% per year (IEA, 2020a). This implies growth in LPG supply of around one-fifth. This will be more than sufficient to support a big increase in the use of LPG for heating, as well as other end-uses. In any case, there is considerable scope for replacing supplies of LPG currently used as feedstock in petrochemicals with other fuels, including natural gas.

4 LPG heating technologies

Several technologies that can provide indoor space heating and hot water using LPG as the primary fuel are available. Today, LPG is mainly used in stand-alone heaters (sometimes portable) and central heating systems using a boiler, with or without a hot water tank, or furnace. But new innovative LPG technologies, including gas heat pumps, micro co-generation systems such fuel cells and hybrid LPG/solar thermal installations, are emerging, increasing opportunities for using LPG even more efficiently and cleanly.

4.1 LPG heaters and furnaces

Stand-alone LPG heaters are relatively straightforward appliances that are connected to a LPG cylinder or tank. They come in different sizes and shapes, and can be portable or fixed (some are suitable for outdoor use). Many heaters employ a so-called piezoelectric igniter, to generate a spark to ignite the fuel. Alternatively, they can include a pilot light – a small flame that uses very little fuel and is designed to burn continuously so as to be ready to light the main burner quickly rather than using the igniter each time. More sophisticated heaters include a thermostat to automatically adjust the usage of the fuel according to the ambient temperature. Depending on size and sophistication, heater prices typically range from around $100 to over $1,000. LPG can also be used in open fireplaces, offering a decorative if generally less efficient source of space heating. Modern LPG and natural gas fireplaces maximise radiant and convective heat, sometimes using a secondary heat exchanger.

LPG heaters may be unvented or connected to a flue gas conduit or chimney. Unvented LPG and oil heaters, including wall-mounted and free-standing heaters as well as open-flame gas fireplaces with ceramic logs that are not actually connected to a chimney, have been sold for decades. However, their sale and use are prohibited in some jurisdictions because of health and safety risks associated with exposure to combustion by-products, notably carbon monoxide.

LPG furnaces can also be used to provide space heat to an entire building. The furnace heats air, which is distributed by a blower through a duct system and released into rooms throughout the building through vents in the floor, wall or ceiling. Furnaces, which can also run on natural gas, oil or electricity, are generally more common in newer homes, notably in the United States, because they generally cost less than boilers to install – sometimes only half as much as a boiler (see next section). In addition, they are less vulnerable to damage caused by leaks and freezing, as only hot air circulates (a boiler system operates with pipes filled with hot water). However, furnaces are generally less efficient than boilers as more energy is lost in transferring and distributing heat from the energy sources to the air than water. Furnaces are also noisier and so usually have to be installed in a basement. In addition, the temperature of air heat is usually not as consistent as steam or hot water so heat is not distributed as evenly throughout the buildings and the air quality is poorer, as heating air makes it drier and can blow dust and allergens into living spaces.

4.2 LPG boiler heating systems

In most advanced economies, notably in Europe, LPG as a heating fuel, like natural gas, is more often used in a central heating system using a boiler, especially in primary residences, commercial premises and public buildings. Boilers are generally more efficient, less noisy and offer better air quality than furnaces for heating large spaces. There are three main types of boilers than can run on gaseous fuels:

- **Conventional boiler**: Also known as a heat-only boiler, it provides heating directly to radiators and sends hot water to a tank to be stored in advance of it being used. They often work on what is called an "open-vented" heating system, incorporating a pipe which rises from the heating system to above the tank and hooks over into it to act as a safety mechanism, releasing excess pressure in the system in the event of over-heating. This type of boiler is generally designed for large residential or commercial buildings, especially because of the need for additional space for the water tank.
- **Combination, or "combi" boiler**: A single unit that provides all the heating needs of the home or office. It heats water via an integral heat exchanger directly from the cold mains, providing instantaneous hot water than can be used directly for washing and cooking as well as piped to radiators for space heating. This eliminates the need for a hot water tank as the boiler only heats the water that is used. It is generally best suited to smaller houses and office units.
- **System boiler**: Like a conventional boiler, a system boiler is combined with a hot-water cylinder but with all the components, such as pumps and valves, integrated into the boiler. It is often installed alongside an unvented hot-water cylinder. This type of boiler is best suited to properties that have high hot-water demand, as the unvented tank can deliver good hot water flow rates to several outlets simultaneously, though this does require high incoming mains water pressure. It also takes up more room than a combi boiler.

Most gas-fired boilers sold today around the world, whether fuelled by LPG or natural gas, use condensing technology. Condensing boilers convert the energy in the fuel to hot water much more efficiently than traditional boilers by condensing the water vapour in the exhaust gases and so recovering its latent heat of vaporisation, which would otherwise be wasted. In many countries, the use of condensing boilers is compulsory or encouraged with financial incentives (see next section). Modern condensing gas boilers have efficiencies of more than 90% compared with 70%-80% with conventional designs (based on the higher heating value of fuels).[1]

A central heating system with a boiler fuelled by LPG often requires a fuel tank located outside the building, though small heating needs (such as hot water alone) can be met with a large cylinder. For aesthetic reasons, the storage tank can be installed underground. All countries regulate the siting and operation of storage tanks, notably the distance from the building and overhead power lines, the construction of a fire wall and access for fuel deliveries, for safety reasons. In most cases, the tank is rented from the fuel supplier. Installation costs for above-ground tanks may be borne by the supplier and effectively recovered through the rent.

[1] The amount of heat or gross energy released during the combustion of a specified amount of it.

4.3 Emerging innovative technologies

4.3.1 Gas heat pumps (GHPs)

One of the most promising innovative technologies involving the use of LPG to provide heating services to buildings, is the gas heat pump (GHP). GHPs incorporate a mechanical or a thermal compressor powered by the combustion of natural gas or LPG. They use the thermal energy released from burning a gaseous fuel to power an electrical process to extract energy from the air, water or the ground in the form of heat in the same way as electrical heat pumps (WLPGA, 2013). This heat is normally provided to a building in the form of hot water and/or some other liquid that can be circulated throughout the building by means of a system of underfloor pipes or radiators. The process of heat extraction can also be reversed, allowing heat pumps to be used to provide cooling for air conditioning or other purposes.

The main attraction of a GHP is that it is more efficient than a conventional or condensing boiler because it draws on ambient energy. There are also fewer energy losses compared with a conventional boiler. This reduces running costs and CO2 emissions. A LPG-powered GHP can also be an independent source of heating/cooling in remote areas off the natural gas grid and/or where there are electricity supply shortages. And as most GHPs can provide both heating and cooling, often simultaneously, only one system is required, saving on installation costs and the need to maintain and find space for two separate systems. LPG-powered GHPs can also be cleaner and less carbon-intensive than electric heat pumps depending on the energy sources used to generate the electricity, and cheaper depending on relative prices. Nonetheless, the higher upfront cost of installing a GHP and minimum size requirements to achieve good efficiency mean that they are generally more suited to commercial and public buildings than houses.

The gas engine heat pump (GEHP) is the most common GHP technology around the world, notably in the Asia-Pacific region. In a GEHP, a gas-powered engine drives a compressor, which in turn drives the heat pump cycle (in the same way that electricity drives the compressor in an electric heat pump), usually extracting ambient energy from the air or the ground. The efficiency of the system can be improved by recovering the heat from the engine for use as hot water. The most efficient models on the market have an Annual Performance Factor – the ratio of the total amount of heat that the equipment can add to the indoor air to the total amount of energy consumed by the equipment during a year – of 5.6. There is an established market for GEHPs in the light commercial and industrial sector for heating and cooling in the range of 20-100 kW with most manufacturers coming from Japan/South Korea.[1] In Japan alone, there are approximately 310,000 LPG-powered units of this type in use nationwide – equal to over 40% of all GEHPs (the rest are fuelled by natural gas).[2]

The other main type of GHP technology is the absorption system, which incorporates a thermal compressor using the physical process of absorption -the dissolution of a gas in a liquid – instead of a mechanical compressor found in a GEHP or standard electrical heat pump. This type, which is already being used with LPG based on ammonia and water as the fluids for

[1] https://lpg-apps.org/index.php?mact=LPGApi,cntnt01,application,0&cntnt01application_id=29&cntnt01returnid=47&cntnt01sector_id=1&cntnt01subsector_id=1

[2] https://www.j-lpgas.gr.jp/en/appliances/cogene.html

absorbing and conducting energy, is the leading GHP technology in Europe. The technology is well-suited to commercial premises and multi-family housing units, and works just as well with LPG and with natural gas as the primary fuel input both for cooling and heating purposes, though upfront costs are higher than for boilers. Adsorption heat pumps, in which the mechanical compressor in an electric or gas engine heat pump is replaced by a system using the physical process of adsorption, is another emerging technology.

4.3.2 Micro combined heat and power (CHP)

Small-scale co-generation, or micro combined heat and power (CHP), systems, which generate simultaneously both electricity and heat, is another emerging technology for residential and small commercial premises.[1] CHP can provide an efficient and cheaper alternative to purchasing electricity from the grid and separate generation of heat using a boiler or heat pump. Micro-CHP systems generally use an internal combustion engine, most efficiently fueled by LPG, to power a small internal electrical generator, while heat exchangers capture the residual heat produced and transfer it for space heating or water heating purposes (WLPGA, 2016). They are used mainly in residential developments and small businesses to both provide heat and generate electricity with higher efficiency and lower emissions levels than conventional heating and grid-supplied power systems.

Micro-CHP systems are typically no larger than a regular air-conditioning unit/gas boiler. They can easily be added or retrofitted to an existing CHP system, helping it to operate more efficiently. They run quietly and are vibration-free, emitting marginally more sound than a typical refrigerator.[2] Several such systems have already been installed around the world, notably in Japan. In Europe, Germany is the leading market for micro-CHP. Other technologies under development include Rankine cycle, which uses a heat-engine operating cycle commonly used in conventional fossil fuel and nuclear generation plants, microturbines, which are designed mainly for producing heat, and fuel cells.

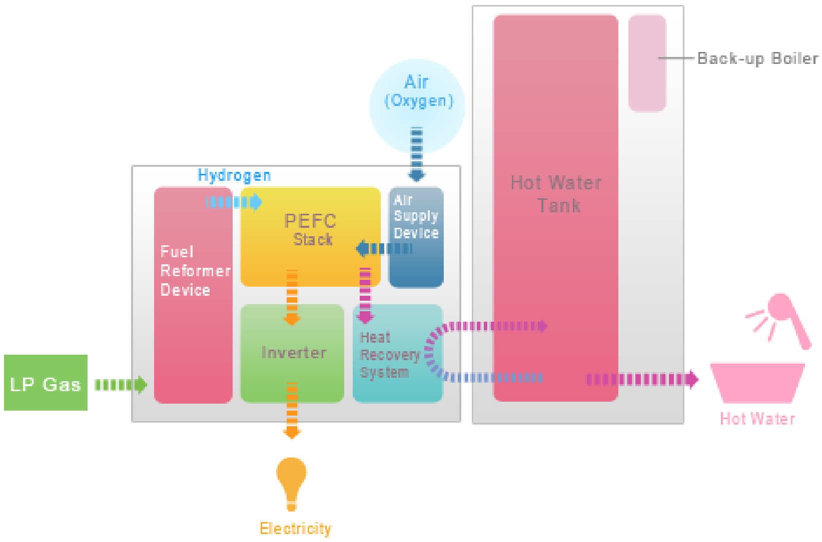
There is considerable potential for deploying LPG-powered fuel cells, as the technology is well-suited to the fuel, requiring only minor modification from natural gas-based designs. A fuel cell is a type of electrochemical engine that extracts hydrogen from LPG and combines it with ambient oxygen to generate electrical power, while simultaneously capturing residual heat that is used to heat up water. It can be much more energy efficient than obtaining electricity from the grid and obtaining heat with a conventional boiler. In addition, as the LPG is converted to hydrogen rather than burned, it emits much less CO2. As they generate heat and power through a solid-state reaction, fuel cell systems operate quietly. In addition, they take up little space, making them a practical option for homes and offices – either in areas off the natural gas grid or as a back-up source of power in areas subject to regular electricity outages.

