SUSTAINABLE RECOVERY:

The role that the LPG industry can play in supporting a sustainable recovery

A World LPG Association (WLPGA) report with analysis provided by Gemserv

November 2021

WLPGA

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LPG EXCEPTIONAL ENERGY

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PROJECT OVERVIEW

As governments develop economic recovery packages following the COVID-19 crisis, this report provides new analysis which considers the positive impact that investments in LPG and bioLPG energy projects could deliver, on the economy and the environment. The report develops four representative recovery packages – clean cooking, clean transport (Autogas), building renovations and investment in biofuel production capacity - focusing each on a selection of countries and use cases across the world.

Please note that all monetary references are in US Dollars (written as $) unless otherwise stated.

Nothing in these documents constitutes a valuation or legal advice. Any party that chooses to rely on this report or dataset does so at its own risk. Details of principal sources are set out within the document and we have satisfied ourselves, so far as possible, that the information presented in the report is consistent with other information which was made available to us by our stakeholders in the course of our work.

WLPGA

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).

Acknowledgements

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EXECUTIVE SUMMARY AND KEY MESSAGES

The world is facing significant challenges, from the pandemic recovery to the climate crisis, and the need to revive economic development in all regions. As communities across the world work to move on from the profound effects of the COVID-19 pandemic, a consistent policy message has emerged, that policy can be used to build back better. From the G7 and G20 summits, to the COP26 conference, policymakers and industry are promoting proposals which boost economic growth, support jobs, and meet environmental and social objectives – such as the need to tackle climate change.

This report contributes to this conversation by analysing the role that the LPG industry can play in supporting recovery packages which boost economic growth, support jobs, and tackle environmental challenges in countries across the world.

To make this assessment, we have valued the economic and environmental benefits which can be accrued by investing $1 million of public/private sector money into four recovery packages. These include finance to support the transition to clean cooking, the conversion of gasoline vehicles to Autogas, the renovation of old homes with energy efficient heating systems, and investment in biofuel production facilities.

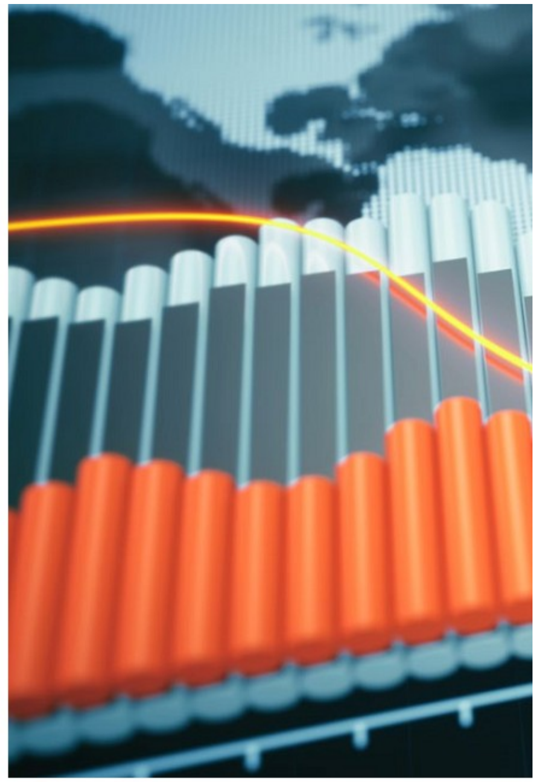
The report finds that:

- Almost three billion people currently use solid fuels or kerosene for cooking globally[4]. Switching to LPG and **clean cooking** fuels can significantly lower harmful household air pollution, reduce carbon emissions, as shorten the labour time spent collecting cooking fuel. Our analysis demonstrates that in Sub-Saharan Africa, investing $1 million into supporting the transition to LPG cooking is enough funding to motivate 13,000 households to transition away from polluting fuels, which would create lasting environmental and health benefits, and a positive economic case with jobs supported (46 direct), fuel cost savings and emission reductions monetised.
- LPG is also a cleaner alternative to gasoline and diesel commonly used in surface transport vehicles. Investment in **Autogas conversions** can help policymakers meet their air quality objectives, reduce carbon emissions (our scenario would save 421 tonnes of CO_2e/year), and deliver fuel savings (average of $1 million/year across the countries analysed).
- **Heating** accounts for a significant proportion of greenhouse emissions worldwide, and in Europe, policymakers are engaged with the **renovation** of older homes to reduce energy consumption and emissions. Investing $1 million to support the replacement of coal and oil heating systems with highly efficient (bio)LPG heating systems can generate fuel bill savings of $482,000/year, greenhouse gas emission savings (1.8 ktCO_2e/year) and reduce air pollution.
- Analysis of energy plans developed by EU Member States and the US EIA's projections suggests that the demand for renewable diesel could grow by over 200% over the next eight years. Investment in **biofuel production** facilities creates opportunities for economic growth supported by global exports, emission reductions from fuel transitions, and employment in a growing industry. In the United Sates, we estimate that investing $150 million in the conversion of an oil refinery to produce HVO and bioLPG will deliver $170 million of gross value-add, sustain 275 direct jobs and a further 236 jobs in the supply chain, as well as generating 1.32 million tonnes of CO_2e savings per year via fuel switching.

SECTION 1

BUILDING BACK BETTER – THE NEED FOR A RESPONSE TO THE COVID-19 CRISIS

1. IMPACT OF THE CRISIS AND KEY OBJECTIVES FOR POLICYMAKERS IN KICKSTARTING A RECOVERY



The worldwide outbreak of COVID-19 has been the deadliest pandemic since the Spanish Flu of 1918.1 Whilst the lasting effects on mental and physical health are yet to be fully understood or appreciated, the economic impacts have been markedly more visible.

With a loss of 255 million full-time jobs worldwide – the economic effects of the crisis have been far-reaching, and often devastating.[2,3] To put that figure in context, it is approximately four times larger than job losses from the 'Great Recession' of 2008. The significance of the March 2020 lockdowns and global pandemic declarations is seen clearly in the stock market, and global GDP (figures 1.1 and 1.2 respectively). The Standard & Poor's (S&P) 500 fell by over 30% in early 2020, as the initial wave of the pandemic reached western economies, whilst global GDP fell nearly 4% over the course of the year.

ANNUAL RATE OF CHANGE IN WORLD GDP 1990-2021

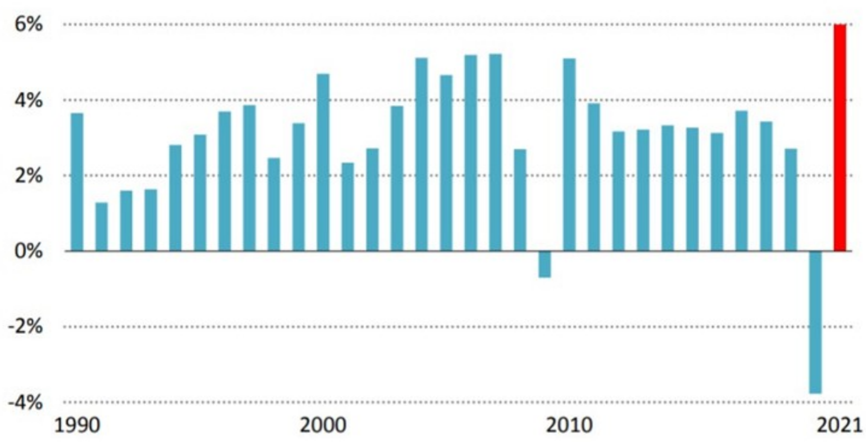
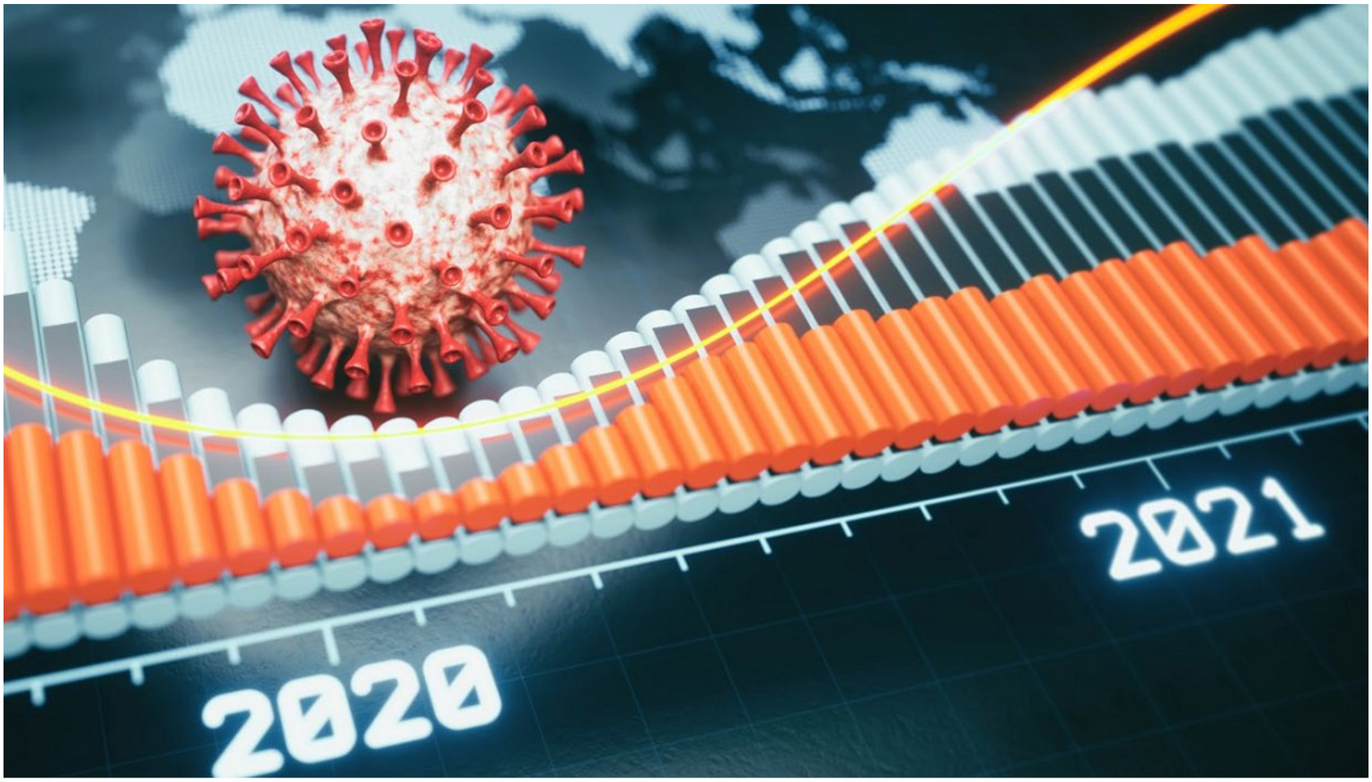


Figure 1.1: Annual global GDP change.[4]



All of this ultimately draws attention towards public policymakers. Whilst there has been an ongoing economic response during the pandemic, particularly with furlough schemes loans, and bailouts, there have been very few post-COVID-19 recovery packages detailed.[5,6]

More narrowly, the energy sector reacted similarly to the rest of the economy – marked declines in demand (and subsequently prices), all followed by significant (if uneven) recovery in 2021:

EVOLUTION OF GLOBAL GDP, TOTAL PRIMARY ENERGY DEMAND, AND ENERGY-RELATED CO_2 EMISSIONS, RELATIVE TO 2019.

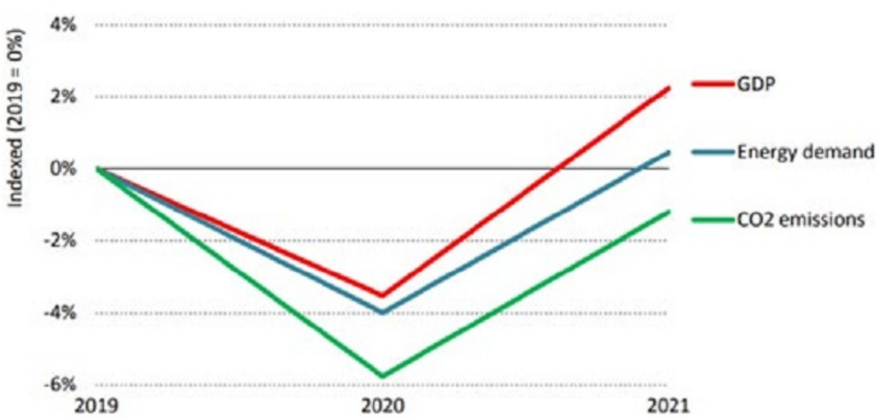


Figure 1.2: GDP, primary energy demand, and energy-related CO_2 emissions.[4]

Yet, whilst the growth in sustainable energy offers hope for the drive towards cleaner economies, the fact remains that time is running out on the climate emergency.[7] Two parallel strands reach a pivotal moment in unison – the economic recovery, soon to be dictated by policy, and the decarbonisation of said economy, with few tipping points left to tip – both enter a crucial phase. Yet, an ordeal can reveal an airfield – the COVID-19 pandemic has presented policymakers with an almost unique opportunity.

An underreported health crisis can also be partially resolved in this way – that of air pollution. Currently, 90% of the world's population breath air that exceed guideline limits.[8] This problem is multi-faceted, with urban areas suffering from smog, and developing countries contending with in-home pollutants due to cooking fuels. Causing a wide range of health issues, air pollution kills seven million people a year, according to WHO estimates. Four million of those are due to polluting cooking methods, an issue disproportionately affecting the developing world – three billion people still use solid fuels, those which release the most pollutants.

The first and most prominent need in any proposed recovery package is its timeliness – particularly with regards to unemployment. Green investment constitutes an immediate demand for labour – construction, installation, and operation of new energy technologies all fit the brief:

This short-term boost clearly meets the above criteria. Comparatively, investment in clean energy creates jobs at an order of difference of one job per annual GWh produced.[11] Additionally, domestic production and ownership is seen as resilient to offshoring, and desirable for policymakers.

Another key objective for any recovery package is the overall boost to economic growth, whilst reductions in unemployment generally constitute a direct benefit to overall production – questions arise regarding a lack

> "Construction projects, including building active travel infrastructure, home energy efficiency retrofits, and planting trees and restoring wetlands are recognised as being capable of delivering jobs at speed. These projects are not susceptible to offshoring, are less import-intensive than many traditional stimulus measures and can create jobs in all regions of the UK" [9,10]

of private finance in the clean energy sector. Whilst renewables are incredibly successful from a return's perspective, the main deterrent is their lack of liquidity.[412] Thankfully, for state investments, this should not be an issue, longer term outcomes can be prioritised against short-term risk.