[1] The industry sometimes makes a distinction between micro-CHP systems, which are sized between several hundred Watts and 5kWe, and mini-CHP, with a capacity of between 5kWe and 50kWe.

[2] https://lpg-apps.org/index.php?mact=LPGApi,cntnt01,application,0&cntnt01application_id=20&cntnt01template=application&cntnt01detailpage=applications&cntnt01returnid=17

LPG-powered fuel cells with electrical capacity of up to 1 kW are already starting to be commercialised. In Japan, the ENE-FARM dual cell system has been launched, with capacity ranging from 0.3kW to 1kW of electricity, which is usually enough to cover the normal power requirements for home electric appliances with additional power needs drawn from the grid (Figure A4.1). The hot-water supply unit holds 200 litres (53 gallons) at 65 degrees Celsius (149 degrees Fahrenheit). The government is targeting the installation of 2.5 million units by 2030 through the introduction of tax incentives and by defraying costs and other measures.[1] A cumulative 305,000 units had been installed at the end of March 2019.[2]

Figure A4.1: LPG-powered ENE-FARM hydrogen fuel cell for water heating and electricity production[3]



In 2020, the German firm Sunfire launched an innovative solid oxide fuel cell home heating unit to supply electricity and heat for single-family homes and apartment blocks, both in new-build and existing buildings. The system can run on LPG or natural gas, and can be combined with other heating technologies, such as battery storage, solar systems and heat pumps. The unit delivers up to 750 watts of electrical power and 1,250 kilowatts of heat, enough to cover the basic requirements of a normal single-family home.[4] According to the manufacturer, more than 250 systems have already been installed.[5]

4.3.4 LPG solar hybrid heating systems

There is also scope for increasing the use of LPG in solar hybrid systems for producing hot water in combination with solar water heating. Solar hot-water systems involve the use of a flat plate solar collector, usually placed on the roof of the house, which contains copper pipes to absorb heat and transfer it to a non-toxic fluid inside the pipes. The hot liquid is sent to a boiler to pre-heat the water for the house through a heat exchanger. After transferring its

[1] https://www.j-lpgas.gr.jp/en/appliances/index.html#ENE-FARM
[2] https://www.iea.org/reports/heating
[3] Japan LPG Association (https://www.j-lpgas.gr.jp/en/appliances/index.html#ENE-FARM).
[4] https://pace-energy.eu/sunfire-launches-the-sunfire-home-the-first-fuel-cell-unit-based-on-liquefied-gas/
[5] https://www.pveurope.eu/electricity/fuel-cell-cogeneration-unit-home

heat, the fluid is circulated back to the collector to heat up again. The heated water is kept in a large, insulated storage tank. In some countries, solar thermal systems can provide all or most of a home's hot water needs during sunny periods, but the intermittency of sunshine means that the system cannot always provide sufficient hot water. LPG can be used as a primary or complementary source of energy to heat the water in storage to provide hot water and, if required, space heating. Such hybrid systems, which are becoming increasingly popular in many parts of the world, combines the reliability of a conventional fuel with the environmental and cost benefits associated with solar energy.

5 LPG heating incentive policies

There are several ways in which governments can encourage the use of LPG for heating, the most important of which involve making it competitive with other fuels through fiscal and other incentives. Other regulatory measures, including restrictions on dirty, inefficient fuels and technologies, together with well-funded information campaigns, can speed up switching to highly efficient LPG heating systems. Incentives for bioLPG will be critical to expanding supplies. Proposed bans on the use of gas in boilers threaten to slow the decarbonisation of the buildings sector and raise costs to consumers.

5.1 Policy approaches

There is a range of different policy strategies and approaches at the disposal of governments to encourage homes and businesses to switch to LPG for heating. In practice, the overall approach adopted and the chosen mix of instruments reflects both ideological and practical considerations. Given that main justification for governments to promote the use of LPG is environmental, intervention should in principle be aimed at correcting the market failure that gives rise to environmental damage in the form of air pollution and emissions of climate-destabilising greenhouse gases.

Environmental damage caused by the use of fossil energy is a type of market failure, since the market fails to put a financial value or penalty on the cost of emissions generated by individuals or organisations. Air quality and the climate are, in economists' parlance, public goods, from which everyone benefits. Damage done to the environment is known as an external cost or externality. It follows that governments have a responsibility to correct these failures, to discourage activities that emit noxious or greenhouse gases and to make sure that each polluter pays for the harm he causes to public goods (WLPGA, 2020).

Levying charges on polluting activities is effectively a way of internalising these environmental externalities. However, placing an exact financial value on them is extremely difficult and inevitably involves a large degree of judgment. Many studies have attempted to assess the health and economic costs of different types of emissions, including greenhouse gases. The social cost of carbon (SCC), for example, is the marginal cost of emitting one extra tonne of carbon (as CO2) at any point in time. Estimates vary widely according to the assumptions made and methodological approaches used. For example, most US states use an SCC of over $40/tonne (based on a 3% discount rate) to analyse the CO2 impacts of various rulemakings. These estimates are highly contentious, in part because they hinge on approaches to intergenerational discounting. Long-term net-zero emission targets, which a growing number of countries are adopting, imply a progressive increase in the SCC to a level that is consistent with the near-total phase out of fossil fuels (see Section 1).[1]

In principle, the most economically efficient approach to internalising external costs is one that relies mainly on financial incentives, i.e. a market-based approach. In other words, the

[1] It is likely that net-zero emissions can only be achieved with some residual use of fossil fuels in certain end uses in what are termed "hard-to-abate" sectors such as aviation, with those emissions being entirely offset by carbon capture and storage (IEA, 2020a).

effective market price of the activity that gives rise to an environmental externality should be adjusted through the application of taxes and/or subsidies large enough to reflect the value or cost of that externality. Once an appropriate fiscal framework is in place, consumers and producers are free to make informed economic choices according to their own preferences. In the case of heating, that can involve taxing or subsidising fuels or the equipment used to heat buildings in such a way that the financial costs to end users of the different fuel and technology options reflect their associated environmental costs. Economic efficiency demands that taxes levied on any given fuel should be applied at the same rate to all users, commercial and non-commercial.

In practice, developing energy and environmental policies that take full account of environmental externalities is extremely difficult – even if reliable quantitative estimates of external costs can be obtained – for practical reasons. It is complex to apply taxes and subsidies exactly according to the actual emissions produced during use. And emission-trading schemes are similarly impractical for heating buildings given the large number of users. In addition, there are social considerations that can complicate matters: raising the price of fossil fuels tends to hurt the poor most, as they are least able to afford to pay more and the cost of fuel for heating usually represents a large share of household spending. Vested interests and broader social impacts can also play a role: for example, discouraging coal use can undermine employment in local mines. For these reasons, governments sometimes deploy other complementary approaches to influencing the choice of heating fuels and technologies that effectively seek to internalise in an implicit manner the external environmental costs of heating while taking account of social costs and benefits.

5.2 Policy toolkit

As discussed above, financial instruments are the primary policy tool to guide the choice of technology and fuel for heating. Regulatory measures, including restrictions on the type of fuel or technology that can be commercialised for heating purposes, are the other main category. Other measures include support for technology development and public awareness programmes. These are summarised in Table A5.1 and are discussed below.

Table A5.1: Typology of government policies and measures to promote LPG for heating[1]

Fiscal/Financial	Regulatory	Other
Excise-duty exemption or rebate on LPG purchases vis-à-vis alternative heating fuels Carbon taxation (favouring LPG and bioLPG over more carbon-intensive heating oil and coal, as well as electricity in some cases) Grant/tax credit or sales/value-added tax exemption for acquisition of heating equipment Rapid depreciation for commercial purchasers of heating equipment and owners of LPG distribution infrastructure	Restrictions on use of coal and/or heating oil in all or some areas/types of building/types of boiler or heater Emissions standards for heating equipment Mandatory labelling of the efficiency and emissions performance of heating equipment Health and safety regulations Mandatory requirements for public buildings to use LPG/bioLPG	Information dissemination and public awareness campaigns Voluntary agreements with heating equipment manufacturers to develop and market LPG and other clean heating technologies Direct funding for research, development, demonstration and deployment of clean heating technologies and bioLPG

5.2.1 Financial instruments

Financial incentives can be directed at the fuels themselves or the technologies that use them. Fuel incentives can take the form of a lower rate of excise duty and/or sales or value-added tax (VAT) or a complete exemption. In some cases, businesses may enjoy a rebate on fuel taxes. Excise taxes may include a carbon tax, which is levied on each heating fuel at a rate that varies according to the carbon intensity of the fuel. Carbon taxation favours LPG and bioLPG over heating oil and coal, as well as electricity in countries with a high-carbon fuel mix in power generation, as it is less carbon-intensive (see Section 3). Excise taxes can also take account of the broader air quality benefits of LPG vis-à-vis other heating fuels. Since differences in excise duty or carbon taxes show up in retail prices, the measure is highly visible, raising public awareness of the potential cost savings from switching to LPG. The lower the rates of duty and tax on LPG relative to other fuels, the bigger the financial incentive to switch. The case for differential fuel taxes and subsidies to achieve environmental objectives is well established, but in practice effective tax rates – and, therefore, final energy prices – are rarely consistent with stated policy goals, for the reasons described above (Coady et al., 2019).

The other main type of financial incentive that can be used to encourage the use of LPG is subsidies on heating equipment. This can take the form of a tax credit, direct grant or a sale-tax exemption for such purchases. Governments can also subsidise investment by businesses in heating equipment or investment by LPG suppliers in distribution infrastructure, for example, through rapid depreciation allowances.

5.2.2 Regulatory and other measures

Governments can strongly influence the choice of heating technology and fuel through the design of the regulatory framework. The most direct type of regulatory intervention is formal

[1] Menecon Consulting analysis.

restrictions on the deployment of specific technologies. Some countries have introduced, or plan to introduce, bans on the use of coal, heating oil and, in some cases, gaseous fossil fuels for heating, including the United Kingdom, France and some US municipalities (see Part B). Other less direct regulatory instruments include emission standards for heating equipment and health and safety regulations, which can effectively prevent some dirty technologies from being commercialised. Mandatory labelling schemes can also promote efficient heating systems using LPG. The deployment of such systems by the government itself in public buildings can also expand the market for LPG and set an example to other end users.

Information dissemination and education can also form a key element of government-incentive programmes for clean technologies. They may take the form of regular communications, such as websites, newsletters or social media, to inform the public of market and technology developments and to indicate how to apply for subsidies if available. Governments can also support the research and development (R&D), demonstration and deployment of clean heating technology either through voluntary agreements with manufacturers and fuel providers or through direct funding of such activities. Voluntary agreements or collaborative partnerships with industry are usually seen as an alternative to stringent, mandatory regulations and punitive fiscal measures.