With interest rates at historically low values (figure 1.3), there is a clear opportunity for policymakers to not only stimulate the economy into revival, following a barren two years, but to do so in a way that allows for a clean, sustainable future. Indeed, interest rates are close to zero in many of the countries featured in this report, creating the conditions for greater levels of public and private investment to spur an economic recovery from the pandemic.

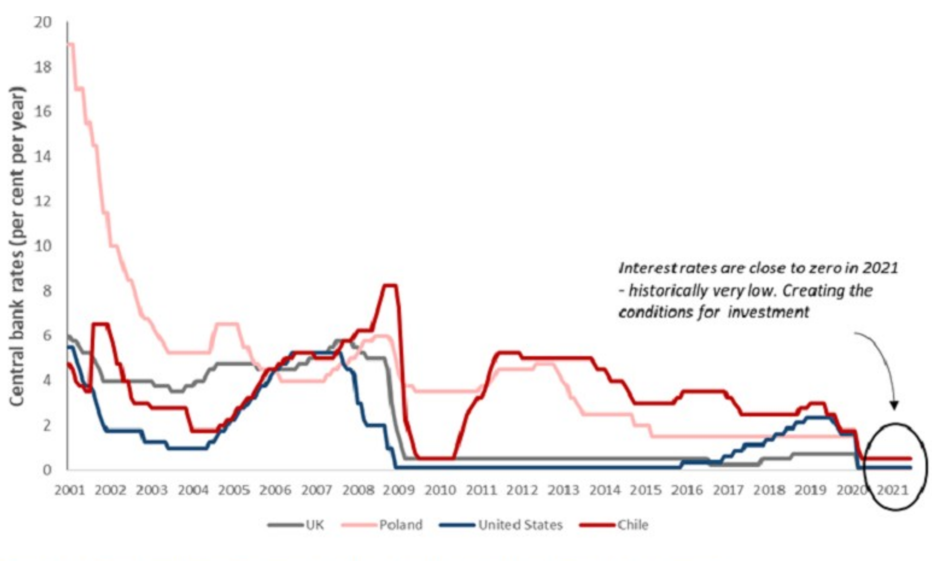


Figure 1.3: Central bank interest rates in a selection of the countries featured in this report (source: Bank for International Settlements)[i]

SECTION 2

THE LPG INDUSTRY'S ROLE IN RESPONDING TO THE CRISIS

2. THE LPG INDUSTRY'S ROLE IN RESPONDING TO THE CRISIS SO FAR

The COVID-19 crisis impacted communities, industries, and people across the world, and continues to disrupt and tragically take lives. In the early months of the pandemic in 2020, the LPG industry stepped in as a provider of essential goods – secure, flexible and reliable energy for hospitals, homes and communities across the world. The sector acted quickly to adapt to changing regulations at a local, and global level, and introduced several procedures to ensure security of supply and to play its part in protecting customers and staff.

WLPGA members rapidly developed procedures to allow for the safe supply of LPG to customers – within offices, plants, and distribution points. For instance, the industry quickly progressed additional disinfection of cylinders, the early use of PPE, implementation of social distancing practices, and proactive communication to staff and customers.

In short, the industry has played an **essential** role in providing fuel to homes, businesses, and facilities such as hospitals which rely on LPG for energy during the pandemic and has demonstrated **resilience** to a rapidly evolving mix of lockdown restrictions and public health regulations. The flexibility, storability, and convenience of LPG as a portable fuel delivered real value for customers in markets across the globe.

As governments continue to grapple with balancing public health, social and economic challenges, this report considers several ways in which the LPG industry can look forward to working with governments across the world to support a sustainable recovery from the crisis.

The following chapters of this report consider four tangible recovery packages which can deliver immediate economic growth, support jobs and are consistent with longer term sustainability objectives.

These are:

1. Clean cooking – approximately three billion people globally depend on biomass, kerosene or coal for cooking, fuels which are recognised to cause health issues and premature death. Our analysis considers the economic and environmental benefits which could be unlocked by a government program to switch households to LPG-based clean cooking.

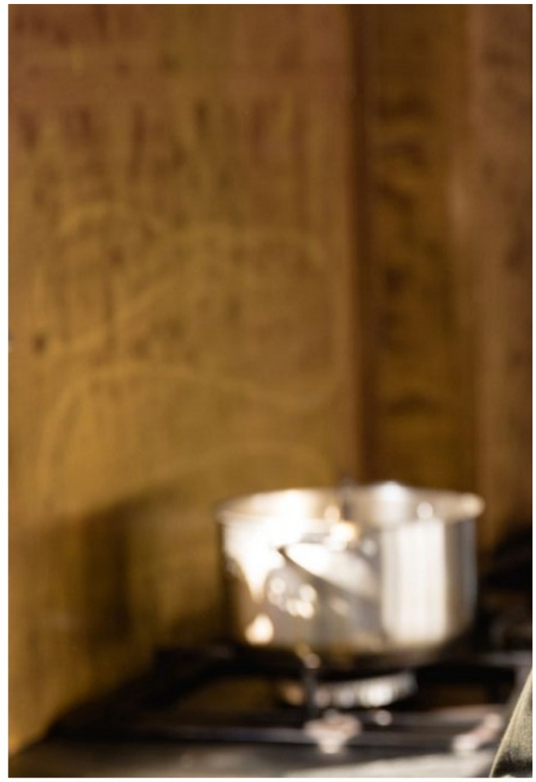
2. Clean transport via Autogas conversions – policymakers across the world have immediate air quality challenges – with seven million premature deaths directly attributable to air pollution. Our analysis assesses the economic and environmental case for government supporting Autogas conversions in six markets across the world.

3. Clean heating via bioLPG-retrofits – with most of today's buildings likely to be standing in 2050 – the net-zero target date for several advanced economies – governments are looking to building retrofit programmes to reduce energy consumption and lower carbon emissions. Our analysis considers the strategic role that bioLPG heating solutions can play in decarbonising rural homes across Europe.

4. Biofuel production – analysis of national government energy strategy projections suggest that biodiesel consumption will increase by over 200% in the coming five years in the United States and across Europe. Given this booming global market, our analysis considers the case for investment in the conversion of an oil refinery to produce HVO and bioLPG.

Our analysis has focused on a selection of activities and regions of the world in which these investments would have greatest impact and relevance to policy national policy challenges. These are highlighted within each chapter.

3. RECOVERY PACKAGE – INVESTMENT IN CLEAN COOKING



INTRODUCTION

Investment in clean cooking can improve air quality, reduce land degradation, and decrease levels of greenhouse gases. To achieve a sustainable recovery, the problem of clean cooking must be solved through multiple low carbon fuel offerings, including LPG.

Globally, approximately three billion people depend on biomass, kerosene or coal for primary cooking.[4] The combustion of these fuels emits harmful pollutants leading to indoor air pollution and severe health problems. Burning biomass, kerosene or coal causes respiratory illnesses, heart disease and nearly four million premature deaths each year.[13] The problem is severe for the continent of Africa where the cost of premature deaths from air pollution was $215 billion in 2013, whilst the global cost was $232 billion.[14] Health problems can cause unemployment, reducing household income and slowing economic activity.

Women and children are adversely affected as they inhale harmful, small soot particles for prolonged time periods whilst preparing meals for their families. Smaller particles such as $PM_{2.5}$ penetrate deep into the lungs, and long-term exposure has been linked to cancer and perinatal outcomes. More than 60% of the premature deaths from household air pollution were among women and children in 2012.[15] Lack of access to clean cooking resides in low to middle income countries including China and Sub-Saharan Africa.[4]

The clean cooking problem also damages the environment. The majority of biomass for cooking is harvested from unsustainable sources, perpetuating land degradation and deforestation resulting in fewer carbon sinks. Lack of forest can impact agricultural productivity, disrupting local economies. In Kenya, the mounting pressure on forests from unsustainable harvesting as well as the production of charcoal has forced the government to set a goal for 2030, where 35% of the population must have access to clean cooking.[13]

LPG is one of the lowest CO_2e emitting fuels for cooking available for large-scale deployment, emitting roughly five times less carbon than burning biomass.[4,16] LPG can reduce levels of harmful pollutants, deforestation and labour time gathering biomass.[4] India bears the greatest

burden; 800 million people depend on polluting fuels for cooking, contributing to 29.6% of ambient $PM_{2.5}$ concentrations. It is common for mothers to have their children strapped to their backs when cooking, which means they are six times more likely to develop Acute Respiratory Infections (ARI) than children who are not exposed in this way.[15] Many women use solid fuels such as wood and waste; the time to find these materials can be saved if LPG is mobilised.

To achieve universal energy access for clean cooking by 2030, 1.4 billion of 2.8 billion people will need to access LPG.[13] This will work to alleviate the social, environmental and economic costs of the clean cooking problem for a sustainable recovery.

This recovery package quantifies the benefits of investing in clean cooking, including the reduction in household air pollution, CO_2eq emissions and fuel gathering labor demands, as well as the creation of jobs and the financial savings from lower fuel costs. These benefits demonstrate that government investment in clean cooking as a sustainable recovery package is an extremely viable option.

ECONOMIC CASE FOR INVESTMENT IN CLEAN COOKING

Policymakers facing the challenge of promoting clean cooking should consider all feasible technologies and evaluate the advantages on a case-by-case basis. Whilst some clean cooking methods may result in greater individual benefits per household, they may also be more expensive and require a greater incentive - meaning fewer households can be incentivised. Policymakers should therefore consider both a clean cooking method's improved level of sustainability, alongside the technology's cost, in tandem. Using this approach, the net benefits *per unit of investment* can be determined. LPG provides not only a lower carbon alternative, but can also be incentivised with minimal cost, resulting in high levels of uptake and therefore significant net benefits.

In Sub-Saharan Africa, fuel costs of LPG are often cheaper than the market cost of the household's current cooking fuel - it is usually the upfront cost involved in the clean cooking transition that limits uptake.[17] Previous programmes such as the Indian Pradhan Mantri Ujjwala Yojana (PMUY) scheme or the Mwananchi Gas Project in

Kenya, have offered LPG equipment cost-free.[18] These programmes have seen varying levels of success in the resulting uptake of clean cooking. As well as targeting grant schemes towards lower income households, the consideration of the fuel's accessibility and the existing delivery network is of critical importance for high consumer uptake. Equipment defects can also lead to lack of use and result in the household resorting to their original, carbon intensive cooking methods. However, with case studies such as the Indian PMUY scheme, there is evidence to show that a carefully thought out and well managed grant scheme, alongside a scaling up of supporting infrastructure and distribution networks, results in reliable uptake of clean cooking methods.

This analysis has used multiple Sub-Saharan countries' pricing information to develop an estimate of a suitable subsidy, sufficient to incentivise a household to transition to clean cooking using LPG. This was calculated to be $76 - enough to cover the total capital cost of the necessary cooking equipment for the average Sub-Saharan household. Average expenditure on LPG is expected to be higher than previous household fuel expenditure, with a significant proportion of cooking fuel currently being gathered biomass, at zero cost. However, with the upfront cost of the equipment covered, the reduced labour time and the health benefits of lower household pollution, are considered to be sufficient incentives for the households to make the transition. Using this subsidy cost it

REGION – SUB-SAHARAN AFRICA

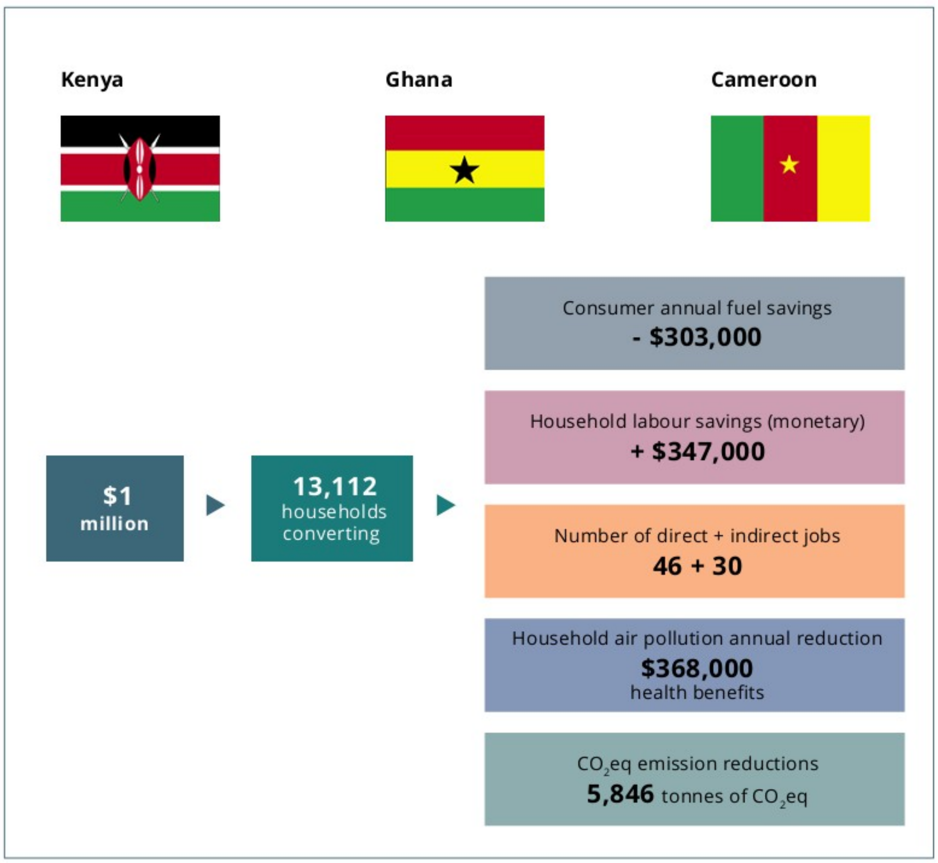


Figure 3.1: Infographic displaying key benefits of investing $1 million in clean cooking in the Sub-Saharan region.

was calculated that **13,112 households** could be incentivised to transition away from high carbon forms of cooking and towards using LPG, for every $1 million that is invested.

Of approximately 160 million households in Sub-Saharan Africa, three-quarters of them currently cook using firewood, charcoal, or kerosene.[19] Incentivising all of these households using carbon intensive cooking fuels, towards using cleaner cooking fuels is estimated to cost $9.2 billion.

The benefits resulting from these household transitions are economic, social and environmental. The labour time savings help to provide households, usually women, with more time to focus on other important tasks and potentially seek formal employment. An increase in delivery networks and filling plants will also help to generate many direct jobs locally, as well as additional indirect jobs in the supply chain. The substantial reduction in household air pollution will reduce many life-threatening health conditions and premature deaths. As well as this reduced health impact translating directly as a societal benefit, this reduction in air pollution can also be indirectly equated to a significant financial saving to health services and individuals by using damage cost estimates. Finally, alongside other environmental benefits such as reduced deforestation, the direct reduction in CO_2eq emissions resulting from a transition to clean cooking technology is central to a sustainable recovery. Again, this reduction in CO_2eq emissions can be translated into a monetary value using market costs of carbon. In this report, estimates of these various benefits have been quantified for every $1 millioninvested into clean cooking.

RESULT OF INVESTING ONE MILLION USD IN CLEAN COOKING

I. Economic benefits per $1 million

Fuel cost savings:

In Sub-Saharan African countries, it is estimated that households converting from firewood, biomass, kerosene and coal to LPG for clean cooking, will require to spend an additional $23 on fuel each year. This estimate was calculated by determining the current distribution of cooking methods across multiple Sub-Saharan African countries and applying the associated market costs for an average annual expenditure on cooking fuel. The average cost of one year of LPG cooking fuel was then subtracted for the estimated additional fuel expenditure. However, these fuel costs include a significant proportion of biomass fuel which is not bought at market but gathered at zero cost, therefore not accounting for the significant benefit of reduced labour time. With 13,112 households converting per $1 million – this equates to an additional annual fuel expenditure of approximately **$303,000** per $1 million.

Reduced labour:

Due to many households gathering biomass cooking fuel at zero monetary cost, the transition to LPG results in an additional fuel cost for the average Sub-Saharan household. However, the labour time saving resulting from the transition to LPG is significant and can be equated to a monetary value by using relevant average monthly income information. Households which gather biomass cooking fuel (predominantly firewood) are estimated to spend two hours of labour time gathering firewood daily and an additional hour in reduced cooking time.[18] These households are therefore incentivised to transition to alternative fuel sources to save time which could otherwise be spent on other important household activities and could even alleviate individuals enough time to seek formal employment.[18]

The result of investing one million USD in clean cooking is estimated to save a total of 7.9 million hours of labour per year, equating to approximately **$347,000** of monetary consumer value. This exceeds the $303,000 increase in annual fuel costs and so the net gain, when combining with reduced labour time, is a total household annual saving of **$44,000**, per $1 million invested.

Air pollution:
An average household in Sub-Saharan Africa cooking with biomass, kerosene and coal, has been estimated to produce 441 grams of harmful particulate matter from cooking with current fuel sources each year. This compares with a significantly lower average of ten grams from households cooking with LPG. The net reductions per $1 million of investment equates to an average of 5.65 tonnes of particulate matter per year. Using damage cost conversions, this equates to **$369,000** of health benefits each year.

Reduced subsidy costs of other fuels:
Another potential economic gain may come from the reduction or elimination of pre-existing fuel subsidies. For example, Indonesia underwent a substantial transition from using kerosene as a dominant cooking fuel to using LPG.[20] One of the motives for this transition was to reduce the large amount of money being spent on kerosene subsidies by the government, with LPG having much lower subsidy costs. However, whilst for countries such as Indonesia, the alleviation of subsidy costs translates to a substantial economic benefit, this was not included in this analysis as the pre-existing fuel subsidies in the countries considered in the Sub-Saharan Africa region are less significant.

II. Number of jobs per $1 million

In addition to consumer fuel savings, health benefits and reduced labour, investing in clean cooking and expanding the networks, also leads to the creation of jobs.

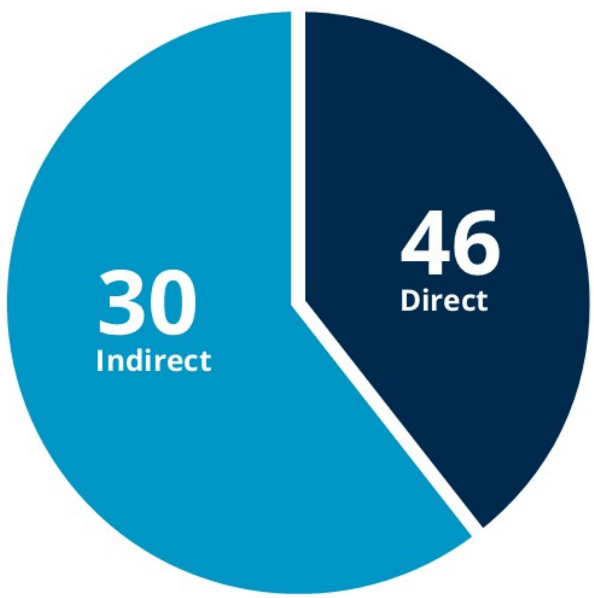


Figure 3.2:
These numbers describe specifically the jobs created through expansion of LPG services. The 46 direct jobs correspond to the creation of jobs relating directly to the roles of cylinder manufacturing, bottling, distribution and retail.[4]
The 30 indirect jobs are jobs which are created as a secondary result of the primary LPG expansion and exist further up the supply chain.

III. CO_2eq reductions per $1 million

Transitioning from carbon intensive cooking fuels to clean cooking technologies and low carbon fuel sources such as LPG, results in a reduction of CO2eq emissions.

LPG has a lower carbon intensity compared to other fuel types such as kerosene, charcoal and firewood. This is in large part due to the relatively low emission of methane, a greenhouse gas 25 times more potent than CO_2.[20] The average household net carbon savings in transitioning to LPG is approximately 446 kgCO_2eq per year. For every $1 million of investment in using LPG as a clean cooking solution, it is estimated that 5,846 tonnes of CO_2eq emissions will be saved annually. This is the equivalent of taking over 1,000 cars off the road every year.

COOKING FUEL SOURCES IN SUB-SAHARAN AFRICA

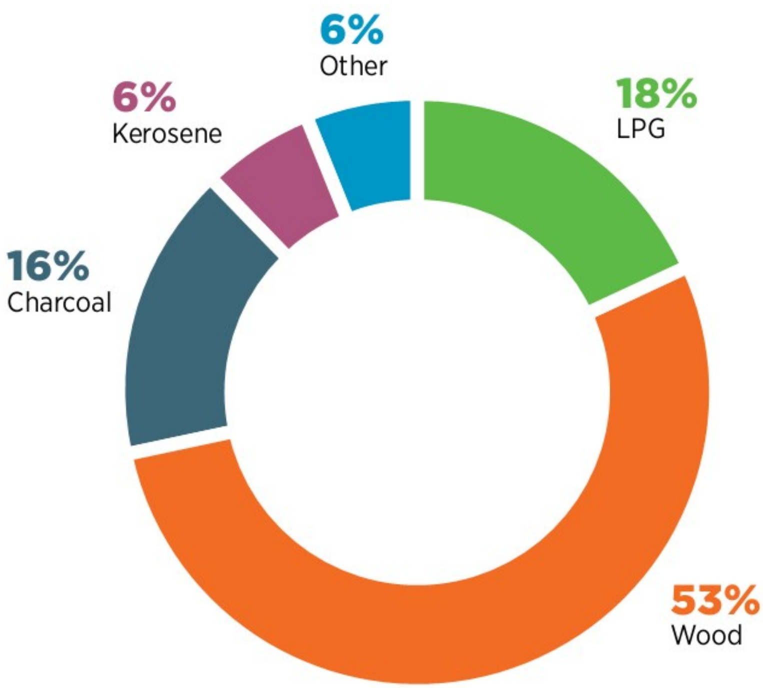


Figure 3.3:
The current distribution of cooking fuels used in Sub-Saharan Africa is shown in the chart to the right. Each of the fuel types emit different amounts of CO_2 and CH4 emissions per unit mass that is burnt. The fuels also have differing calorific values, meaning that a larger mass of low-energy density fuel is required to cook when compared with higher energy density fuels.

In a similar way to the reduction in labour time, the reduction in CO_2eq emissions can be converted to a monetary value. There are multiple ways of applying a cost conversion, including using a 'social cost' of carbon, which aims to attribute the actual total global economic impact resulting from the emission of a tonne of CO_2. However, a more tangible, 'market cost' estimate of CO_2 can be derived from using a specific carbon tax. A carbon tax aims to encompass the social cost of carbon, but the estimates tend to be far lower due to market constraints limiting taxes on products. Carbon taxes therefore vary greatly from country to country and higher GDP countries, with lower net carbon emissions, can afford to attach a higher carbon tax compared with lower GDP countries with higher net carbon emissions. Carbon taxes belonging to Sub-Saharan African countries are as a result, very low; a figure of \$7/tonne CO_2eq, belonging to South Africa, has been used here to represent the cost of carbon.[21]

In many countries, carbon taxes are increasing rapidly. The IEA have published 2030 forecast estimates of carbon taxes in developing countries at a much higher \$75/tonne CO_2eq emissions, which has also been included.[22] Using these values, the economic benefit of the CO_2eq reductions resulting from investing \$1 million in clean cooking are estimated to be \$41,000 per year at present, rising to \$438,000 per year by 2030 – using IEA estimates. These more theoretical cost estimates do not contribute to the net economic gain estimate and exist primarily for the sake of comparison.

SUMMARY

The key benefits resulting from investment in clean cooking include: labour time savings from not having to gather fuel, health benefits from reduced air pollutants, and a reduction in CO_2eq emissions. Figure 5 below displays all of these monetised benefits resulting from \$1 million of investment, after a five-year period.

FIGURE 3.4A:
CO_2EQ EMISSIONS BY FUEL TYPE

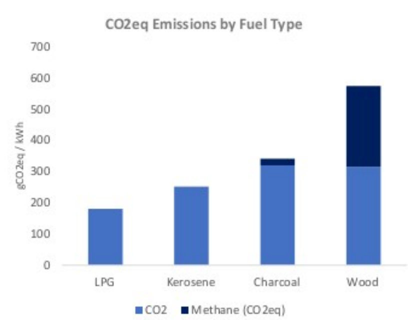
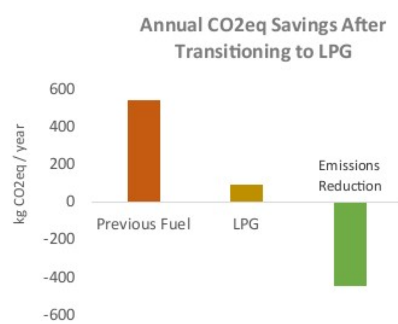


FIGURE 3.4B:
ANNUAL CO_2EQ SAVINGS AFTER TRANSITIONING TO LPG



Figures 3.4a/b:
Figure 3.4a displays the net CO2eq emissions, per unit of thermal energy generated, for the four major cooking fuel types used in Sub-Saharan Africa. These CO_2eq emissions are broken down into CO_2 emissions and methane emissions (which have been calibrated to a CO_2 radiative forcing equivalency). Figure 3.4b shows the reduction in CO_2eq emissions resulting from the average Sub-Saharan household transitioning away from firewood, charcoal and kerosene and towards LPG.

In summary, for every $1 million invested in clean cooking, approximately 13,112 households can be incentivised to transition to an LPG system. This results in an estimated total fuel cost increase of $303,000 per year, countered by reduced labour time, equivalent to $347,000 per year. There are additional health benefits from reduced air pollution, equivalent to $369,000 per year in damage costs. These costs sum to a total of $412,000 economic gain a year and **$1.07 million** of net economic gain five years after the investment, (subtracting the original $1 million investment). Not included in this net economic gain is the reduction of 5,800 tonnes of CO2eq emissions per year but is calculated to be the equivalent to a present-day market cost of $41,000 per year, rising to a predicted $438,000 by 2030.

With a $9.2 billion investment, assuming steady market costs with scalability, it is estimated that the majority of households in Sub-Saharan Africa can be incentivised to transition away from carbon intensive cooking fuels and towards clean cooking methods. This could result in a total net economic gain of $9.8 billion within five years on investing. It would also equate to 53.8 Mt of CO_2eq reductions per year, the equivalent of removing approximately 12 million cars off the road.[23]

CLEAN COOKING - RETURN ON $1 MILLION AFTER 5 YEARS

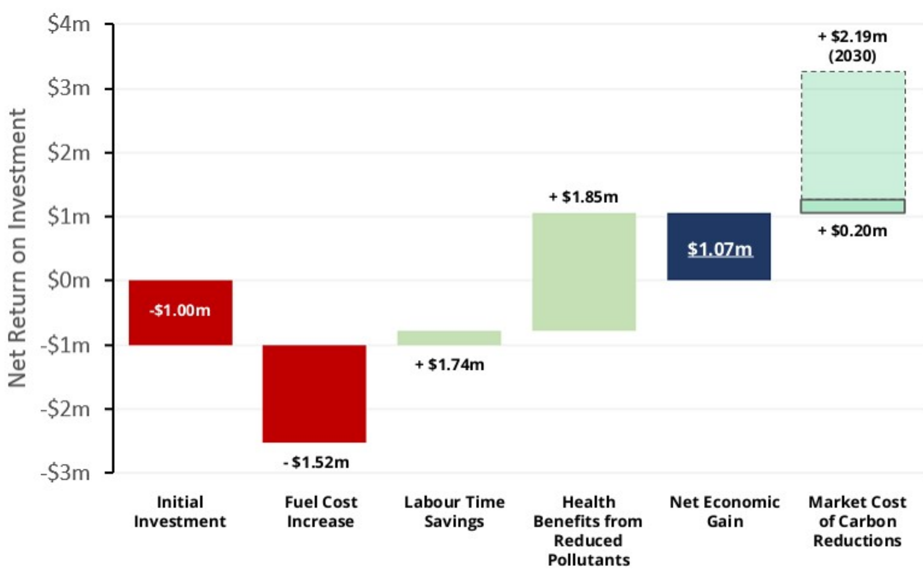
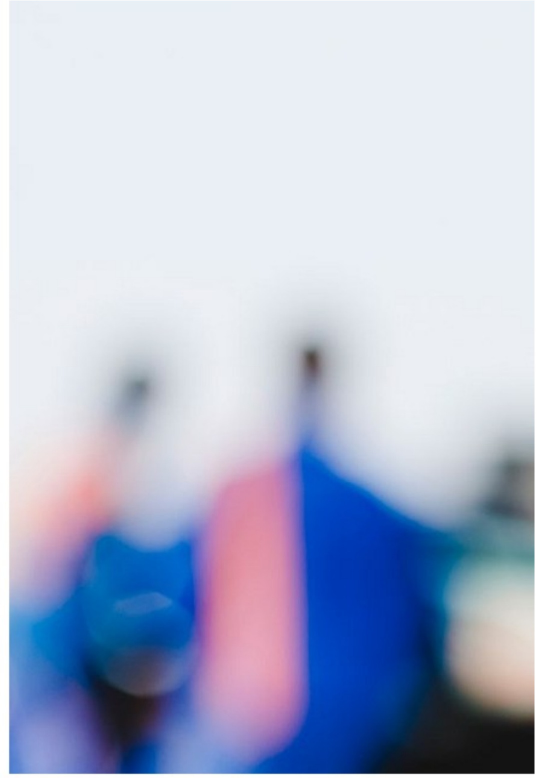


Figure 3.5:
Displays the key benefits resulting from $1 million of investment in clean cooking.
Air pollution, labour time and carbon reductions values have been 'monetised' so that they can be compared against each other graphically.