5.3 Comparison of policies in surveyed countries

The use and effectiveness of polices to incentivise LPG in heating varies considerably among the countries surveyed in this report. Chile has adopted policies that actively encourage LPG use for social, economic and environmental reasons. The federal governments of the United States and Germany have adopted a more technology-neutral approach that allows given fuels and technologies to compete freely within a regulatory framework aimed at lowering energy use and energy-related environmental effects, though specific incentives for installing efficient LPG heating systems do exist. France, Germany and the United Kingdom have all adopted policies that aim to phase-out conventional LPG as a heating fuel, though France still offers incentives for switching to LPG in some cases. Table A5.2 summarises the principal measures deployed in the countries surveyed in this report and their overall impact on LPG use.

The impact of financial incentives, including differential taxes and support for heating technologies, varies markedly across the countries surveyed. In the United States, a range of federal and state tax credits for efficient boilers probably has the overall effect of encouraging households and commercial premises to install LPG heating systems. Similar incentives most likely boost LPG installations in France too. By contrast, such incentives are limited to renewable energy-based systems in Germany. The taxation of heating fuels themselves is generally favourable in France, the United Kingdom and the United States (notably with respect to heating oil) and unfavourable in Germany (Table A5.3); it is neutral in Chile, though subsidies to kerosene in Chile undoubtedly undermine the use of LPG for heating there yet taxes only partially explain differences in relative fuel prices across the five countries. For example, LPG is relatively competitive with heating oil in Germany, despite higher taxes on LPG (Figure A5.1).

Table A5.2: Summary of main heating incentive policies and impact on LPG use in surveyed countries, 2020

	Financial	Regulatory	Other
Chile	Heating fuels not taxed	Building codes	Information campaigns to switch to clean fuels
	Subsidies on kerosene	Sustainable Heating Programme (to replace wood)	
France	LPG taxed less than oil & electricity	New emissions standards that effectively ban LPG in new homes	
	Incentives for efficient LPG boilers		
Germany	Higher taxes on LPG than oil & natural gas	Planned carbon pricing for homes	
	Tax rebate for LPG used in co-generation	Tighter building codes from 2021	
	Incentives to install non-fossil fuel heating systems	Ban on installing oil heating systems from 2026 (already banned in new buildings)	
United Kingdom	Excise tax on oil only for households	Recent tightening of boiler standards & building codes	Support for Simple Energy Advice
	Carbon tax on heating fuels for businesses	Plans to ban oil & gas boilers from 2025	Service
United States	No federal taxes on heating fuels	Boiler standards frozen in 2018	Federal Trade Commission and Energy Star labelling programmes
	Federal & state tax credits for efficient LPG boilers	Some cities have introduced bans on installation of oil and gas boilers in new homes	Federal support for boiler R&D
	Investment tax credit for co-generation (including LPG)		Federal office procurement rules impose condensing boilers

Note: Green indicates that the policy encourages LPG use; red that it discourage its use; yellow that it is neutral (no clear net impact or can be either positive or negative for LPG use).

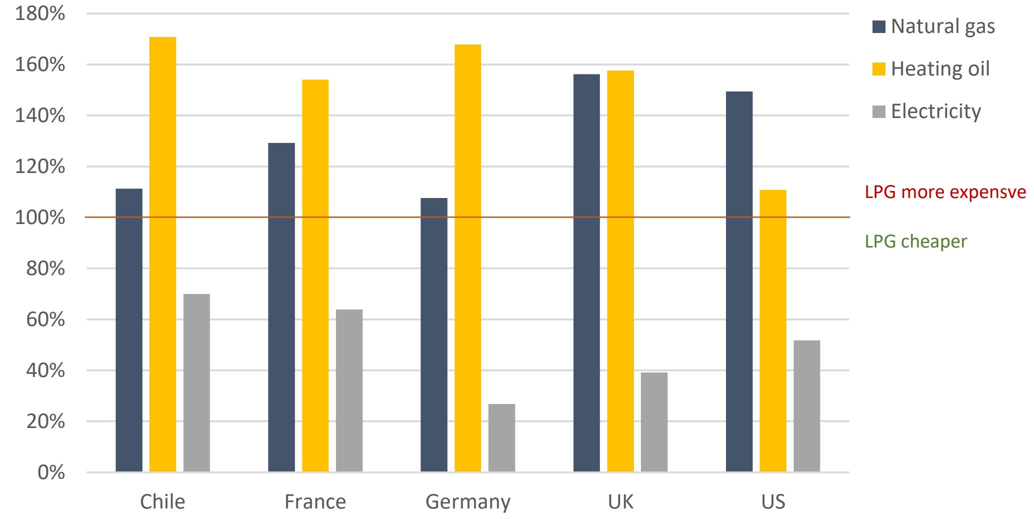
Table A5.3: Share of taxes in household price of heating fuels in surveyed countries

	LPG	Natural gas	Heating oil	Electricity
Chile	16%	16%	16%	16%
France	30%	28%	37%	35%
Germany	31%	23%	27%	53%
United Kingdom	5%	5%	29%	5%
United States	0%	0%	5%	0%

Note: Percentages are calculated on a volume basis. Taxes in the United States are federal only.

Regulatory measures affecting the installation of heating systems similarly vary in their impact on demand for LPG heaters and boilers. In Germany, the planned introduction of carbon pricing and a ban on the installation of oil boilers should favour LPG. In Chile, new building codes and efforts to discourage the use of firewood for heating should also encourage the uptake of LPG. By contrast, new restrictions on gas boilers in France, the United Kingdom and some US cities will impede the use of LPG for heating, though the impact may be alleviated by other financial measures to encourage efficient boilers. In some countries, notably the United States and Chile, consumer awareness campaigns and labelling are an effective means of promoting efficient heating, including using LPG.

Figure A5.1: Retail price of LPG relative to competing fuels for households in surveyed countries, 2020[1]



Note: Ratios are calculated on an energy-content basis.

5.4 *Recommendations for policy action*

Government policies are critical to encouraging the use of LPG for heating in off-grid locations. Policy intervention is justified by the considerable environmental and socioeconomic benefits that conventional LPG can bring as a bridging fuel within a least-cost strategy to achieve the energy transition, while the prospect of blending in growing volumes of bioLPG provide a pathway to making LPG part of the long-term solution. The development of policies to encourage LPG for heating needs to take place within the broader strategic framework for sustainable buildings, including the overall energy performance of building envelopes and urban planning. In designing incentives, policy makers need to take account of the critical success factors behind the development of a sustainable market.

Experience in the five countries surveyed in this report shows that policies must involve making LPG competitive with other heating fuels for households and businesses. Fuel-pricing strategies (including taxes and subsidies) need to ensure market equality for all technologies. Removing subsidies on fossil fuels, which often benefit heating oil over LPG and natural gas, is critical in this regard. The goal should be to tax heating fuels according to their comparative environmental attributes – CO2 and air pollutant emissions – which implies a lower tax on LPG than heating oil and coal (electricity prices should reflect appropriate taxes on the fuel inputs to power generation) and an exemption for bioLPG. Taxes on final and intermediate fuels should, in principle, include an explicit carbon tax to reflect differences in carbon intensity to discourage the dirtiest fuels. This would lower the running cost of LPG relative to non-gaseous fossil fuels and make it more attractive to end users.

[1] Menecon Consulting analysis based on IEA databases and national sources.

Ensuring that LPG is priced competitively through a rationale energy-tax system is a necessary but not always a sufficient condition for encouraging large-scale switching to the fuel for heating. Governments need to consider the case for subsidising the replacement of existing dirty heating systems with clean technologies, including LPG-fuelled systems. Other government incentives may be necessary. In view of the urgent need to reduce urban air pollution and cut CO2 emissions everywhere, all governments will need to consider whether to introduce a ban on the installation of heating oil and solid fuel heating systems, at a minimum for new buildings. Depending on the fuel mix in power generation, there is unlikely to be a case for extending the ban to fossil-based gaseous fuels (natural gas and LPG). In countries where fossil fuels are expected to continue to play an important role in generating electricity, any such ban is likely to raise CO2 emissions, at least in the medium term (see Section 3).

It is vitally important that policy makers recognise explicitly the environmental advantages of bioLPG, either sold as a pure renewable for of energy or blended into conventional LPG. BioLPG should be categorised as a renewable fuel and enjoy the same benefits as biomethane (biogas) and other biofuels such as ethanol and fatty acid methyl ester (FAME) biodiesel, including exemptions from excise taxes. There may also be a case for subsidies to the use and production of bioLPG, as well as research and development, alongside other biofuels and renewable energy sources. For example, European and national R&D funding should be made available for processes at an early stage of technology readiness to obtain bioLPG through the EU Horizon Europe and LIFE programmes (LGE, 2021).

Energy and emissions standards are another crucial area where government need to act to address air pollution and lower CO2 emissions. At the very least, governments everywhere need to implement and update minimum energy performance standards (MEPS) for heating equipment to steer markets towards clean-energy technologies, including LPG-fuelled boilers. Most countries – including all the countries surveyed in this study bar Chile – have already introduced MEPS for boilers. In some cases, additional technological requirements may be required, such as flue gas heat recovery systems or smart controls to automate and optimise system operation that are required in the United Kingdom. Some other countries have also introduced emissions standards. For example, the European Union adopted the Ecodesign Directive in 2009, which allows the Commission to set requirements for environmental performance including emissions. Those standards, which must not lower the functionality of a product, its safety, or have a negative impact on its affordability or consumers' health, must be met in order to place a product on the market across the Union.

Technical and safety standards are another important area of responsibility for governments in partnership with LPG suppliers and equipment manufacturers. It is essential for the authorities to lay down and enforce harmonised operating standards for all types of heating equipment, including installation. Poor-quality systems can undermine emission performance and jeopardise safety, which must be an overriding concern for policymakers everywhere. Fuel providers and end users need to be reassured that the transportation, handling and storage of LPG pose no safety risks. The drafting and implementation of safety regulations specific to LPG need to be based on an objective assessment of risk. In most cases, there is no need for policy makers to draw up technical and safety standards and regulations from scratch, since several countries have developed effective frameworks based on many years of experience. Governments need to collaborate with industry and trade associations to ensure proper equipment installation and maintenance.

Labelling is also an effective way of raising the awareness of the energy efficiency and emissions performance of alternative heating systems. Many countries have already labelling schemes for heating equipment to increase consumer awareness of energy technology choices, but these can be expanded and improved. Informational tools could make use of the increasing quantity of building energy data available through digitalisation, for as long as the underlying data management frameworks address data privacy and cyber-related issues.1 Energy labels, including energy performance certificates for buildings, should take account of the energy use and emissions associated with the supply of the fuel so as not to unduly favour electric heat pumps, which can often involve higher emissions and energy consumption in power generation.[2]

There is no "one-size-fits-all" approach to formulating and implementing a government programme of incentives to promote the development of LPG and other clean heating systems. The appropriate strategy for each country depends on specific national circumstances. This would address budgetary considerations, which might limit available funds for subsidies, the seriousness of local pollution problems, fuel-supply and cost issues, the stage of development of the market and prevailing barriers to fuel switching. The starting point should be to set out a detailed roadmap in consultation with the industry and other stakeholders.