4. COVERY PACKAGE – AUTOGAS CONVERSIONS



INTRODUCTION

In 2020, as the COVID-19 pandemic intensified, several studies demonstrated a link between areas with poor air quality and higher than expected incidence of mortality across a number of countries including the United States, China and Italy. The influence of air quality on respiratory health and ultimately susceptibility to a serious COVID-19 infection will continue to be researched, but the negative impact of air pollution more generally has been well-established.

Close to seven million premature deaths are directly attributable to air pollution worldwide, with 249,000 premature deaths recorded in 2016 in the Americas.[24] Particulate matter emissions ($PM_{2.5}$) from diesel vehicles been classified by World Health Organisation (WHO) as a Group One Carcinogen to humans.[25]

Autogas is the most commonly used alternative fuel to petroleum-based transport fuels.[26] Its mixture of propane and butane mean emissions from combustion of are considerably lower than its petroleum-based counterparts. One of the key drivers for government support for Autogas stems from concern over human health.

Mobilising Autogas reduces levels of carbon monoxide, greenhouse gas emissions, nitrogen oxide and other air pollutants and is not as toxic to the environment when leaked or split.[27] Over 60% of global LPG supply is derived from natural gas processing plants which, when compared with the full lifecycle for petroleum fuels, causes less environmental damage.

Global consumption of Autogas has followed an upward trend reaching 27.2 million tonnes in 2019, with 27.8 million Autogas vehicles across the globe. The greatest increases in absolute demand for Autogas from 2009-2019 occurred in the Ukraine, Russia and Turkey. These trends have been driven by incentives such as Autogas subsidies, grants for Autogas conversions, tax breaks for filling station investment and supportive government policy. In the early 2000s, the Turkish government developed social policy of low taxation stimulating demand for Autogas. In the same period, Russian authorities made a change to policy that diverted LPG to the domestic sector and allowed the Autogas market to prosper.[28] Alternately the Australian experience is instructive. While the country has a relatively long history of Autogas use, consumption began to decline significantly in 2011 when the government introduced

a progressive increase in excise tax. This coupled with a change vehicle tastes of Australian consumers and the phase-out of federal and state government grants for converting or buying Autogas vehicles led to a significant drop in Autogas consumption in Australia[ii].

The pandemic impacted the Autogas sector more than other segments of the LPG industry. Global consumption fell by over 10% in 2020[iii] to below 25 million tonnes for the first time since 2012[iv]. It is unclear what the repercussions of this shock on the segment will be in the long-term.

Some low- to middle-income countries do not have the infrastructure to support the electrification of transport, but investment in the conversion of gasoline and diesel engines to LPG vehicles will reduce emissions for better health. Chile has recently lifted the ban to convert private vehicles to Autogas for cleaner air, presenting an economic opportunity to maximise the potential of Autogas.[29]

This recovery package stresses the severity of the impact of air pollution from petroleum-based vehicles. Autogas offers an alternative that emits considerably less harmful pollutants and through its entire lifecycle, causes less environmental damage than petroleum-based fuels. Investing in Autogas is a sustainable solution that does not overburden the electricity network, where many countries such as Chile, Peru and Poland do not have adequate infrastructure to support the electrification of the transport system. This recovery package details the economic and environmental value of investment in Autogas vehicle conversions, to replace gasoline and diesel engines.

ECONOMIC CASE FOR INVESTMENT IN AUTOGAS CONVERSIONS

For national governments, the establishment of an Autogas market can help tackle air pollution challenges, lower oil-imports, and reduce greenhouse gas emissions. Many countries have now set dates to ban the sale of new internal combustion engine vehicles. Additionally, low-emission zones have been set up in many cities to directly address the health impacts of air pollution. In Germany for example, in 2018 a court ruling approved the banning of diesel vehicles in several German cities.[30] Whilst electric vehicles are being promoted as the most viable alternative in countries such as Germany, for other countries, with more carbon intensive electricity networks, or with a less feasible charging infrastructure, Autogas may provide the most economically feasible diesel substitute for both governments and car owners alike. This chapter will highlight a range of economic benefits which could be accessed by a recovery package which supports vehicle conversion from gasoline and diesel. The package provides an immediate economic stimulus, supports jobs, and is aligned with long-term environmental goals.

From the perspective of a car owner, the financial decision of converting to Autogas depends on both the initial cost of the conversion and the ongoing cost of fuelling with Autogas, compared with their existing fuel source (usually gasoline or diesel).[32] Both the conversion cost and the Autogas fuel cost can be controlled via tax and other subsidies to determine the financial attractiveness. An additional key consumer consideration, however, is the fuelling infrastructure. Countries with a currently limited Autogas fuelling network will struggle to incentivise car owners to transition to Autogas without investing significantly in the relevant infrastructure.

This study has focussed on six countries which already have a recognised Autogas fuelling network and therefore where Autogas re-fuelling is less problematic. These countries are: Chile, Peru, India, Poland, Turkey and South Korea. The effectiveness of financial incentive schemes, targeting the affordability of Autogas conversions, are therefore more predictable, with re-fuelling being of limited concern.

REGION – GLOBAL SPREAD:

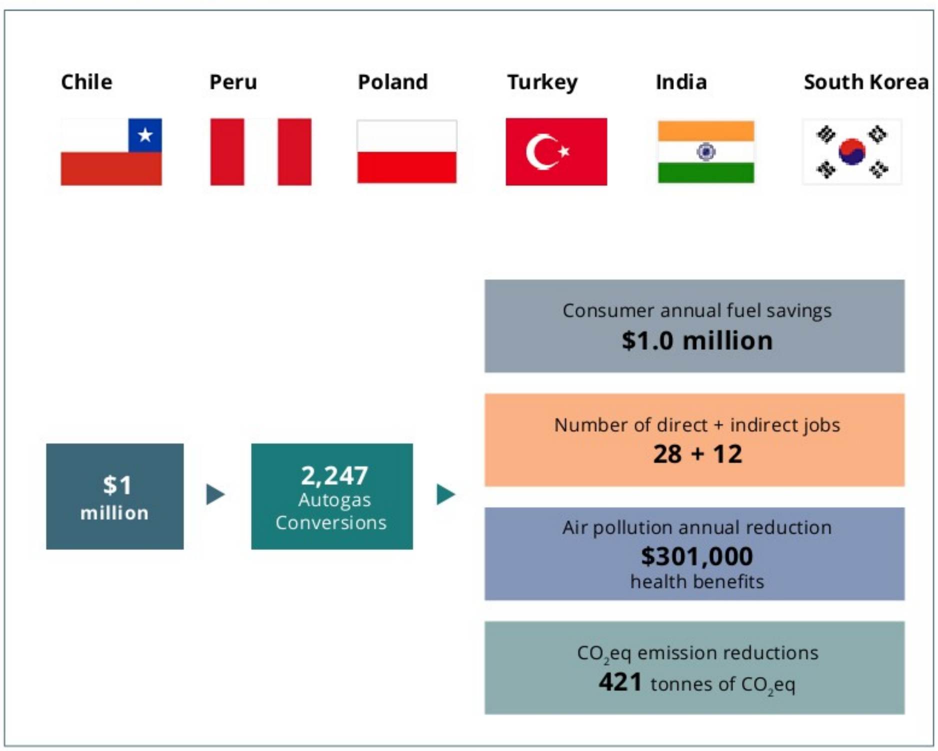


Figure 4.1: Infographic displaying benefits of investing $1 million in Autogas conversions, averaging across six countries situated worldwide.

The 'cost per litre' of gasoline, diesel and Autogas differs to the more critical 'cost per km' travelled, due to the energy densities of the fuels and the efficiencies at which they are combusted. For all six countries considered in the analysis, Autogas has the lowest cost per km and this helps to make the fuel source financially attractive. The key hinderance to car owners in converting to Autogas in these countries is therefore the upfront cost of the conversion. This is therefore the most logical cost to target via government incentives.

In countries with adequate Autogas refuelling infrastructure, car owners can be incentivised to convert if the payback time on the conversion, via fuel cast savings, is sufficiently fast. Subsiding the upfront cost of the conversion therefore reduces this payback time. The required payback time will vary from consumer to consumer, but generally this timeframe needs to be less than two to three years.[32] This analysis has chosen 1.5 years to be an adequately fast payback time for car owners to be considered incentivised to pay for the remaining cost of the Autogas conversion. From the estimated grant for each country, the average number of conversions per $1 million invested in Autogas subsidies was calculated to be **2,247**.

The resulting benefits of these conversions include: the fuel savings of the car owners, increasing levels of disposable income and benefiting the broader economy; the generation of jobs, both directly via the conversion process, and indirectly within the supply chain; reduced levels of air pollution – greatly reducing related health impacts, which have a measurable economic benefit; and lower levels of greenhouse gas emissions, helping countries to reach decarbonisation targets.

RESULT OF INVESTING $1 MILLION IN AUTOGAS CONVERSIONS

I. Economic benefits per $1 million

Fuel cost savings:

Across the six countries considered, the average annual reduction in fuel cost between using gasoline and diesel versus Autogas varies widely, between $303/year (Turkey) and $901/year (South Korea), but the average savings are $539/year. It is assumed that the average *remaining* ownership of the car after its conversion is six years - resulting in lifetime fuel savings of $3,235 and a net saving of $2,743 (after conversion cost is subtracted).

For every $1 million invested in Autogas conversions, total consumer savings amount to **$6.16 million** over the cars remaining six-year lifetime.

Air pollution:

An average petrol/diesel light vehicle emits approximately 5.7kg of NOx, 0.42kg of PM10 and 0.28kg of PM2.5 every year of use.[33] Whilst these values appear low, small concentrations

of these air pollutants are incredibly harmful to people's health, and are therefore significant.[34] The conversion of petrol and diesel vehicles to Autogas can result in a net reduction of air pollutants equating to a damage cost of $301,000 each year and a total of $1.8 million over the average six year vehicle remaining lifetime.

II. Number of jobs per $1 million

The average time required to convert a vehicle to Autogas is one day, usually requiring at least two mechanics.[35] The labour resulting from 2,247 conversions, following $1 million of investment is 19 'job years' – which can be equated to 19 short term jobs generated.[4] An estimated seven indirect jobs are predicted to be generated further within the supply chain.

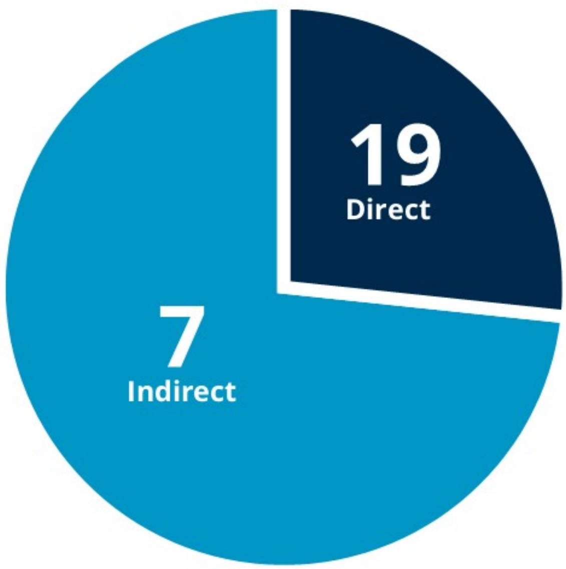


Figure 4.2:
The numbers in the chart to the right describe the number of jobs resulting from $1 million of investment in incentivising Autogas conversions. The 19 direct jobs correspond to the creation of jobs involved directly in the conversion process, primarily mechanics. The seven indirect jobs are jobs which are created as a secondary result, existing further up the supply chain.

III. CO_2eq reductions per $1 million

Transitioning from carbon intensive gasoline and diesel to LPG fuel sources results in a reduction of CO_2eq emissions. Autogas is combusted slightly less efficiently than gasoline and diesel, but due its chemistry results less CO_2 emissions per km travelled overall.

As well as producing fewer air emissions than diesel and gasoline, the combustion of Autogas also results in less CO_2eq emissions. Whilst not being as low carbon as electric vehicles, Autogas provides a more suitable decarbonisation method fir the second-hand vehicle market, with the cost of an Autogas conversion being significantly less than a new electric vehicle.

The annual reduction in CO_2eq emissions resulting from converting a vehicle from petrol/ diesel to Autogas as estimated to be 187 kgCO_2eq emissions per year. The result of investing $1 million in Autogas incentive results in average annual reduction of 421 tonnes of CO_2eq and **2,526** tonnes over six years.

EMISSIONS OF CO_2 PER KM

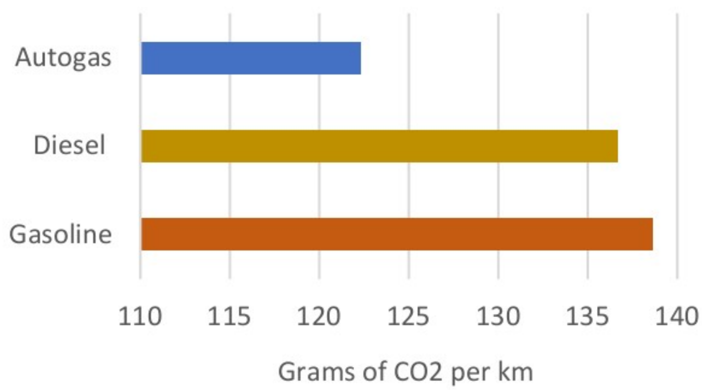
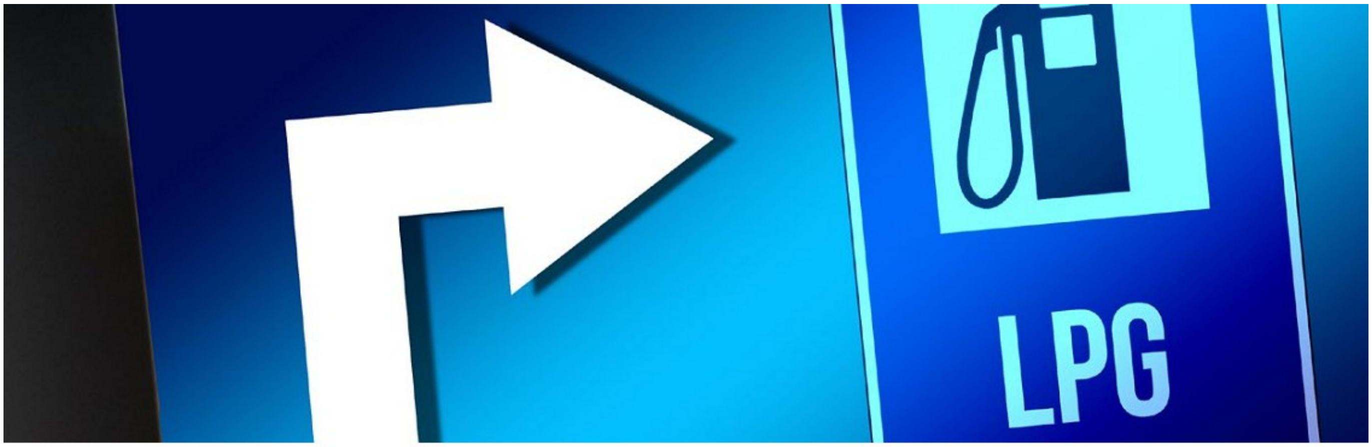


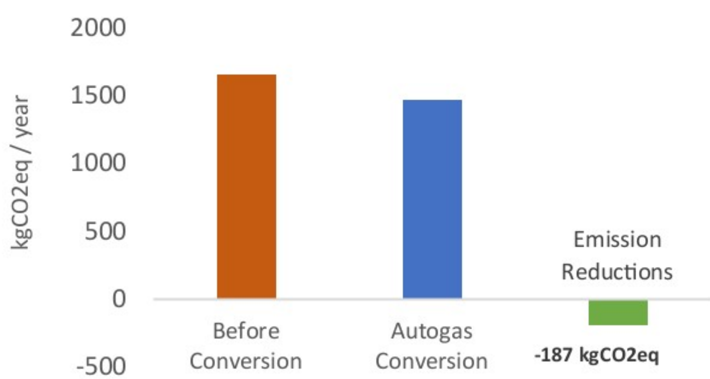
Figure 4.3:
The relative emissions resulting from the combustion of different vehicle fuel types. Diesel results in slightly less CO_2 emissions per km compared with gasoline, and Autogas results in significantly less CO_2 per km, making it the least carbon intensive of the three fuel types considered.



The CO_2eq reductions can be converted into a monetary value by using a 'market cost' of carbon. This is by using the current carbon tax which is applied in each of the relevant regions used in this analysis section. An average cost of $12.7/tonne of CO_2eq emissions applied to the total emission reductions to determine a monetary value of $32,000 resulting from $1 million of investment in Autogas conversions.[21]

As the market cost of carbon is predicted to rise rapidly worldwide, a second, future market cost of $87.5/tonne of CO_2eq emissions has been also determined, using values estimated by the IEA.22 This much higher value reflects the predicted future cost of carbon by the year 2030. Neither the upper or the lower market cost estimate of CO_2eq reductions contributes to the estimate of net economic gain with the values being more theoretical than the other, more tangible monetised costs, and exist primarily for the sake of comparison.

ANNUAL CO_2EQ SAVINGS AFTER AUTOGAS CONVERSION



Figures 4.4:
Displays the annual CO_2eq emissions before and after an Autogas conversion along with the relative annual reduction of emissions. An average of 187kg of CO_2eq emissions is saved each year per conversion.

SUMMARY

The key benefits resulting from investment in Autogas conversions include: consumer fuel cost savings, health benefits from reduced air pollutants and a reduction in CO_2eq emissions. Figure 5 below displays all of these monetised benefits resulting from $1 million of investment, over the six years of expected vehicle remaining lifetime.

In summary, for every $1 million invested in Autogas conversions, 2,247 car owners can be incentivised. This results in an estimated fuel cost saving of $1.2 million per year and health benefits from reduced air pollution, equivalent to $301,000 per year in damage costs. These costs sum to a total of $1.5 million economic gain a year and **$6.97 million** of net economic gain over the remaining six-year average expected vehicle remaining lifetime (subtracting the original $1 million investment as well as the car owner expenditure). Not included in this net economic gain is, the reduction of 421 tonnes of CO_2eq emissions per year but is calculated to be the equivalent to a present-day market cost of $7,200 per year, rising to a predicted $37,000 per year by 2030.

AUTOGAS CONVERSIONS - RETURN ON $1 MILLION OVER VEHICLE'S REMAINING LIFETIME

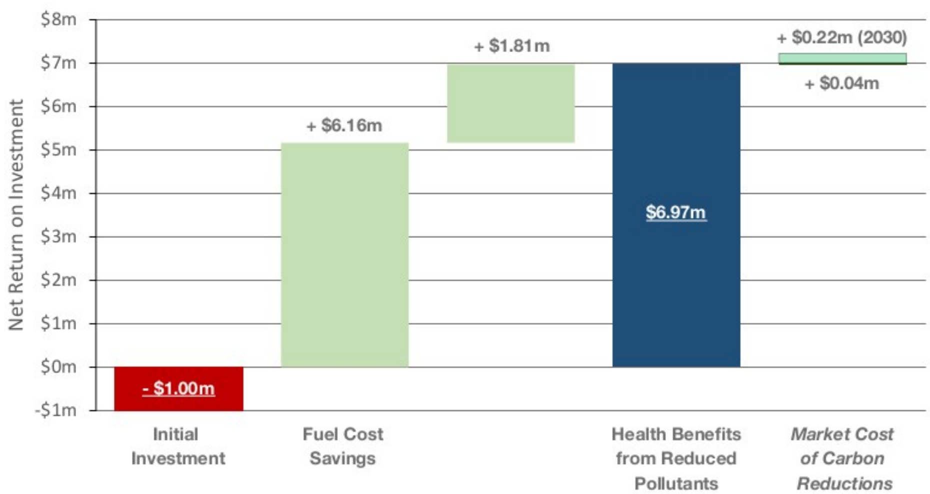
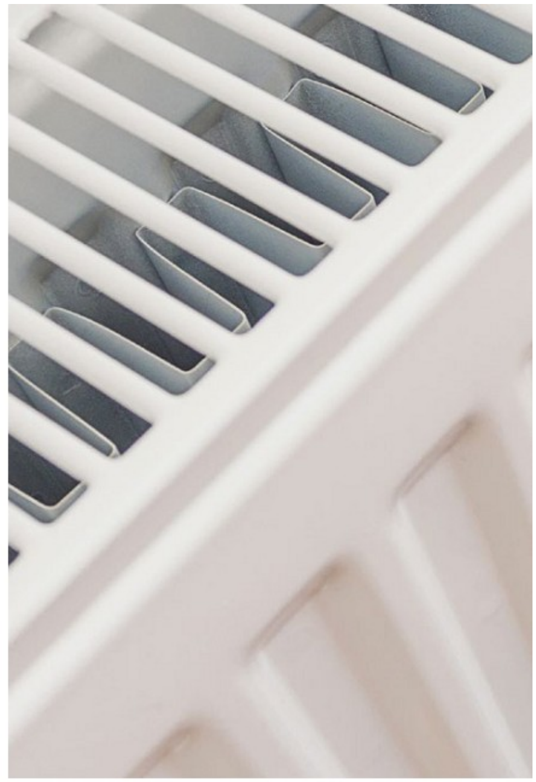


Figure 4.5:
Displays the key benefits resulting from $1 million of investment in incentivising Autogas conversions. Air pollution and carbon reductions values have been 'monetised' so that they can be compared against each other graphically.

5. RECOVERY PACKAGE – ENERGY EFFICIENCY RETROFITS



INTRODUCTION

Retrofitting our existing building stock to improve energy efficiency is shown to be one of the most effective ways of reducing CO_2e levels for net zero. The European Union (EU) has a target of 55% reduction in emissions by 2030 and net zero emissions by 2060. Across the bloc only 0.2% of approximately 220 million buildings carry out deep renovations each year, which reduces energy consumption by a minimum of 60%.[36]

EU policymakers foresee a unique opportunity to redesign and renovate buildings across Europe for a sustainable future, whilst engendering a sustainable recovery from the COVID-19 crisis. The EU is focusing on a 'Renovation Wave,' emphasising the need for investment over a sustained period. Starting with public buildings, the Renovation Wave will create employment and economic growth throughout the renovation supply chain. The slow rate of renovation has meant only 11% of the building stock undergoes some level of retrofit renovation each year.[36] A wide range of technologies including LPG heating systems will appeal to consumers to facilitate a quick rate of renovation.

By 2030, an additional 160,000 green jobs could be created in the EU construction sector via the Renovation Wave.[36] A large skilled workforce with specialised technical knowledge will be required to transform the building stock for climate-neutrality. There is great potential for job creation and retention in the retrofitting and energy efficiency sector, as well as further up the supply chain in manufacturing. LPG presents an alternative to traditional fossil-fuel heating for energy efficiency retrofit. There will be many fossil-fuelled homes across Europe in which low carbon heating technologies such as heat pumps or solar thermal panels are neither effective nor desirable. Homes such as these can have solid walls and can be found in rural, off-gas grid areas. There are 40.7 million European households in rural areas that are not connected to a gas grid.[37]

In almost all EU countries, 50% of the housing stock was built before the first thermal regulations in 1970.37 In Germany, 73% of the stock was built before 1978, and in the UK 35% of buildings were built before 1945 so many have not undergone any renovation.[37, 38] Many of these properties rely on high-carbon fossil

fuel heating. In Poland, 50% of the final energy consumption is derived from coal.[36] These properties are likely to require LPG and biofuels (such as bioLPG) in order to decarbonise, as electric heat pumps are not well-suited to operating in thermally inefficient buildings.

BioLPG offers a lower carbon fuel alternative to LPG and can use the existing heating system which keeps costs low in comparison to other renewable heating options. A mixed technology approach is required given the variability of the building stock, where bioLPG will play an important role for older rural homes. Replacing old polluting heating systems in Europe will lower air pollution, carbon emissions, consumer bills and energy use.[39] This will be crucial for EU policymakers in renovating the building stock, there is ample opportunity for LPG and bioLPG fuels in the route to decarbonisation.

This recovery package argues the case for LPG and bioLPG retrofit solutions, that tend to be more suited to rural off-gas homes to address the carbon emissions for such properties. The EU Renovation Wave engages industry to invest in the supply chain to retrofit the building stock for employment and economic stimulus. Investing in energy efficiency measures alongside low carbon offerings such as bioLPG boilers generates significant benefits for the consumer and the environment.

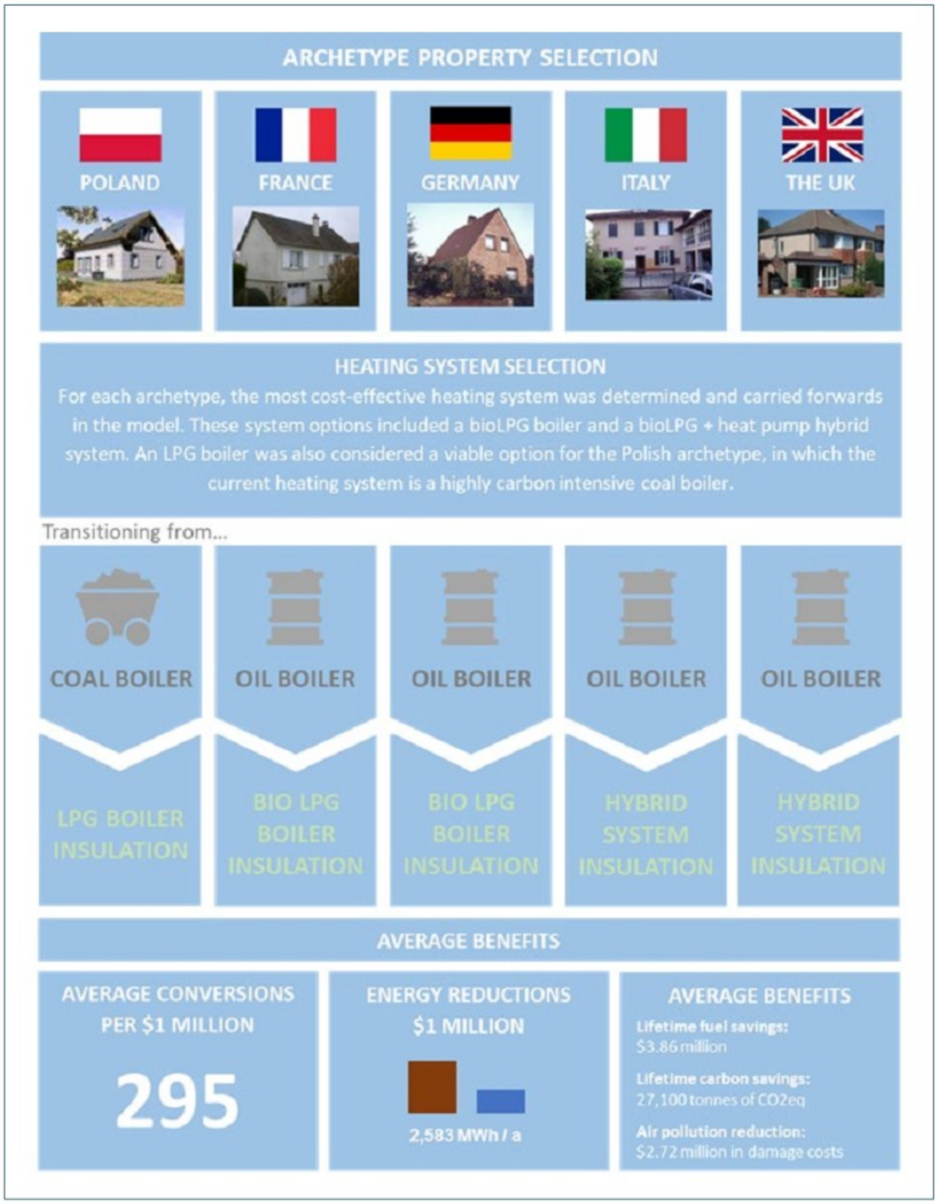
ECONOMIC CASE FOR INVESTMENT IN ENERGY EFFICIENCY RETROFITS

Without an immediate ban on high carbon heating systems, incentivising the sale of low-carbon heating systems will require government grants to reduce their cost and their payback period. A payback period of seven years is often considered a sufficient for households to invest in higher upfront cost heating system alternatives.[40]

Many low-carbon heating systems already provide low operational fuel costs but have high and often restrictive upfront costs, particularly in high heating demand properties. BioLPG boilers are an exception to this trend, with upfront costs usually lower than oil and coal boilers, and far lower than their low-carbon heating system counterparts, such as heat pumps and biomass boilers. Investing in energy efficiency measures alongside a bioLPG boiler, can reduce fuel consumption and result in annual bioLPG fuel costs lower than the annual costs of oil or coal. Therefore, government grants aiming to improve energy efficiency measures can help to incentivise the uptake of bioLPG boilers, alongside heat pump and hybrid heat pump systems.