Policy stability and a strong, long-term commitment by the government to achieving environmental-policy objectives are crucial to success in promoting switching to LPG. Stakeholders need to be given clear advance warning of any major shift in policy. Without policy stability, coherence and consistency, neither fuel suppliers, equipment suppliers nor consumers will be confident that they are making the right choice to heat with LPG.

[1] https://www.iea.org/reports/heating

[2] The energy performance certificate scheme in the United Kingdom unduly favours more carbon-intensive heating oil over LPG for heating in off-grid buildings (see section B.4).

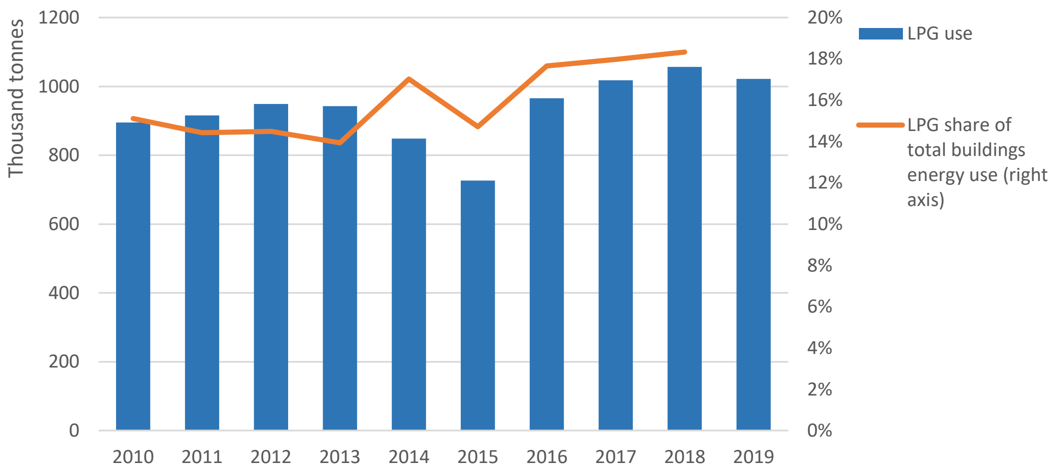
PART B: COUNTRY SURVEYS

1 Chile

1.1 LPG heating market trends

LPG plays an important role in meeting energy needs in buildings in Chile, notably for water heating. Total consumption reached just over 1 Mt in 2019, accounting for close to one-fifth of total buildings energy consumption (Figure B1.1). Close to three-quarters of this consumption was in the residential sector. Total LPG use for heating in buildings is estimated to have reached about 800,000 tonnes.[1]

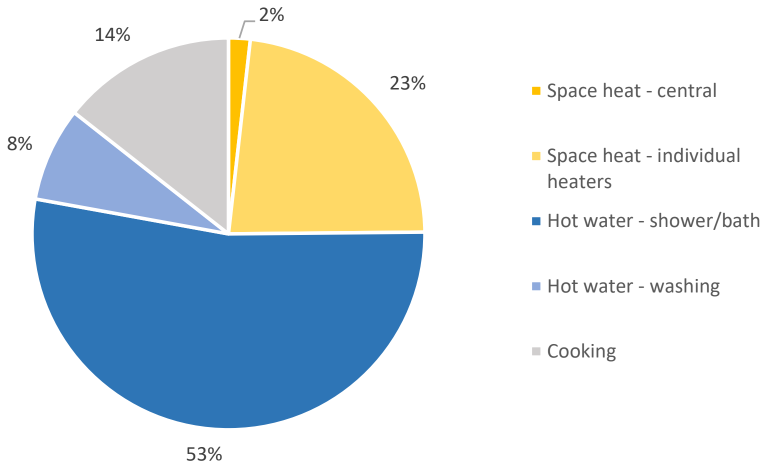
Figure B1.1: LPG consumption in buildings – Chile[2]



LPG is the main commercial fuel used for heating in the residential sector. Total LPG use for that purpose totalled 670,000 tonnes in 2018,[3] equal to roughly 30% of total energy use for residential heating. The bulk of this – close to 480,000 tonnes – was used to provide hot water; just under 200,000 tonnes was used for space heating, mainly using individual room heaters (Figure B1.2). Another 110,000 tonnes were used for cooking. LPG is the second most important source of energy for heating after biomass, which meets roughly 55% of the country's heating needs and provides almost all heating in rural areas (much of it, non-commercial). Around 80% of households in Chile use energy for space heating, the vast majority using individual heaters (CDT, 2019). Firewood is the main fuel used for individual space heaters, with LPG used in one-fifth of them; LPG accounts for half of the country's central heating systems.

[1] Time series data on estimated LPG use for heating purposes is not available.
[2] IEA databases; Menecon Consulting analysis.
[3] The last year for which detailed data on heating use by fuel is available.

Figure B1.2: LPG consumption in buildings by end-use application, 2018 – Chile[1]



The country's heavy reliance on biomass for heating and cooking using inefficient stoves and boilers is a major environmental problem. By causing excessive concentrations of particulate matter in the air, it is the primary source of premature death and ill health and results in high public spending on remedial measures (Paardekooper, 2020). It also contributes to the degradation of native forests, especially in the south of the country (IEA, 2018). Wood burning is common even in urban areas: more than half the 1.05 million households in the ten largest cities in Chile have at least one wood stove.[2]

1.2 Government heating policies

Heating policies in Chile are devised within the framework of the National Energy Policy 2050 that was launched in 2014, setting twenty principal energy goals, ten by 2035 and ten by 2050, covering the development of a competitive, modern and sustainable energy sector. In the buildings sector, the government is giving high priority to achieving sustainable heating through the adoption of improved heating technologies, alongside better insulation of buildings and improvements to the quality of firewood. The aim is for all vulnerable households to gain access to modern affordable energy by 2035 and all households by 2050. In addition, all new buildings should meet OECD standards for efficient construction and be fitted with intelligent control and management systems by 2050. The Ministry of Environment's Sustainable Heating Programme is aimed at replacing old wood stoves for heating or cooking with new heating systems, including gas stoves and boilers. This programme is mostly focus on the most polluted cities.

Public awareness campaigns and labelling form an important element of the strategy to improve the efficiency of heating. The country has also adopted buildings codes setting standards for insulation in residential (but not commercial) buildings, though it has not yet introduced minimum performance standards or energy labels for boilers. The Sustainable Energy Agency, a non-profit private organisation, runs several programmes aimed at informing the public about energy sustainability, including through the education system.

[1] CDT (2019).
[2] https://unece.org/fileadmin/DAM/env/documents/2018/Air/WGSR/Rodrigo_Dittborn.pdf

Fuels used in the residential and commercial sectors are not subject to excise taxes. VAT of 19% is currently applied on all fuels (Table B1.1). LPG and most other fuel prices are unregulated. For many years, the government used a fuel price stabilisation mechanism (MEPCO – Mecanismo de Estabilización de Precios de los Combustibles) and an oil-price-stabilisation fund (FEPP – El Fondo de Estabilización de Precios del Petróleo) to soften the impact of international oil price fluctuations on domestic consumers. The FEPP still exists today, but currently only applies to kerosene for domestic heating.

Table B1.1: Household heating fuel prices and taxes per tonne of oil equivalent – Chile[1]

	Chilean pesos					US Dollars
	2016	2017	2018	2019	2020	2020
Pre-tax prices						
LPG	746,578	853,780	946,952	933,980	1,000,936	1,263
Heating oil	543,587	543,828	641,957	652,318	571,153	721
Natural gas	659,057	717,540	818,908	856,011	876,744	1,107
Electricity	1,119,142	1,263,424	1,235,503	1,348,266	1,395,476	1,761
Total taxes						
LPG	123,139	135,203	150,945	149,123	160,012	202
Heating oil	107,367	102,323	121,733	123,940	108,679	137
Natural gas	125,221	136,333	155,593	162,642	166,581	210
Electricity	212,637	240,051	234,745	256,170	265,141	335
Final prices						
LPG	869,717	988,983	1,097,898	1,083,103	1,160,948	1,465
Heating oil	650,954	646,151	763,690	776,258	679,832	858
Natural gas	784,277	853,872	974,501	1,018,654	1,043,325	1,317
Electricity	1,331,779	1,503,475	1,470,248	1,604,436	1,660,617	2,096
Total taxes as % of final price						
LPG	16%	16%	16%	16%	16%	-
Heating oil	16%	16%	16%	16%	16%	-
Natural gas	16%	16%	16%	16%	16%	-
Electricity	16%	16%	16%	16%	16%	-

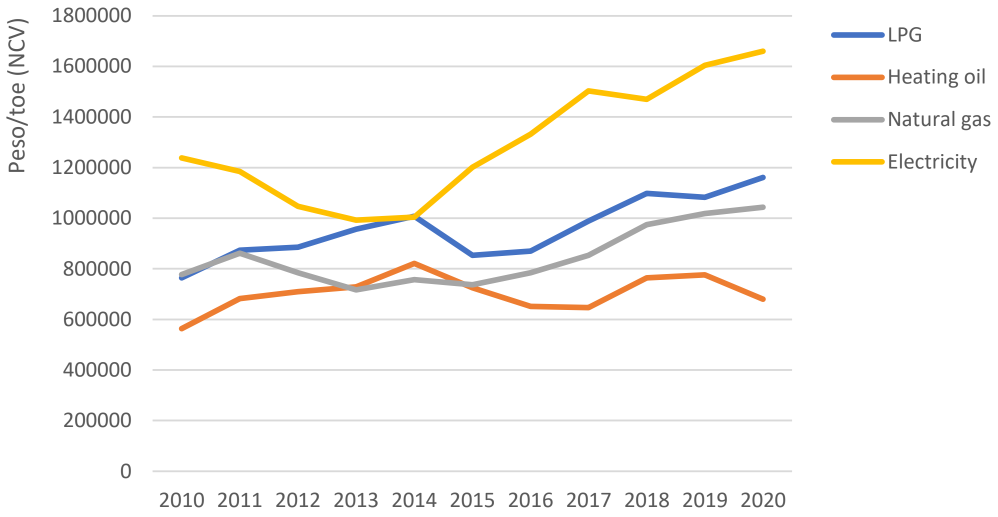
Note: Net calorific value.

1.3 Competitiveness of LPG for heating

LPG is currently at a competitive disadvantage to heating oil (kerosene) as a heating fuel for homes and offices. The price of LPG averaged 1.16 million pesos/tonne in 2020 – around 70% more than heating oil on an energy equivalent basis (Figure B1.3). The price of LPG relative to heating oil has tended to widen over the last few years. Electricity prices are considerably higher, making it uncompetitive for heating in most cases. The price of natural gas was only marginally below that of LPG in 2020, making the latter an attractive option for small heating loads in some locations given the cost of connecting to the grid.

[1] IEA databases; Menecon Consulting analysis.

Figure B1.3: Retail price of heating fuels – Chile[1]



Note: LPG prices are based on the average of regional prices for a 15 kg bottle.