This study compared the financial attractiveness of LPG boilers, bioLPG boilers and heat pump + bioLPG hybrid systems, combined with energy efficiency retrofit measures, against the cost of a new oil boiler or coal boiler. A grant was determined which would result in a seven-year payback period of the low-carbon heating system option, compared with the high carbon

RESULT OF INVESTING $1 MILLION IN ENERGY EFFICIENCY RETROFITS



option, and calculated the resulting lifetime consumer fuel savings.

This analysis was applied to four European archetype properties, Poland, France, Germany and Italy, in addition to a UK archetype. For each country's archetype, the cost effectiveness of a determined country specific grant scheme was compared between the low carbon heating options (LPG boiler, bioLPG boiler and heat pump + bioLPG hybrid system). The effectiveness of these grants varied due to the specifics of the archetype property chosen, as well as the country specific fuel and system costs. The bioLPG boiler was found to be a more effective system to subsidise in France and Germany, whilst the hybrid system was more cost effective in Italy and the UK. In these four countries LPG boilers were not considered a viable low-carbon option. However, in Poland, which has a highly dominant coal boiler market, LPG boilers were considered a viable option. The average number of conversions incentivised per $1 million of investment across all five countries was determined to be **295**.

The benefits resulting from these energy efficiency investments and renovations are economic, social and environmental. Greater disposable income will result from household fuel savings, helping to boost the wider economy. Direct jobs will be created through renovation and installation activities and a significant creation of indirect jobs within the supply chain is likely to occur. The reduction in oil combustion will significantly reduce ambient air pollution in residential areas – most significantly in densely populated areas. This reduction in air pollution can also be equated to a large financial saving to health services and

REGION – THE EUROPEAN UNION AND THE UK:

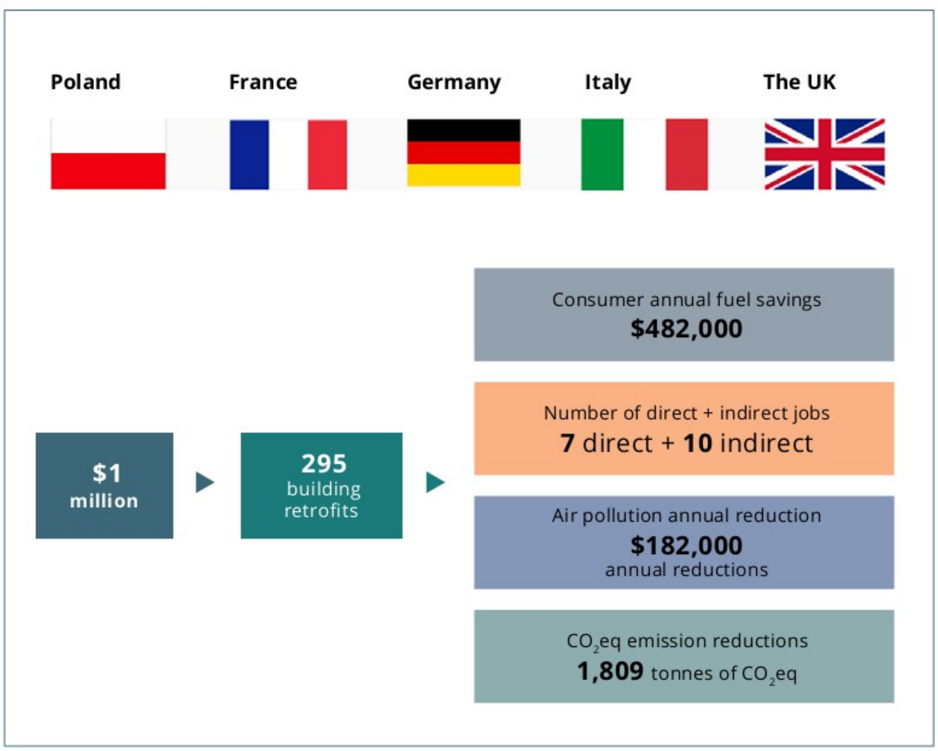


Figure 5.1: Infographic displaying key benefits of investing $1 million in building retrofits within Europe and the UK

individuals by using damage cost estimates. The combined reduction of energy demand, and the substitution of oil and coal for the much less carbon intensive alternatives, also results in a direct reduction of CO_2eq emissions and is therefore of key importance to a sustainable recovery. Again, this reduction in CO_2eq emissions can be translated into a monetary value using market costs of carbon.

I. Economic benefits per $1 million

Fuel cost savings:

For every $1 million spent on energy efficiency measures in European countries, an average of 295 households can improve thermal efficiency, reduce annual energy demand and substantially reduce their carbon footprint. This reduction in energy demand reduces fuel bills and a total of $482,000 can be saved by consumers, each year, for every $1 million invested. Over the heating system lifetime, this results in a net consumer gain of $3.9 million, compared to if they, without the grant, invested in an oil/coal boiler. These fuel savings increase a household's average disposable income, which will re-enter the economy and stimulate broader economic growth.

Air pollution:

In addition to fuel cost savings, the reduction in air pollution results in a significant reduction of health impacts that saves both individuals and health services money. For every $1 million invested, an estimated total reduction of 14 tonnes of $PM_{2.5}$/PM_{10}, 23 tonnes of NOx and 57 tonnes of SO_2 is expected over the system's lifetime. This equates to a total damage cost saving of $2.72 million for every $1 million that is invested.

II. Number of jobs per $1 million

In addition to consumer fuel savings and health benefits, investing in energy efficiency retrofits and low-carbon fuel alternatives, also leads to the creation of jobs.

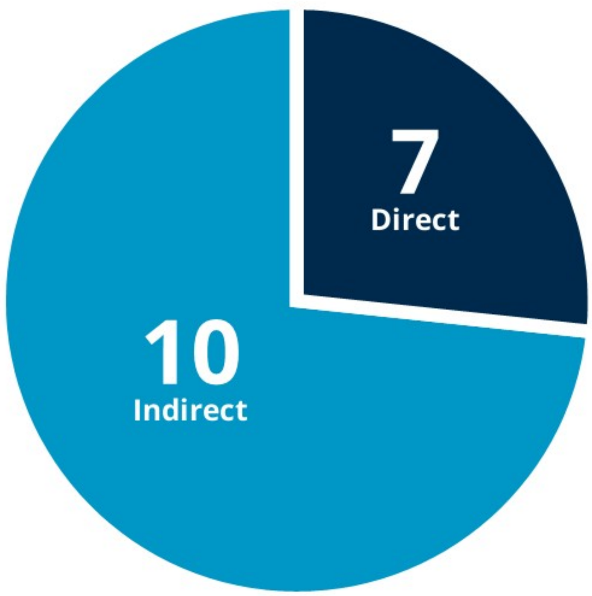


Figure 5.2:
An expected seven direct jobs are predicted for each $1 million spent in energy efficiency measures. These jobs include the renovating of properties with thermal efficiency measures, such as wall/loft insulation, as well as the installation of new heating systems. A substantial ten further indirect jobs are created as a secondary result of the energy efficiency measures, including the manufacturing of the materials and equipment.

III. CO_2eq reductions per $1 million

The methods for decarbonising domestic heating come in two main forms. Firstly, reducing energy demand through improved thermal efficiency, and secondly, exchanging high carbon forms of heating for low-carbon heating systems. The largest reductions in CO_2eq emissions result with a combination of transitioning to low-carbon heating alongside retrofit measures. Figure 5.3 below displays the relative annual carbon emissions of an average European household for four different heating scenarios.

HOUSEHOLD'S ANNUAL CARBON EMISSIONS

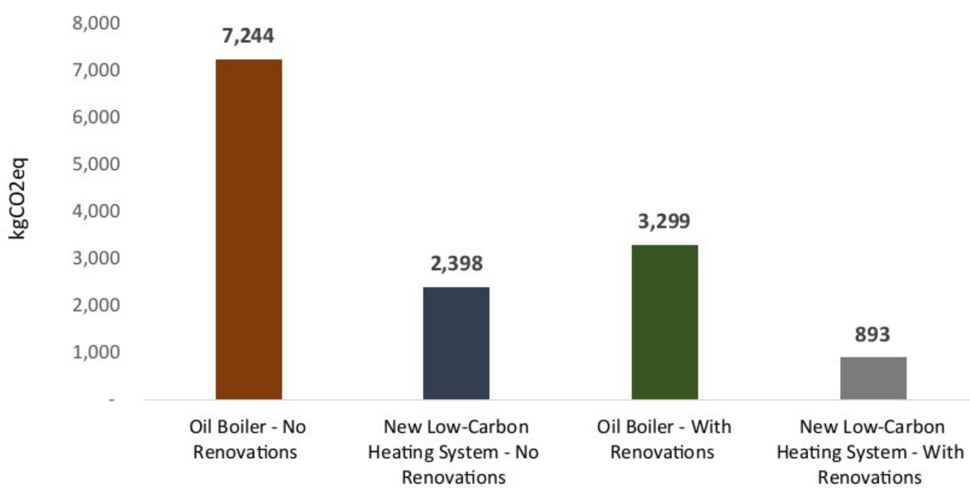


Figure 5.3:
Displays a typical European household's annual CO_2eq emissions, resulting from heating, for four different scenarios: heating using an oil boiler in a property without renovations produced the highest annual emissions; renovating the property and improving thermal efficiency reduces these emissions by over half; swapping an oil boiler for a low-carbon heating system reduces the emissions even more; finally, combining renovation measures with a new low-carbon system results in annual CO_2eq emissions over eight times less than an oil boiler with no renovations.

This reduction in CO_2eq emissions per household is multiplied by the 295 households transitioning per $1 million invested, for a significant annual carbon reduction of 1,809 tCO_2eq emissions. Over the heating systems' lifetimes of an assumed 15 years, the total emission reductions amount to **27,100 tonnes** of carbon equivalent emissions, per $1 million invested. This is approximately the equivalent of removing 7,000 cars from the road.

This reduction in emissions can be converted into a monetary value by multiplying by the 'market cost of carbon'. This was determined by averaging the carbon tax applied to each of the five countries considered to derive a value of 24.25 USD/tonne.[21] This market value is however distinct from the 'social cost of carbon', which tend to be much higher. Carbon taxes are expected to increase rapidly over the next decade and the IEA predict that by 2030, the carbon tax in OECD could be on average $100/tonne.[22] This study has included both values.

Using these market costs, the lifetime reduction in CO_2eq emissions equates to between $0.66 million and $2.71 million. The monetised carbon reductions, however, exist only for the sake of comparison and do not contribute to the final net economic gain figure. Their derivation being more academic and less tangible than the other economic benefits.

SUMMARY

The key benefits resulting from investment in building energy efficiency include consumer fuel cost savings, health benefits from reduced air pollutants and a reduction in CO2eq emissions. Figure 5 below displays all of these monetised benefits resulting from $1 million of investment, over the heating system's 15-year lifetime.

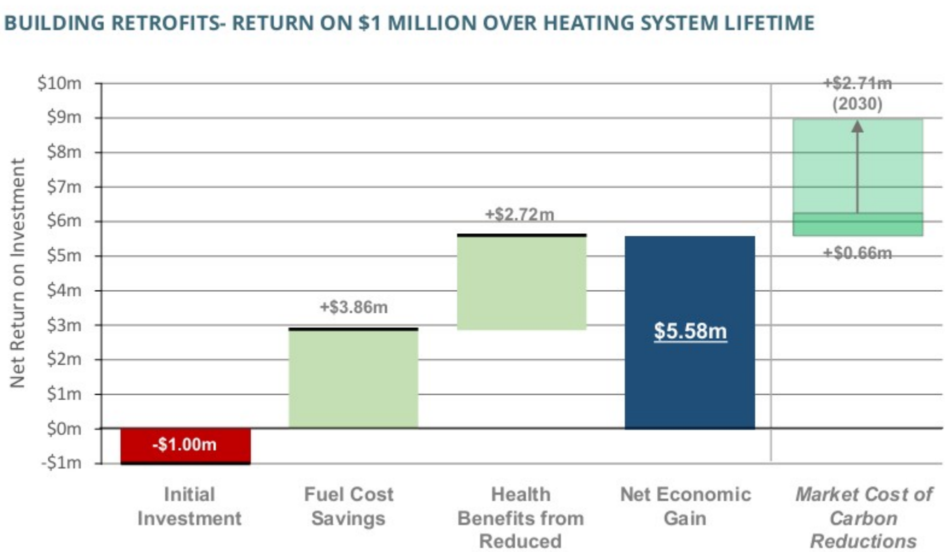


Figure 5.4:
Displays the key benefits resulting from $1 million of investment in energy efficiency retrofits. Air pollution and carbon reductions values have been 'monetised' so that they can be compared against each other graphically. The market cost of carbon is a more theoretical figure and so does not contribute to the 'net economic gain'.

In summary, for every $1 million invested in building energy efficiency retrofits, approximately 295 households can be incentivised to upgrade. This results in an estimated total fuel cost saving of $482,000 per year and health benefits from reduced air pollution, equivalent to $182,000 per year in damage costs. Over the system's lifetime, a net economic gain of **$5.58 million** has been calculated, after subtracting the initial investment and the upfront costs to the consumer. Not included in this net economic gain is the net reduction of 27 kilo-tonnes of CO_2eq emissions but this is calculated to be the equivalent to a present-day market cost of $0.66 million, rising to a predicted $2.71 million by 2030.