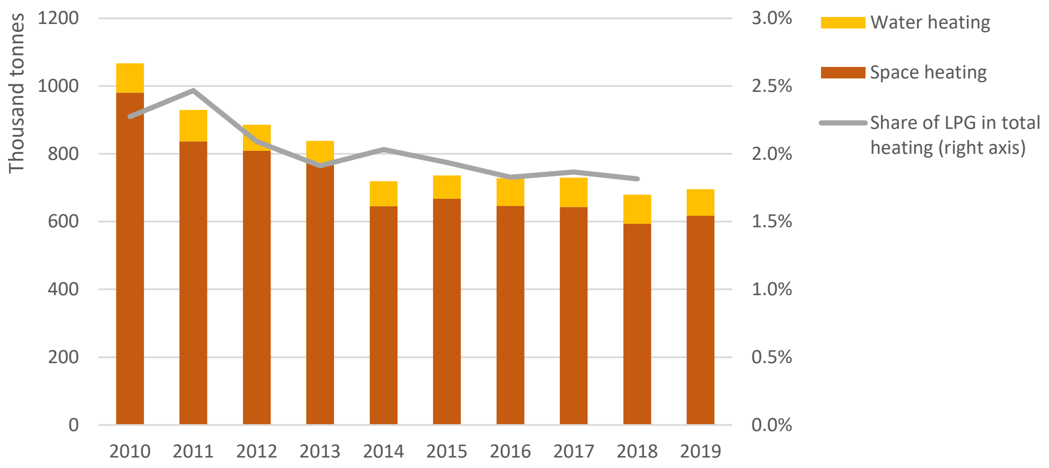
[1] IEA databases; national sources; Menecon Consulting analysis.

2 France

2.1 LPG heating market trends

LPG plays a significant though declining role in providing space and water heating to residential and commercial buildings in France, mainly in areas off the gas grid. LPG consumption for heating is estimated at around 700,000 tonnes in 2019, slightly lower than in 2014 but well down compared with 2010 (Figure B2.1). LPG meets less than 2% of the country's total heating needs. Natural gas holds the largest share of the heating market (36% of total energy use), followed by biomass (23%) and electricity (20%) and heating oil (16%).

Figure B2.1: LPG consumption for heating and share of overall heating market – France[1]



There are close to 11 million homes across France that use LPG regularly or occasionally, the bulk of which are in the 27,000 municipalities that are not connected to the natural gas grid because it is not economical due to their remoteness.[2] Most of those homes use LPG mainly for cooking, but often for water heating and space heating too. Around 700,000 homes have external storage tanks – usually underground – with the rest relying on bottles.[3] The use of LPG for heating is highest in the south and east of the country, notably in coastal areas, where winters are relatively mild and heating needs are less; heating oil, biomass and electricity account for almost all off-grid heating in the north of France.

2.2 Government heating policies

Government policies with respect to heating buildings in France are increasingly driven by the country's climate objectives, which in turn are underpinned by EU climate policies, including the 2020 climate package and the 2030 climate framework. The Energy Transition for Green Growth Act (Loi relative à la transition énergétique pour la croissance verte) was adopted in 2015 and is being implemented through more than 150 regulations. The Act includes several legally binding energy and climate targets, including a reduction of greenhouse-gas emissions by 40% in 2030, a reduction of final energy consumption by 20% in 2030 and a reduction of fossil fuel consumption of 30% by 2030 compared with 2012. In 2019, a new law (Loi relative

[1] Menecon Consulting analysis based on IEA databases.
[2] https://www.francegazliquides.fr/les-usages/usages-domestiques/pour-quels-usages/
[3] https://selectra.info/energie/propane/citernes/consommation

a l’energie et au climat) established a commitment to net-zero emissions by 2050, as well as several measures affecting energy use in buildings aimed at improving energy efficiency. A new law incorporating proposals by a citizens’ commission on climate change, including stronger measures to lower emissions from buildings, is currently being considered by parliament.

Most of the measures that have been introduced to date to support the energy transition favour the development of electric heating, notably heat pumps. However, there are a number of financial incentives that are offered by the national housing agency and other authorities to encourage the installation of highly efficient LPG or natural gas boilers, including a boiler conversion grant (coup de pouce)[1,] subsidies for home improvements that increase energy efficiency (Ma PrimeRenov’)[2], zero-interest loans (l’Eco-PTZ) and a lower rate of VAT.[3] A tax credit (Crédit d’Impôt pour la Transition Énergétique) and the MaPrimeRénov’ are also available for replacing a heating oil tank. In most cases, these incentives are restricted to low- or middle-income households.

In November 2020, the government announced a set of new environmental and heating regulations covering new construction that have the effect of largely excluding LPG as a heating option for residential buildings. The regulations set a new standard for CO2 emissions of 4 kilogrammes per square metre for individual homes from 2021, which all but rules out LPG and natural gas for all but the most well-isolated houses. For collective housing units, the standard is higher, at 14 kg/m2 until the end of 2023 and 6 kg/m2 thereafter. In addition, the installation of heating oil and coal-fired boilers will be forbidden in any type of building from July 2021.

2.3 Competitiveness of LPG for heating

LPG sales to homes and businesses carry an excise duty of €207/tonne, compared with just under €300/tonne for heating oil. The share of taxes in the final price of LPG for households averaged 30% in 2020, compared with 37% for heating oil and 35% for electricity (Table B2.1 and Figure B2.2). In 2020, LPG cost around €1,380 per tonne of oil equivalent on average, compared with €895 for heating oil, €1,070 for natural gas and well over €2,100 for electricity. Although the running costs of heating oil are marginally lower than for LPG (adjusting for differences in efficiency), installation costs are generally higher while LPG offers a number of practical advantages (see Part A, Section 4).

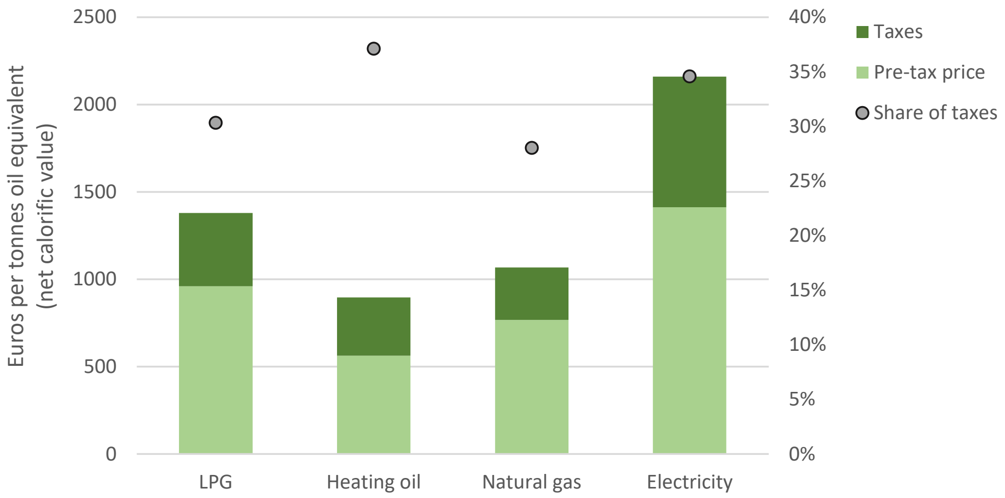
Table B2.1: Household heating fuel prices and taxes per tonne of oil equivalent – France[4]

[1] https://www.service-public.fr/particuliers/vosdroits/F34421
[2] https://www.ecologie.gouv.fr/sites/default/files/19164_maPrimeRenov_DP_Janvier%202021.pdf
[3] https://www.francegazliquides.fr/remplacer-sa-chaudiere-fioul-par-un-chauffage-propane/#three
[4] IEA databases; Menecon Consulting analysis.

	Euros					US Dollars
	2016	2017	2018	2019	2020	2020
Pre-tax prices						
LPG	837	857	926	976	960	1,095
Heating oil	506	582	708	724	563	642
Natural gas	697	679	707	767	768	875
Electricity	1,221	1,232	1,279	1,339	1,413	1,611
Total taxes						
LPG	320	351	410	421	418	477
Heating oil	237	283	360	364	332	379
Natural gas	203	234	277	292	299	341
Electricity	695	700	715	730	747	851
Final prices						
LPG	1,157	1,208	1,337	1,397	1,378	1,571
Heating oil	742	865	1,069	1,088	895	1,020
Natural gas	900	913	984	1,059	1,066	1,216
Electricity	1,916	1,932	1,993	2,069	2,159	2,462
Total taxes as % of final price						
LPG	28%	29%	31%	30%	30%	-
Heating oil	32%	33%	34%	33%	37%	-
Natural gas	23%	26%	28%	28%	28%	-
Electricity	36%	36%	36%	35%	35%	-

Note: Net calorific value. In 2020, prices are the average of the first three quarters for natural gas and electricity.

Figure B2.2: Retail price of heating fuels and share of taxes, 2020 – France [1]



Note: Net calorific value. Prices are the average of the first three quarters for natural gas and electricity.

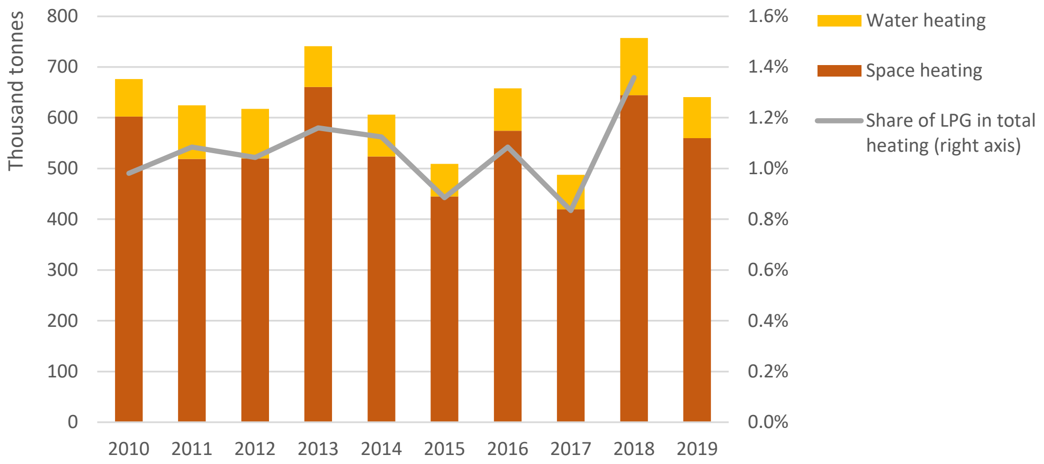
[1] IEA databases; Menecon Consulting analysis.

3 Germany

3.1 LPG heating market trends

The heating market in Germany is dominated by natural gas and heating oil, with LPG playing a small role in meeting heating needs in areas not served by the gas grid. In 2019, around 630,000 tonnes of LPG were consumed for space and water heating – equal to just under 14% of all the LPG consumed in the country (the bulk is used as a petrochemicals and refinery feedstock and in industry, as well as for Autogas and for cooking) and a little over 1% of all the energy used for heating in buildings (Figure B3.1). Almost half of the country's heating needs are met by natural gas, followed by heating oil (21%), biomass (13%) and electricity (10%), based on 2018 data. The use of LPG for heating has fluctuated markedly in recent years, largely in response to variations in winter temperatures; the overall trend is broadly flat.

Figure B3.1: LPG consumption for heating and share of overall heating market – Germany [1]



The scope for using LPG for heating is limited by the country's extensive natural gas grid, incorporating around 50,000 km of pipelines, which has been developed since the 1970's based primarily on imports from the Netherlands, Russia and Algeria. Germany also has the largest heating oil market in Europe, totalling more than 12 million tonnes in 2019, though sales have fallen steadily in recent years as natural gas has gained market share. There are an estimated 2.94 million homes not connected to the gas grid that use heating oil (including 1.9 million single-family homes), many of which are in rural areas (26% of Germany's population is rural); around a quarter of those rural homes use heating oil.[2]

A recent study carried out by DBI Gas and Environmental Technology on behalf of the German Association of Liquid Gas shows that there is considerable potential for switching from heating oil to LPG for heating in the residential sector, thereby reducing CO2 emissions (DBI, 2020). If all homes in areas off the gas grid that currently use heating oil were to switch to LPG, sales would rise by around 5.5 Mtoe – five times current total LPG sales to buildings across the country and almost nine times the use of LPG for heating alone. These homes are concentrated in the southeast and west of the country. CO2 emissions would be cut by a total of 4 million tonnes per year – equal to about 3% of Germany's current buildings emissions,

[1] Menecon Consulting analysis based on IEA databases.

[2] https://www.liquidgaseurope.eu/images/what-is-lpg/GERMANY_.pdf

thanks to the lower carbon intensity of LPG vis-à-vis heating oil and the higher efficiency of LPG boilers.

3.2 Government heating policies

Germany's policies with respect to heating are shifting, largely in response to increasing pressure to address climate change. As in France, climate policy is guided by EU climate policies, including the 2020 climate package and the 2030 climate framework. The Energiewende – a plan introduced in 2010 to transform the country's energy system to make it more efficient and supplied mainly by renewable energy sources – remains the central policy pillar. Under that plan, residential buildings are to consume 80% less primary energy, with the remaining energy needs to be covered primarily by renewables by mid-century. Germany's most recent national climate change strategy, which has important implications for heating, is defined in the Climate Action Plan 2050, which was released in 2016. It sets out a pathway for sector-specific greenhouse-gas emissions reductions: overall, the goal is to lower emissions by 40% by 2020, 55% by 2030, 70% by 2040, and 80-95% by 2050 compared with 1990.[1] These targets are complemented with short- and medium-term targets for emissions, energy consumption and renewable energy supply.

The Climate Action Plan 2050 lays down 2030 targets for individual sectors, including buildings. These targets were tightened in the Federal Climate Protection Act of 2019, which set of goal of 70 Mt of emissions from buildings in 2030 (emissions in 2019 were just over 120 Mt). The Act also introduced a carbon tax from 2021. The latest Action Plan incorporates a new zero-energy building standard for new buildings, which came into effect at the start of 2021; it will be progressively tightened in the coming years to make installing new heating systems that use renewable energy sources efficiently a far more attractive option to homeowners than those that run on fossil fuels. Existing buildings are also due to be upgraded over the coming decade through energy efficiency measures and greater use of renewable energy so that they meet the standards of virtually climate-neutral buildings (IEA, 2020). In addition, the German Renewable Energy Heating Act requires all new residential and commercial buildings to include a sustainable heating scheme from 2016 and bans the installation of oil burners in new buildings completely.[2]

To meet its ambitious greenhouse-gas emissions reduction target for 2030, a package of measures (Climate Action Programme 2030), including a phased carbon-pricing system for the buildings sector and a ban on the sale of new oil-based heating systems for existing buildings from 2026[3], as well as bigger incentives for retrofitting of buildings was adopted into law by the German parliament in December 2019. The package, which includes tax relief and a reduction in taxes and fees on electricity for households and businesses. A national CO2

[1] https://www.bmu.de/en/topics/climate-energy/climate/national-climate-policy/greenhouse-gas-neutral-germany-2050/

[2] https://heatpumpingtechnologies.org/germany-new-regulations-likely-drive-heat-pump-market/

[3] Houses that cannot be supplied with natural gas or district heating or could not be heated by renewable energies are exempt from the ban. Households that replace their old oil-fired heating system replaced by a more climate-friendly alternative can obtain a grant (http://www.xinhuanet.com/english/2019-10/23/c_138497175.htm).

certificate trading scheme was introduced at the beginning of 2021 in parallel with the new carbon tax.

***Table B3.1: Household heating fuel prices and taxes per tonne of oil equivalent – Germany*[1]**

	Euros					US Dollars
	2016	2017	2018	2019	2020	2020
Pre-tax prices						
LPG	539	605	672	681	657	749
Heating oil	397	471	588	571	411	469
Natural gas	674	650	638	667	679	774
Electricity	1,610	1,612	1,603	1,624	1,663	1,896
Total taxes						
LPG	281	293	306	308	291	332
Heating oil	158	172	194	191	154	175
Natural gas	213	208	206	211	202	231
Electricity	1,847	1,933	1,878	1,844	1,876	2,138
Final prices						
LPG	820	898	978	989	948	1,081
Heating oil	554	643	782	762	565	644
Natural gas	887	858	844	878	881	1,004
Electricity	3,457	3,544	3,481	3,469	3,538	4,034
Total taxes as % of final price						
LPG	34%	33%	31%	31%	32%	-
Heating oil	28%	27%	25%	25%	27%	-
Natural gas	24%	24%	24%	24%	23%	-
Electricity	53%	55%	54%	53%	53%	-

Note: Net calorific value. For 2020, electricity prices are for the first half of the year.

Fuel taxation in Germany is harmonised with the 2003 EU Energy Taxation Directive, which lays out minimum excise duty rates on energy products in member countries. Germany has set higher national rates for most fuels. An energy tax is applied on oil products, natural gas, LPG and coal used for heating for commercial and household consumers. An excise tax of €60.60 per tonne is levied on LPG sales to households; some stationary industrial uses are taxed at the same rate, though heating uses carries a tax of €45.45/tonne.[2] VAT is charged at a standard rate of 19% as for all heating fuels but was reduced to temporary to 2016 in 2020 in response to the Covid-19 crisis. The Energy Duty Act provides for several tax concessions, depending on how they are used; for example, rebates are available for certain types of co-generation plant, which incurs an excise tax at the rate of €60.60 per tonne. Overall, taxes are highest on electricity and lowest on natural gas in proportionate terms (Table B3.1).

3.3 Competitiveness of LPG for heating

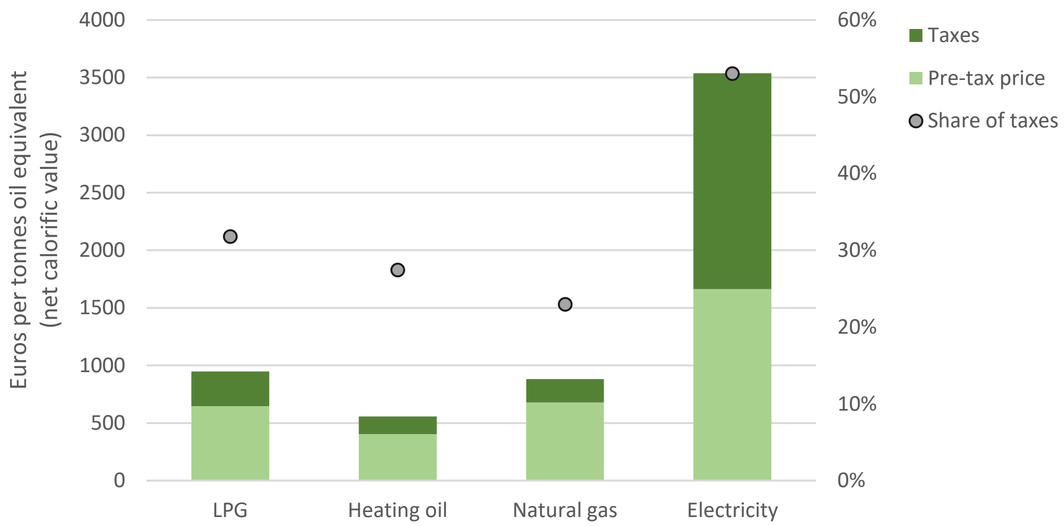
On an energy basis, LPG is generally taxed on average a lot less than electricity, but more than natural gas and heating oil. In total, taxes made up close one-third of the retail price of LPG to households in 2020 on average (Figure B3.2). As a result, LPG is much cheaper than

[1] IEA databases; Menecon Consulting analysis.

[2] https://ec.europa.eu/taxation_customs/sites/taxation/files/resources/documents/taxation/excise_duties/energy_products/rates/excise_duties-part_ii_energy_products_en.pdf

electricity, but more expensive than heating oil and slightly more costly than natural gas. Were LPG taxed at the same rate as natural gas, it would be cheaper.

Figure B3.2: Retail price of heating fuels and share of taxes, 2020 – Germany[1]



Note: For 2020, electricity prices are for the first half of the year.

Despite the higher price of LPG, it can still be an attractive heating option. A case study for a large, single-family home in Germany commissioned by Liquid Gas Europe compares how alternative technology options compare with an existing oil boiler. It shows that switching to LPG would yield annual CO2 savings of 63% (90% in the case of bioLPG), NOx emissions savings of 68%, particulate matter emissions savings of 66% and annual savings on the energy bill of €933 euros with a capital cost payback of 8.4 years. LPG performs better than all the other options on several criteria (Figure B3.3).

[1] IEA databases; Menecon Consulting analysis.

Figure B3.3: Alternative heating technologies compared with an existing oil boiler – Germany[1]

Technology Options	Upfront cost*	Running cost	Lifetime CO_2 reduction	Lifetime air pollution reduction
LPG boiler: *New, condensing* + **Thermal insulation**	Similar to oil boiler	Substantially lower than oil boiler assuming that efficiency improvements are achieved (new boiler and thermal insulation)	Considerably lower than current oil boiler (over 60% using LPG, up to 90% using bioLPG)	Markedly lower than current oil boiler (60-80%)
Air Source Heat Pump + **Thermal insulation**	7-8 times more expensive than an oil boiler	Lower than oil boiler due to higher operating efficiency and thermal insulation	Lower than current oil boiler. Relatively high carbon-intensive energy mix (up to 70%)	Substantially lower than current oil boiler (up to 99%)
Biomass boiler: *New, automatic Pellet or log fuelled* + **Thermal insulation**	Up to 10 times more expensive than an oil boiler	Slightly lower than oil boiler	Substantially lower than current oil boiler (more than 90%)	PM emissions higher irrespective of wood type (more than 1000%) NOx emissions lower than oil (up to 60%)

Note: Red indicates performs worse than an old oil boiler and green better.

[1] Liquid Gas Europe (https://www.liquidgaseurope.eu/campaign-beyondthegasgrid).

4 United Kingdom

4.1 LPG heating market trends

The United Kingdom heating market is dominated by natural gas, by virtue of its historic reliance on indigenous supplies from the North Sea and the country's relatively high density of population, which means that most of the country's town and cities are connected to the national gas grid. As a result, gas meets over three-quarters of the country's heating needs, with LPG largely used in remote rural areas. We estimate that roughly 400,000 tonnes of LPG were used for space and water heating in 2019 – roughly half of all the LPG consumed in the buildings sector and around 0.8% of all the energy used for heating in buildings. The use of LPG for heating in the United Kingdom fluctuated over the early part of the 2010's, but has been fairly stable in recent years, despite some variations in average winter temperatures.