6. RECOVERY PACKAGE – INVESTMENT IN BIOFUEL PRODUCTION

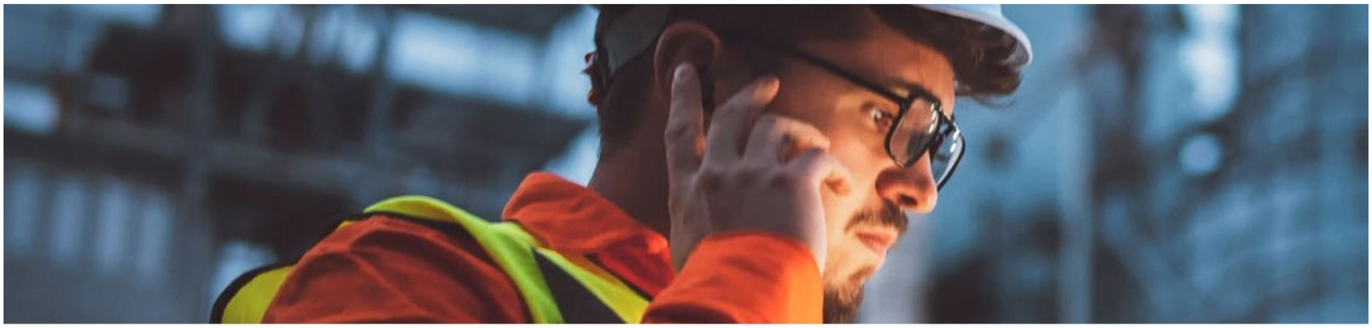
INTRODUCTION

In March 2021, US President Biden released a $2 trillion Jobs and Infrastructure Plan, to include an expansion of biobased products and renewable fuel production.[v] A mobilisation of clean fuels not only creates new jobs, but it allows for a just transition for workers and communities reliant on oil and gas extraction. It can provide direct monetary benefit to workers in particular low-income workers, by investing in infrastructure and providing high-road employment opportunities.[vi] This policy support coupled with clean fuel standards including the Federal Renewable Fuel Standard (RFS2), gives way to the doubling of US HVO biodiesel production capacity in the next two years.[vii]

Tighter Low Carbon Fuel Standards (LCFS) in California, Oregon and Canadian province British Colombia is set to increase demand for low-carbon HVO using waste and residue feedstocks. These areas present production facility opportunities.[viii]

The EU, US and other nation states have also set ambitious climate targets of net zero emissions for 2050. BioLPG can work to decarbonise transport and off-grid residential heating whilst operating the existing transmission/distribution infrastructure and hit the net zero targets. Off-grid rural homes often have low levels of energy efficiency with poor insulation, so other sources of renewable heat such as heat pumps are therefore unsuitable. BioLPG can provide up to 80% emissions reduction when compared with conventional LPG, and between 73-81% emission savings against fossil fuel baseline standard.[ix] This carbon savings reduces damage to air quality. Low-emission fuels are imperative in the transition to net zero where energy needs cannot be easily met by electricity.

BioLPG is chemically identical to LPG but is produced from renewable feedstocks including plant or vegetable waste material. Currently, most bioLPG is made as a co-product via hydrotreated vegetable oil (HVO) diesel production, used as renewable diesel or sustainable aviation fuel. Biodiesel is also commonly produced via transesterification of vegetable oils to make fatty acid methyl ester (FAME) biodiesel glycerine.[x] Subsequently, the dehydration of glycerine produces bioLPG.



In the European Union (EU) FAME biodiesel production has been reducing, but HVO production has increased by 195% between 2012-2020.[xi] Future demand is expected to equal 8-12 million tonnes of LPG, which can be met with bioLPG where production is on the rise following the COVID-19 crisis.[xii] The US and Indonesia are set to increase biodiesel expansion in the next few years, increasing the global biofuel production by 7% from 2021-2022.[xiii]

This recovery package describes the economic benefits of investment into biofuel production facilities focusing on the conversion of existing oil-refineries to HVO production for bioLPG. Investing in HVO production for bioLPG will match the global expansion in demand for biodiesel and seizing the economic opportunity. BioLPG can reduce emissions by up to 80% when compared with fossil fuels - necessary for a sustainable recovery. The focus for this analysis is Europe and the United States, both of which have identified low carbon fuels as playing a strategic role in the decarbonisation of transport, heat and wider sectors of the economy.

ECONOMIC CASE FOR INVESTMENT IN BIOFUEL PRODUCTION FACILITIES

Biofuels play a key role in national and regional energy strategies. At a European level, analysis of each Member State's National Energy and Climate Plans (NECPs) illustrates that governments see an increasing role for biofuels over the next decade, with total EU biofuel demand set to increase by 225% by 2030.

BioLPG is chemically identical to LPG but is produced from renewable feedstocks including plant or vegetable waste material. It has advantages over other biofuels (such as FAME bio-oil) proposed for use in heating systems as it can be dropped-into existing LPG boilers and appliances, meaning that expensive and time-consuming retrofits are not needed. Therefore, the bioLPG pathway to renewable heat is low-hassle for many consumers.

Currently, most bioLPG is made as a co-product via HVO diesel production, used as renewable diesel or sustainable aviation fuel. Biodiesel is also commonly produced via transesterification of vegetable oils to make fatty acid methyl ester (FAME) biodiesel glycerine.[xiv] Subsequently, the dehydration of glycerine produces bioLPG. In the European Union (EU) FAME biodiesel production has been reducing, but HVO production has increased by 195% between 2012-2020.[xv] Future demand is expected to equal 8-12 million tonnes of LPG, which can be met with bioLPG where production is on the rise following the COVID-19 crisis.[xvi] The US and Indonesia are set to increase biodiesel expansion in the next few years, increasing the global biofuel production by 7% from 2021-2022.[xvii]

This recovery package considers the economic case for investment in biofuel production facilities – specifically the conversion of existing oil-refineries to HVO production – which delivers bioLPG as a by-product and meets a globally expanding demand for biodiesel. The focus for this analysis is Europe and the United States, both of which have identified low carbon fuels as playing a strategic role in the decarbonisation of transport, heat and wider sectors of the economy.

ECONOMIC CASE FOR INVESTMENT IN BIOFUEL PRODUCTION FACILITIES

Biofuels play a key role in national and regional energy strategies. At a European level, analysis of each Member State's National Energy and Climate Plans (NECPs) illustrates that governments see an increasing role for biofuels over the next decade, with total EU biofuel demand set to increase by 225% by 2030.

As illustrated in figure 6.1 below, policymakers view biofuels as playing a strategic and crucial role in the decarbonisation of transport. Globally, transport is responsible for nearly a quarter (24%) of all CO_2 emissions associated with fossil fuel combustion . As governments look to tackle twin challenges of decarbonisation and harmful air pollution, biofuels have been identified as an important alternative to conventional fossil fuels - particularly for larger vehicle-types such as buses and HDVs,

TOTAL EU BIOFUEL DEMAND SET TO INCREASE 225% BY 2030

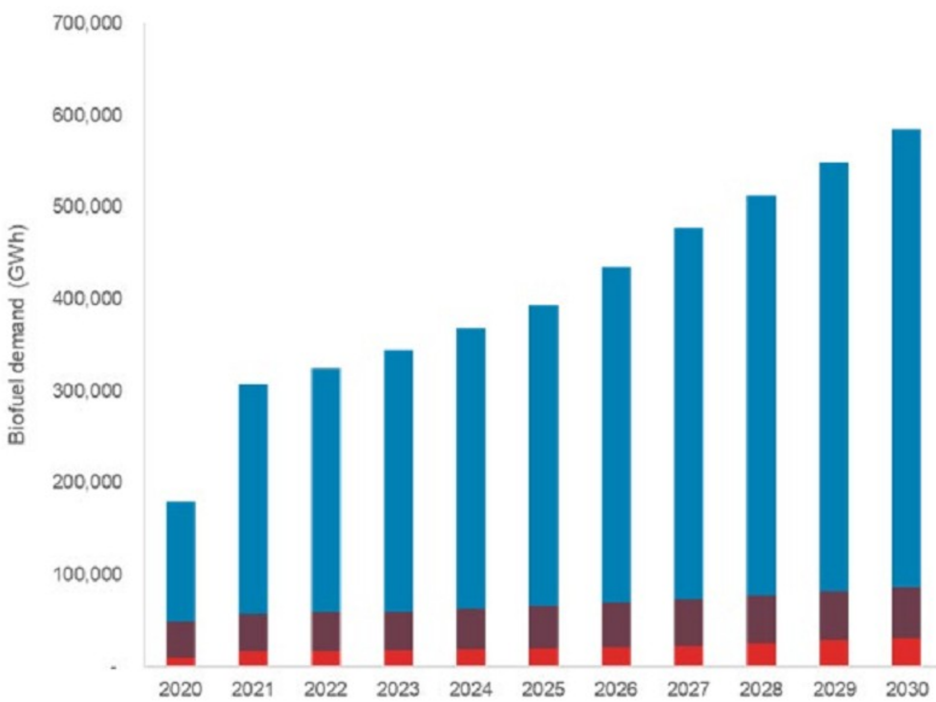


Figure 6.1: projected biofuel demand across European Member States (source: NECPs)

where the electrification of transport has some challenges.

Indeed, as illustrated in Figure 6.2 below, European governments have targeted renewable fuel consumption in the transport sector. Partially this is driven by the Renewable Energy Directive sub-target of 14% of transport fuels coming from renewable sources, but some Member States have gone further with national targets exceeding 30% in Nordic countries. Further to this, the European sub-target could increase in the expected revision of the RED.

In summary, this picture is one of increased demand for biofuels across Europe. Comparing to the United States, the government's own energy consumption projections project an increase in the use of renewable diesel and gasoline by 200% in the next eight years - a similar rate of increase in demand.

To meet rising demand, the global production of biodiesel is expected to increase over the coming years. Figure X below shows an average 7% increase in the global production of biodiesel per annum, from 42 million tonnes per year in 2019 top 49 million tonnes by 2022, with HVO increasingly taking a more prominent role as the preferred fuel over FAME biodiesel.

Yet generally, these biofuel production figures fall short of the IEA's Sustainable Development Scenario pathway to 2030 - a scenario which

MEMBER STATES % OF RENEWABLES IN TRANSPORT IN 2030

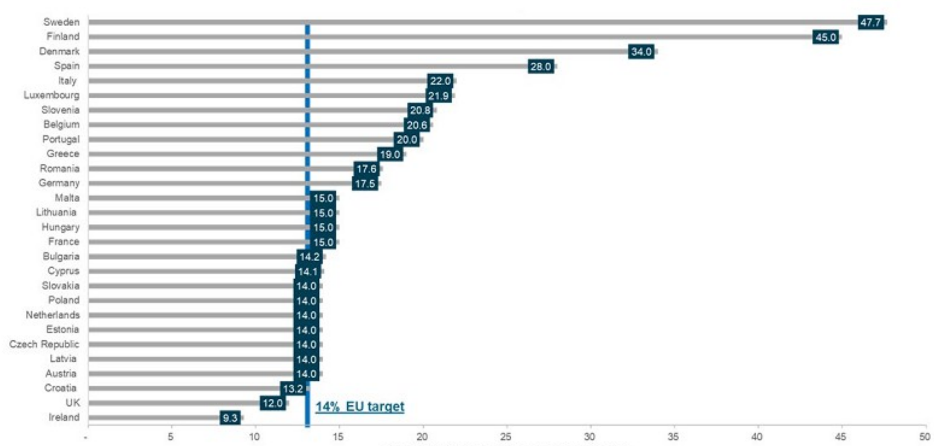


Figure 6.2: renewable transport fuel targets across EU Member States (source: European Commission and NECPs)

is aligned with the Paris Agreement and COP26 discussions. Indeed, transport biofuel production needs to grow at a sustained rate of 10% per year to hit the intermediate targets set out in the SDS pathway.

Ultimately policy is needed to unlock greater volumes of biodiesel supply in the short term, as the cleaner fuel is more expensive to produce than conventional fossil alternatives. Governments therefore have a role to play in supporting and de-risking investment in biofuel production facilities, and securing market demand via quotas, blending mandates, and financial instruments (such as taxes and subsidies).

This is not just a story about economic costs, and the estimates featured in this chapter highlight the numerous economic benefits which can be unlocked by government investment in biofuel production facilities. This is in addition to non-market benefits including reduced carbon and air pollution emissions.

RESULT FROM BIOFUEL PRODUCTION PLANT INVESTMENT

Our analysis focuses on a specific investment proposition. We have focused on the case for investment in the conversion of existing oil refineries to produce HVO - a process which

RENEWABLE DIESEL AND GASOLUNE CONSUMPTION, UNITED STATES GOVT. REFERENCE CASE PROJECTION

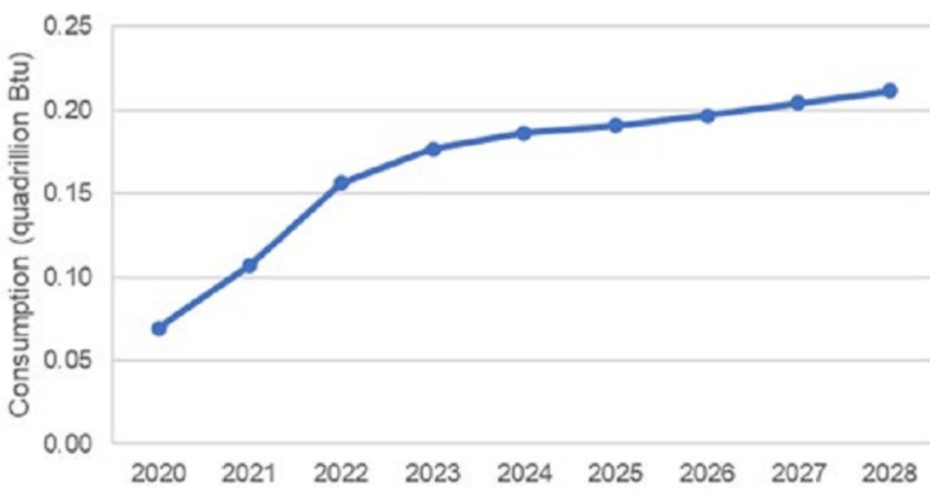


Figure 6.3: United States Energy Information Administration's (EIA) Annual Energy Outlook 2021 – renewable diesel and gasoline consumption in the reference case

also produces bioLPG. According to the US government, there are 124 refineries operating in the country as at 2021, and five idle from use .

I. Economic cost of biofuel plant investment

Based on publicly available data, converting a refinery to produce HVO is estimated to cost in the region of $150 million for a typical plant which an output of 350,000 tonnes per year. To carry out the economic analysis, we break this figure down into sub-categories of cost and investment.

Figure 6.5 utilises estimates from a Canadian renewable diesel study – which assumes the development of the HVO plant on the site of an existing oil refinery – to breakdown the investment cost into its component parts .

As displayed, the installation cost accounts for nearly half of the total investment, with the equipment cost and engineering accounting for a further 35%.