Almost all the LPG used for heating is in buildings situated in areas off the gas grid. In total, LPG is the primary heating fuel in 193,000 residential buildings[1] – equal to roughly one-tenth of all off-grid properties. Most off-grid houses and offices are heated with heating oil (kerosene) or electricity, which is the primary cooking fuel. An estimated 55% of rural homes use heating oil and tens of thousands of rural hotels.[2]

4.2 Government heating policies

Traditionally, the government has favoured natural gas for heating to exploit the abundance of supply from the North Sea. For social reasons, the government applies a reduced rate of VAT (5% compared with the standard rate of 20%) on sales of all heating fuels (including LPG) and electricity in the residential sector (Table B4.1). The only heating fuel that attracts an excise duty in the household sector is heating oil. Businesses and public sector consumers, by contrast, must pay an excise duty, which applies to liquid fuels, LPG and natural gas, as well as the Climate Change Levy (CCL). Commercial end users benefit from a refund equivalent to one-third of the excise duty paid when used for energy transformation purposes. In addition, businesses can pay a reduced rate of CCL charges if they enter into a voluntary Climate Change Agreement (CCA) with the Environment Agency. Businesses which agree to be bound by a CCA receive a reduction of 90% in the CCL rate paid on electricity bills and a 65% reduction on all other fuels. The current excise duty on LPG is £21.75/tonne and the CCL £0.406 pence/kWh (from March 2020).

[1] https://www.liquidgasuk.org/about/lpg-in-the-home
[2] https://www.liquidgaseurope.eu/images/what-is-lpg/UK_4.pdf

Table B4.1: Household heating fuel prices and taxes per tonne of oil equivalent – United Kingdom[1]

	Pounds					US Dollars
	2016	2017	2018	2019	2020	2020
Pre-tax prices						
LPG	814	838	884	884	796	1,021
Heating oil	339	425	523	517	377	483
Natural gas	543	530	549	566	510	654
Electricity	1,668	1,765	1,902	2,029	2,032	2,606
Total taxes						
LPG	41	42	44	44	40	51
Heating oil	152	156	161	160	153	197
Natural gas	27	27	27	28	25	33
Electricity	83	88	95	101	102	130
Final prices						
LPG	855	879	928	928	836	1,072
Heating oil	490	581	683	677	530	680
Natural gas	570	557	577	595	535	686
Electricity	1,751	1,853	1,997	2,130	2,134	2,736
Total taxes as % of final price						
LPG	5%	5%	5%	5%	5%	-
Heating oil	31%	27%	24%	24%	29%	-
Natural gas	5%	5%	5%	5%	5%	-
Electricity	5%	5%	5%	5%	5%	-

Note: Net calorific value. Prices for heating oil, natural gas and electricity in 2020 are the average for the first three quarters.

The government is undertaking a major reform of its policies relating to heating in buildings. On 27 June 2019, the United Kingdom government set a legally binding target to achieve net zero greenhouse-gas emissions from across the United Kingdom economy by 2050. It is now looking at the best ways to cut carbon emissions from heat during the 2020's and how to reduce reliance on subsidy.

The government is due to publish in 2021 a heat and building strategy that will set out immediate actions for reducing emissions from buildings, including measures aimed at achieving a transition to low-carbon heating. It is consulting stakeholders on regulatory options to phase out the installation of fossil fuel heating systems as part of its new Future Homes Standard, which will require new build homes to be future proofed with low-carbon heating and world leading levels of energy efficiency.[2] An energy white paper released in December 2020 indicated that the government expects all newly installed heating systems to be low-carbon or to be appliances that could be converted to a clean fuel supply by the mid-2030's.[3] The government had announced earlier in 2020 its intention to introduce a ban on the installation of all types of gas and oil boilers – including LPG boilers – covering new housing from 2025.

[1] IEA databases; national sources; Menecon Consulting analysis.

[2] The government has proposed that homes built to this standard should have 75% to 80% fewer CO2 emissions than those built to current building regulations. https://www.gov.uk/government/groups/heat-in-buildings

[3] https://www.gov.uk/government/publications/energy-white-paper-powering-our-net-zero-future/energy-white-paper-powering-our-net-zero-future-accessible-html-version#chapter-4-buildings

Existing measures relating to heating in buildings already in place include the following:

- **Boiler standards**: Improved standards (Boiler Plus standards) for domestic gas boilers were introduced in April 2018. The new minimum performance standard was set at 92%. The standards also make timers and room thermostats an explicit requirement for all gas and oil systems, as well as an addition efficiency measure when a gas combi boiler is installed. The energy-saving technologies that can be used to comply include flue gas heat recovery systems and smart controls.
- **Building codes**: The Buildings Mission, the first mission of the Clean Growth Grand Challenge, has the objective to at least halve the energy use of all new buildings by 2030 through efficiency improvements in building envelope and equipment. The government is consulting on how to tighten energy efficiency standards for new homes and non-domestic buildings, and for building work to existing buildings, as well as on preventing overheating in buildings.
- **Consumer advice**: Following the recommendations of the Each Home Counts Review, the government has worked with consumer groups and other partners to develop the Simple Energy Advice website,[1] where consumers can find a range of trusted, impartial advice on making their homes warmer, greener, and more energy-efficient and information on financial assistance schemes available.

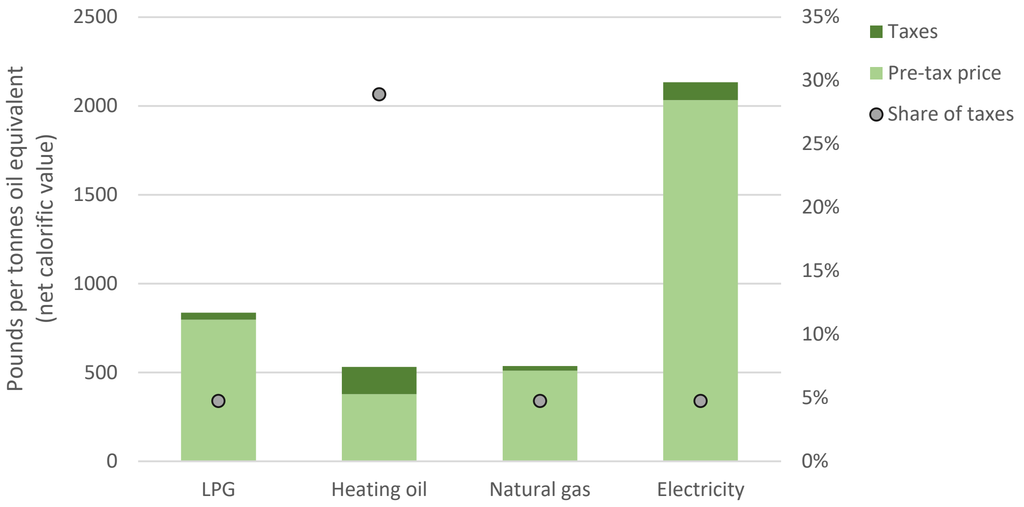
Liquid Gas UK (LGUK), the trade association for the LPG industry in the United Kingdom, has called on the Government to revise the methodology for Energy Performance Certificates (EPCs), which currently encourages owners of off-grid properties to choose higher carbon heating solutions, such as heating oil, over more energy efficient options, such as LPG. EPCs, which are mandatory when selling or renting a property, provide information about a property's energy use and typical energy costs, and recommendations about how to reduce energy use and save money. The current methodology means two homes built to same standards can have different EPC ratings, depending on whether they are on or off grid, as they measure energy cost per square metre of floor space through the inclusion and weighting of fuel costs.[2]

[1] https://www.simpleenergyadvice.org.uk/
[2] https://www.liquidgasuk.org/news/articles/2020/government-urged-to-level-the-playing-field-on-epcs-for-off-grid-homes

4.3 Competitiveness of LPG for heating

LPG is a competitive heating fuel when compared with natural gas and heating oil. (Figure B4.2). LPG was still much cheaper than electricity. There has been little change in the competitive position of LPG in recent years.

Figure B4.2: Retail price of heating fuels and share of taxes, 2020 – United Kingdom[1]



LPG remains one of the most attractive heating option for off-grid buildings. A recent study commissioned by Liquid Gas Europe compares how alternative technology options compare with an existing traditional oil boiler for an existing rural British hotel built before 1918.[2] It shows that switching to a LPG condensing boiler would yield annual CO2 savings of 35% (82% in the case of bioLPG), NOx emissions savings of 56%, particulate matter emissions savings of 85% and annual savings on the energy bill of €819 with a capital cost payback of just six years. All the options took account of thermal insulation. LPG performs better than all the other options on several criteria (Figure B4.3).

[1] IEA databases; national sources; Menecon Consulting analysis.
[2] https://www.liquidgaseurope.eu/campaign-beyondthegasgrid

Figure B4.3: Alternative heating technologies compared with an existing oil boiler – United Kingdom[1]

Technology Options	Upfront cost*	Running cost	Lifetime CO_2 reduction	Lifetime air pollution reduction
LPG boiler: *New, condensing*	Similar to oil boiler	Slightly lower than oil boiler assuming that efficiency improvements are achieved	Lower than current oil boiler (up to 40% using LPG, up to 90% using bioLPG)	Substantially lower than current oil boiler (up to 60%)
Air Source Heat Pump	4-5 times more expensive than an oil boiler	Lower than oil boiler due to efficiency improvements	Substantially lower than current oil boiler (more than 90%)	Substantially lower than current oil boiler (up to 99%)
Biomass boiler: *New, automatic (Pellet or log fuelled)*	7-8 times more expensive than an oil boiler	Potentially higher than oil. Dependent on wood type (pellet or logs).	Substantially lower than current oil boiler (more than 90%)	Substantially higher than current oil boiler. PM emissions are higher irrespective of wood type (more than 1000%)

Note: Red indicates performs worse than an old oil boiler and green better.

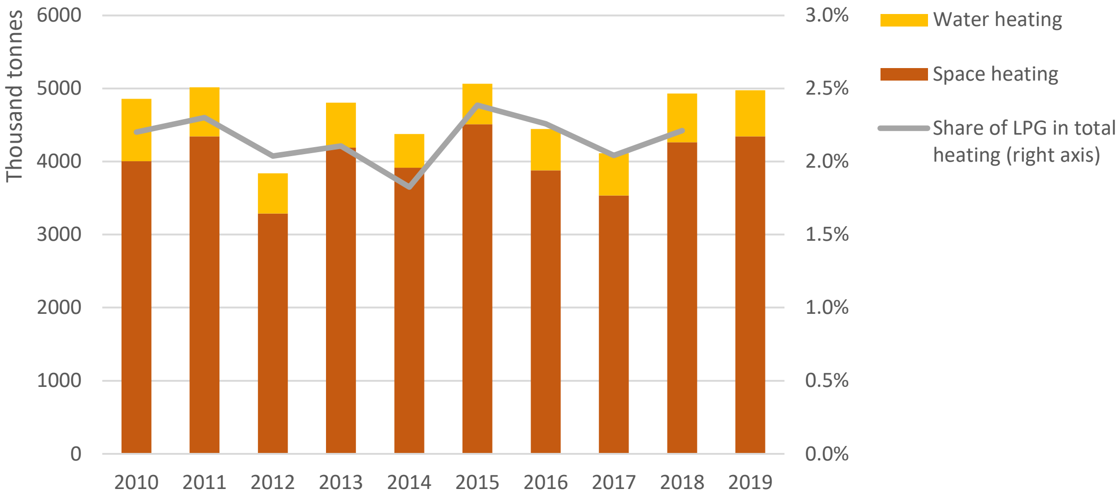
[1] Liquid Gas Europe (https://www.liquidgaseurope.eu/campaign-beyondthegasgrid).

5 United States

5.1 LPG heating market trends

LPG (propane) makes a significant contribution to meeting heating needs in the United States by virtue of the cold winter weather in many northerly parts of the country and ample local availability of the fuel. An estimated 5 Mt out of a total of 5.7 Mt of LPG consumed in buildings and total LPG use of 45.9 Mt in 2019 was used for space and water heating (Figure B5.1). Space heating alone accounted for 4.3 Mt, or 87%, of all the LPG used for heating. Most of the remaining 700,000 tonnes were used for cooking.[1] LPG made up around 2.2% of national energy use for heating. Both these shares and total volumes have fluctuated around a broadly flat trend over the last decade.

Figure B5.1: LPG consumption for heating and share of overall heating market – United States[2]



LPG competes mainly with heating oil in off-grid areas in most parts of the country. In the warmer southern states, where winter heating needs are usually minimal and most energy use in buildings is for water heating and cooking, electricity is the primary competing fuel. The share of LPG in total energy use for heating is broadly similar across the United States, while the shares of heating oil, natural gas – by far the single biggest heating fuel, supplying around two-thirds of national energy demand for heating – and electricity vary markedly by region.[3] Many homes in rural areas use LPG to meet most heating and cooking needs.[4] Consumption is highly seasonal, with the largest consumption occurring in the fall and winter months. LPG sold as a fuel for domestic use is generally defined as HD-5, which contains a minimum of 90% propane by volume, with small quantities of other hydrocarbon gases. HD-10, which contains up to 10% propylene, is the accepted standard in California.[5] In contrast to most other parts of the world, furnaces are thought to outnumber boilers in central heating systems in homes in the United States.

[1] Including LPG use for grilling food outdoors, a common practice throughout the country.
[2] Menecon Consulting analysis based on IEA databases.
[3] https://www.climatecentral.org/news/your-heating-fuel-depends-on-where-you-live-18084
[4] https://www.eia.gov/energyexplained/use-of-energy/homes.php
[5] https://www.eia.gov/energyexplained/hydrocarbon-gas-liquids/uses-of-hydrocarbon-gas-liquids.php

5.2 Government heating policies

Consumer choices concerning heating technologies in the buildings sector are influenced by a myriad of energy and environmental policies and measures at all levels of government. At the federal level, LPG is rarely targeted as a heating fuel, but can benefit from many of these policies as a clean, economic and practical fuel, notably in areas where supplies of natural gas are limited or unavailable. In general, US policies and regulations tend to favour tax relief and other financial incentives over punitive taxation to influence consumer choice of heating fuel and technology.

The main instruments and areas in which government policies incentivise LPG for heating include the following:

- **Energy efficiency incentives:** The federal government offers household tax credits for installing energy-saving equipment as well as efficiency upgrades to building envelopes (DOE, 2019d). They include the Residential Energy Efficient Property Credit of 30% for installation of qualified equipment, including efficient LPG boilers and furnaces.[1] In addition, under the Bipartisan Budget Act of 2018, Congress extended the Non-Business Energy Property Credit of 10% (up to $500) for qualified energy-saving improvements, such as thermal insulation and high-efficiency heating systems such as condensing LPG boilers.[2] Several other federal energy efficiency tax credits, however, have expired, including for commercial builders of new efficient homes and retrofitted buildings with efficient heating systems. Several states also offer energy efficiency tax benefits, especially as sales or property tax exemptions for installing qualified equipment.[3]
- **Boiler and heater efficiency standards and labels**: Boilers, furnaces and heaters are included in the Appliance and Equipment Standards Program run by the federal Department of Energy (DOE)'s Building Technologies Office. The DOE is required by law to review standards at least once every six years to take account of technological advances. Domestic boiler standards were frozen in 2018 on the grounds of affordability. There are also energy labelling requirements for boilers, furnaces and heaters. The Federal Trade Commission requires all heating equipment alongside a range of other appliances to be labelled by the manufacturer, informing the consumer of the products' energy consumption or energy efficiency. The labels show the highest and lowest energy consumption or efficiency estimates of similar appliance models.[4] In addition, the Environmental Protection Agency and the DOE jointly administer a voluntary labelling programme called Energy Star, which certifies products that meet predetermined energy-efficiency criteria; certified boilers currently require an annual fuel utilisation efficiency rating of at least 87% for oil boilers and 90% for gas boilers.[5]

[1] https://www.irs.gov/newsroom/energy-incentives-for-individuals-residential-property-updated-questions-and-answers
[2] The credit will phase down after 2019 until the end of 2021, when it fully expires.
[3] Many are listed on the Database of State Incentives for Renewables & Efficiency at https://www.dsireusa.org/.
[4] https://www.ftc.gov/tips-advice/business-center/guidance/energyguide-labeling-faqs-appliance-manufacturers
[5] https://www.energystar.gov/products/heating_cooling/boilers

LPG storage water heaters are eligible for Energy Star qualification, whereas electric resistance units and heating oil units are not.[1]

- **Co-generation**: Under the Bipartisan Budget Act of 2018, Congress reinstated a 10% investment tax credit for co-generation projects, including those fuelled by LPG, up to 50 MW in capacity (limited to the project's first 15 MW) that exceed 60% energy efficiency and that commence construction by the end of 2021 (ICF, 2018). The Act also includes other benefits for co-generation projects, including depreciation allowances.
- **Federal energy use**: The federal government itself uses large amounts of energy to heat offices and other public buildings. The DOE's Federal Energy Management Program (FEMP) works with multiple stakeholders, including federal agencies, national laboratories, Congress and industry in order to achieve the energy-efficiency goals of federal agencies. A 2018 Executive Order removed non-statutory requirements for energy efficiency but grants more discretion to agencies in improving their operational efficiency (IEA, 2019b). Previously, the FEMP had updated the minimum efficiency requirements associated with gas-fired boilers to require 94% or greater thermal efficiency, essentially requires all federal agencies to install condensing boilers for all boiler replacements.
- **Federal support for research and development (R&D):** Funding to applied R&D of energy-efficient technologies has expanded substantially in recent years (IEA, 2019b). Research in national laboratories and institutions has helped develop more efficient boiler technologies, including condensing boilers.

Several cities and counties across the United States have introduced, or have attempted to introduce, a prohibition on the installation of gas boilers, including those fuelled with LPG, in new housing units in order to meet long-term decarbonisation goals. Over 42 California cities and counties, including Berkeley, have adopted such a ban or otherwise discouraged gas for heating; California's building code allows cities to set stricter energy standards than those imposed by the state.[2] In response to the growing pressure from municipalities to enact stricter building and air quality codes than currently exist at the state level, more than half of the US states have enacted laws or introduced legislation that would prohibit municipal restriction of the use of LPG or natural gas.[3]

There are no federal taxes on domestic or commercial heating fuels in the United States. Most states apply a sales tax, though there are exemptions for certain users; sales tax rates vary from 0% to 9%. Some states also apply an ad valorem or excise tax on the retail price of fuels or the earnings of fuel distribution companies. Data on the average effective rate of taxation is not available.

[1] There are currently about 270 certified propane storage water heaters (https://propane.com/propane-products/water-heating/).
[2] https://www.latimes.com/environment/newsletter/2021-02-04/bay-area-cities-have-banned-gas-to-fight-climate-change-but-not-los-angeles-boiling-point
[3] See, for example, https://www.eenews.net/stories/1063674561

5.3 Competitiveness of LPG for heating

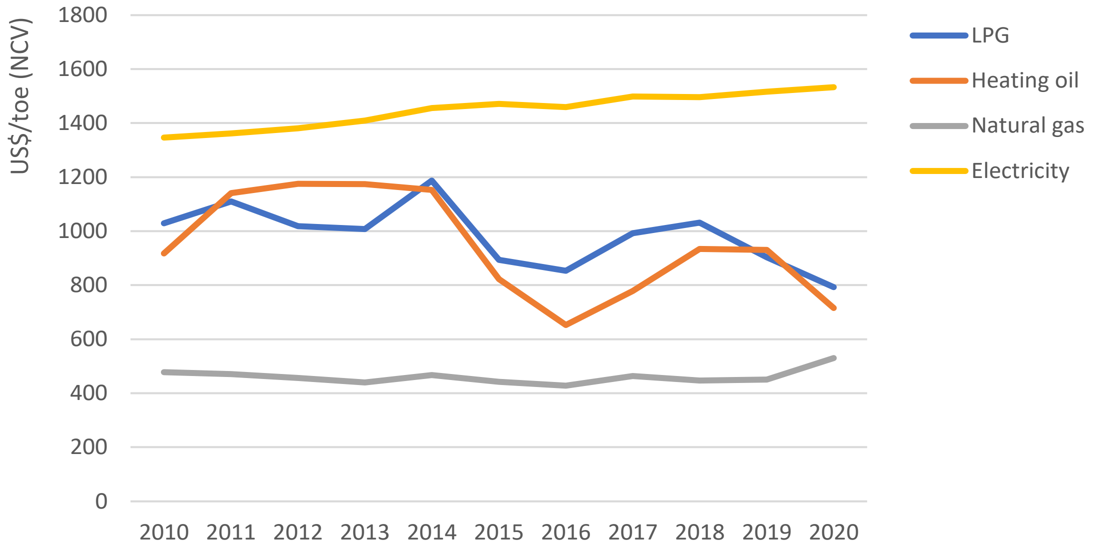
LPG is highly competitive as a heating fuel for buildings in off-grid areas. In 2020, the price of LPG averaged around $790/toe – more than that of heating oil but much lower than that of electricity (Table B5.1). The competitive position of LPG has improved in recent years vis-à-vis heating oil and electricity, as well as natural gas, though gas is still significantly cheaper than LPG in most parts of the country (Figure B5.2). Booming supply of LPG thanks to rising shale gas production has tended to drive down the price of LPG relative to oil products, increasing the potential for expanding the use of LPG for heating.

Table B5.1: Household heating fuel retail prices and taxes per tonne of oil equivalent – United States[1]

	Dollars					Euros
	2016	2017	2018	2019	2020	2020
LPG	853	993	1 031	904	793	696
Heating oil	653	778	935	931	716	628
Natural gas	429	464	447	451	531	466
Electricity	1,459	1,499	1,496	1,516	1,533	1,345

Note: Net calorific value.

Figure B5.2: Retail price of heating fuels – United States[2]



[1] IEA databases; national sources; Menecon Consulting analysis.
[2] IEA databases; national sources; Menecon Consulting analysis.

Annex 1:

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Annex 2:

Note on data sources

Data on energy consumption for heating were compiled from a range of sources. For the countries surveyed (except for Chile) and for the world as a whole, data on total energy use in buildings by fuel (including LPG) were obtained from the online energy balance and statistics databases of the International Energy Agency (IEA).[1] In addition, data on space and water heating by major fuel category (including oil, but not LPG) were taken from a separate IEA database on energy indicators. All these data are currently available to 2018. For Chile, detailed official data on heating by end-use type and fuel, including LPG, for 2018 alone were obtained from CDT (2019). Data on total LPG use in the buildings sector for 2019 is available from Argus/WLPGA (2020).

Data on fuel taxes and prices were mostly taken from online IEA energy prices and taxes databases. In some cases, data on LPG prices were obtained from national sources.

[1] https://www.iea.org/data-subscriber-login

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