COOKING FUEL SOURCES IN SUB-SAHARAN AFRICA

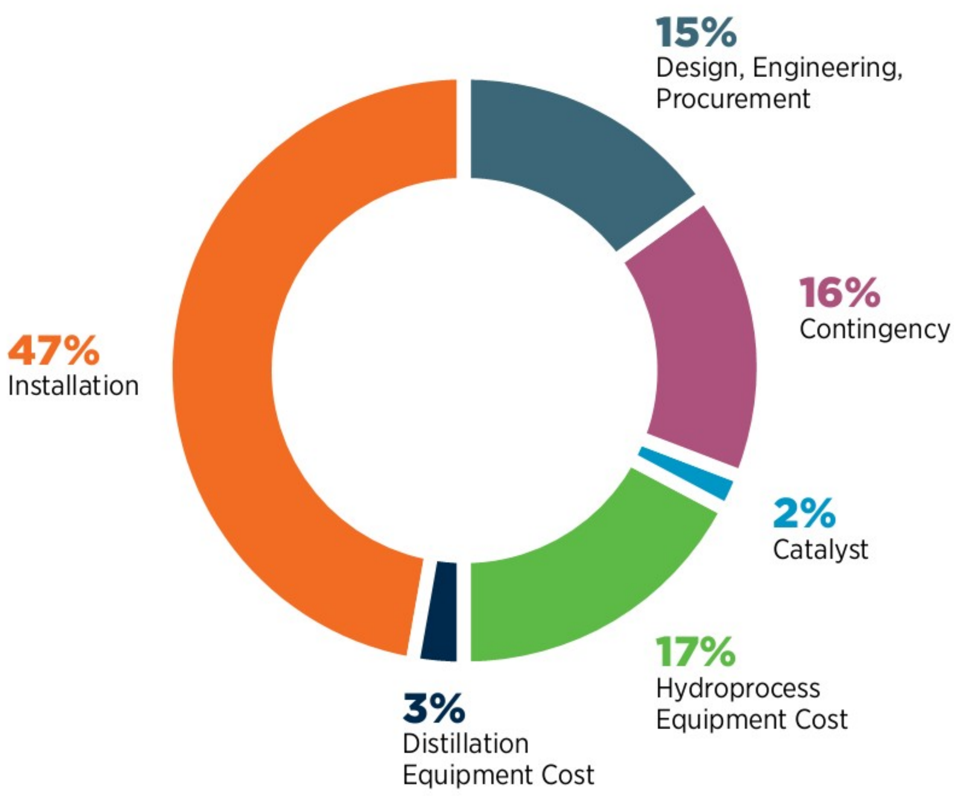


Figure 6.5: cost breakdown of HVO-plant investment

Capex element	Share - %	Cost - $mn	NAICS activity	NAICS code
Design, engineering, procurement	19%	28.5	Architectural, engineering, and related services	5412OP
Catalyst	2%	3.6	Chemical products	325
Hydroprocess equipment cost	20%	30.4	Petroleum refineries	324
Distillation equipment cost	4%	5.4	Petroleum refineries	324
Installation	55%	82.5	Construction	23

Table 6.1: breakdown of HVO production facility capital cost and attribution to industry classification codes

II. Economic benefit from biofuel plant investment

In addition to stimulating immediate economic activity, policymakers will be keen to understand the positive spill-over benefits which will create a sustainable increase in growth and prosperity. Investing in the HVO plant creates a direct contribution, but also a wider footprint throughout the economy through spill-over activity across the supply chain.

Capital spending generates turnover, creates jobs, and adds economic value to the economy. The positive economic impact is captured both directly in the producing industry and indirectly via the wider supply chain – creating a ripple effect of activity.

Our approach to the analysis utilises United States Input-Output tables and economic modelling to make this assessment based on current data which sheds light on how the US economy behaves. Specifically, attributing the cost streams featured in figure 6.5 to specific sectors (see table 6.1 below) allows for an assessment of the degree to which each sector of the economy trade with others, and imports/ exports products and services. This allows us to estimate how a direct investment in the development of an HVO production plant, can create a ripple of wider economic activity across the economy.

Our analysis of the $150 million investment shows that after the cost of the inputs are accounted for and subtracted, the investment

Figure 6.6: economic contribution to the US economy from an investment in an HVO-plant

in the biofuel production plant stands to create $170 million of gross value-added contribution to the US economy. As shown in figure 6.6, this is made up of direct GVA contributions from the investment in the products and services needed to build the plant, and also value-added activity across the supply chain.

Another key opportunity for policymakers is to establish a comparative advantage for domestic industries in a growing global market for biofuels and specifically HVO. This chapter has illustrated a range of credible biodiesel and HVO projections from several national governments which show increasing demand for the fuel in the next two decades.

Utilising public reports of planned increases in HVO production capacity worldwide, our analysis shows a planned increase of just under six million tonnes of production capacity by 2025 across the world. Taking a typical investment figure for the development of an HVO production plant, this is a growing market expected to worth over $5 billion in capital spending over the next four to five years.

For instance, our analysis shows that some of the sectors which stand to benefit (such as engineering practices) have relatively high export rates and are well-placed to benefit from a growing global market.

III. Number of jobs supported by biofuel plant investment

An investment in biofuel production facilities not only generate economic growth, but of course also supports employment – which is vital for policymakers over the coming years. Utilising data accessed from the Bureau of Economic Analysis which estimates economic output and the number of full-time equivalent employees by industry, we can build up a picture of labour intensity per unit of output in each of our sub-sectors. This gives an estimate of the number of direct jobs which can be supported by our gross output estimates.

The direct impact of spending is only a portion of the whole story. As with the economic growth estimates, we have estimated the indirect jobs supported by the HVO plant investment across

Figure 6.7: employment impact of HVO plant investment

the supply chain, using employment multipliers developed by the Economic Policy Institute.

In sum, we estimate that a $150 million investment in the development of an HVO plant from an existing refinery will sustain 275 full time-equivalent (FTE) direct jobs, and a further 236 indirect jobs further up the supply chain.

IV. CO_2eq reductions

The HVO plant analysed in this chapter has been specified to produce 350,000 tonnes of HVO per year. The potential bioLPG yield as a co-product from the HVO process, can range up to 70% of total fuel yield , but in this report we have chosen a more conservative assumption of 4% - giving a yearly production figure of 13,500 tonnes of bioLPG.

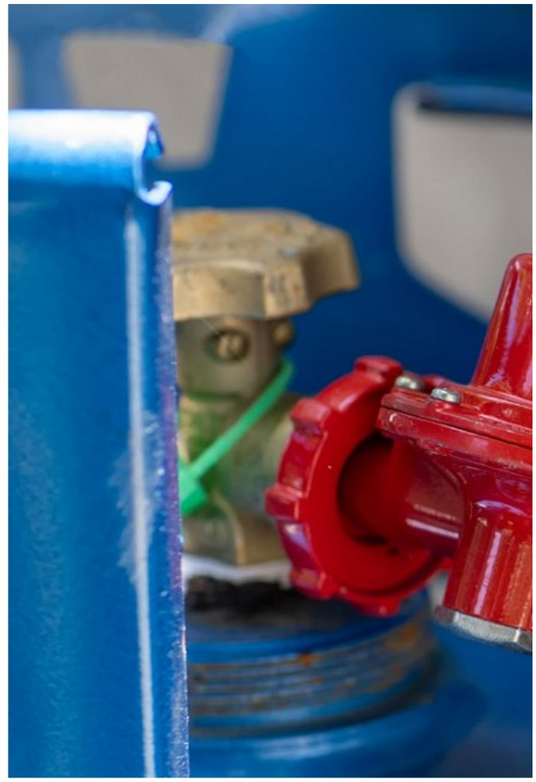
Renewable LPG has numerous use cases, many of which are detailed in this report. To develop estimates of carbon emission reductions from the development of these fuels, we assume that they are used to displace diesel in vehicles – as described in chapter 4.

Taking the full lifecycle emissions from these fuels – table 6.2 details the emission savings which could be expected to be achieved as a result of the production of HVO and bioLPG. In total, over 1.32 million tonnes of CO2e can be saved per year following the displacement of diesel fuel.

	Direct, scope 1 emission factor ($kgCO_2e/kg$)	Indirect emission factor, scope 3 ($kgCO_2e/kg$)	Fuel production in scenario, ktonnes/year	CO_2 emissions ($MtCO_2e/year$)
Diesel	3.209	0.746	364	1.44
Biopropane	0.004	0.565	13.5	0.01
HVO	0.046	0.273	350	0.11
Emission savings per year				**1.32**

Source: BEIS (2021)

7. SUMMARY



The COVID-19 crisis has shown that policymakers can intervene decisively for the social good. With significant economic and environmental challenges ahead, this paper has illustrated four LPG recovery packages that policymakers could support to boost jobs, economic growth, and create environmental benefit.

CLEAN COOKING

With almost three billion people currently using carbon intensive biomass, kerosene or coal as cooking fuel, there is great opportunity to reduce greenhouse gas emissions by transitioning households across the globe to clean cooking methods.4 Whilst many alternative methods of clean cooking exist, LPG provides one of the cheapest cooking alternatives that can be effectively and rapidly mobilised. In addition to reducing CO_2eq emissions resulting from household cooking, there are other substantial benefits that come from substituting biomass, kerosene and coal for LPG. These include highly significant reductions in levels of household air pollution, reduced labour time spent gathering cooking fuel, a burden that disproportionately affects women, and household savings in cheaper cooking fuel. LPG is therefore a highly appealing clean cooking method for improved sustainability, as well as being a feasible option for large scale deployment.

In the Sub-Saharan Africa region, market costs of fuel types used currently are on average higher than those of LPG. The key financial restriction for households transitioning is therefore the upfront cost of the LPG cooking equipment. A grant scheme which covers the total capital cost of the cooking equipment, if well managed and appropriately targeted, could motivate 13,112 households to transition to LPG, for every $1 million invested. The net benefits of investing $1 million in increasing the uptake of LPG as a clean cooking method are as follow:

- Households will save a total of $805,000 in reduced fuel costs per year. This will help to reduce levels of poverty and will boost the economies of the countries investing in the grant scheme.
- There will be a massive 5.65 tonne reduction in annual particulate matter emissions, resulting in greatly minimised household air pollution.

This has been equated to approximately $368,000 of equivalent health impacts per year, currently burdening both individuals and health services.

- 5.1 million hours of labour time spent gathering biofuel has been estimated to be saved each year, a labour burden that adversely affects women. This time saving has been equated to an estimated $232,000 of time per year, (not included in the final economic gain value).
- There will be an approximate reduction of 5,800 tonnes of CO_2eq emissions per year from this investment. This is the equivalent of taking 1000 gasoline cars off the road every year.
- Finally, an estimated 46 jobs will be directly created within cylinder manufacturing, bottling, distribution and retail, as well as 30 indirect jobs further within the supply chain.

AUTOGAS CONVERSIONS

LPG can be used as an alternative fuel source to gasoline or petrol for domestic transport, more commonly referred to as Autogas. Being a less carbon intensive fuel source, it can provide a key role in decarbonising the domestic transport sector globally, particularly in countries where electric vehicles are less affordable, or where electric vehicle charging infrastructure is less feasible. A key advantage of Autogas over gasoline and diesel is the significantly lower emission of air pollutants, which can result in serious health impacts in populated areas.

Autogas as a fuel source itself tends to be cheaper than gasoline or diesel – the primary financial restriction for car owners is the upfront cost of the Autogas conversion, which is required to make the vehicle Autogas compatible. The other important consideration for consumers is the country's Autogas re-fuelling infrastructure. This analysis chose six countries across the globe with a recognised Autogas refuelling infrastructure and where therefore the financial cost of an Autogas conversions are typically the limiting factor in increased uptake. A grant scheme was determined which would reduce the payback time of this conversion to less than 1.5 years. The average grant required, averaged across the six countries, was calculated to be $492 per vehicle. Therefore, for every $1 million invested in Autogas conversions, an estimated 2,247 diesel/gasoline vehicles can be converted to using LPG. The net benefits resulting from these 2,247 conversions include:

- An average fuel saving of $1 million per year. This rapid rate of return for the consumer will mean they are quickly generating an increased disposable income, leading to greater individual savings and helping to stimulate the economy of the country overall.
- A substantial reduction in ambient air pollution equating to an estimated $301,000 of health benefits each year.
- A reduction of 421 tonnes of CO_2eq emissions per year. This is less significant than other packages in this report, but this annual reduction will increase as the LPG fuel source transitions towards bioLPG.
- Twenty-eight jobs are calculated to be required for every $1 million invested and 2,247 conversions undertaken. A further 12 jobs are estimated to be generated within the supply chain.

ENERGY EFFICIENCY RETROFITS

Heating results in a significant proportion of global greenhouse emissions, accounting for 40% of total energy related emissions in 2014.41 Decarbonising heat is infamously difficult with conventional high-carbon sources being highly cost-competitive and new low-carbon heating systems such as heat pumps and biomass boilers demanding high upfront costs. (Bio)LPG boilers offer an attractive compromise, available at low capital costs and levelised costs.

As well as replacing high carbon heating system technologies, reducing total heat demand through energy efficiency measures is critical for a financially feasible and thorough decarbonisation. Ultimately, the combination of energy efficiency renovation measures and high-carbon heating system phase out is necessary for deep carbon reductions. The analysis in the study focused on countries in the EU which has embraced this route with the idea of a 'Renovation Wave', in which there is a focus on reducing total heating energy demand. By combining the renovation options with the installation of a (bio)LPG boiler, the annual fuel costs can be made lower than the predecessor oil/coal fuel source. The financial incentives in this analysis therefore focussed on subsiding the capital cost of the new heating system and the renovation measures. Across four European countries and the UK, a grant cost was determined for incentivising the transition away from oil and coal boilers towards LPG boilers, bioLPG boilers, and bioLPG + heat pump hybrid system options, alongside sensible renovation measures. The results of the analysis showed that 295 households could be incentivised to invest in heating system plus renovation measures, per $1 million invested, via an appropriate grant scheme. The net benefits of these 295 household transitions are as follows:

- Total annual fuel cost savings of $482,000 for households which will increase household disposable income and help to stimulate the economy.
- Reductions in air pollutant emissions translating to health benefits amounted to approximately $182,000 per year to individuals and health services.
- There will be a significant reduction in carbon equivalent emissions of 1,809 tonnes per year.
- With the new heating systems having an expected lifetime of at least 15 years, and renovation measures having even longer lifetimes, the net lifetime saving in fuel cost, air pollution and carbon emissions, resulting from the initial investment in the grant scheme, are substantial for this package (see figure 5.4).

- The number of jobs created, resulting from investment in energy efficiency retrofits, is less significant than in other packages, at seven direct jobs and ten indirect per $1 million invested. This is largely a result of a higher cost incentive scheme, resulting in a less significant consumer transition per unit investment.

INVESTMENT IN BIOFUEL PRODUCTION

Biofuels play a key role in national and regional energy strategies, as economies transition away from fossil fuel dependency. Indeed, analysis of EU Member State's National Energy and Climate Plans (NECPs) illustrate a close to 225% increase in demand by 2030, with the United States' EIA projecting a similar (200%) increase in the use of renewable diesel and gasoline over the next eight years. In short, there is a booming global market for biofuels.

Investment in biofuel production plants is capital intensive, can support economic growth and local jobs – whilst paving the way for decarbonisation of transport and heating fuels. For illustration in this chapter, we considered the economic case for investment in the conversion of oil refineries to produce HVO – a process which delivers bioLPG as a by-product.

The United States has 124 oil refineries operating in the country, with a further five sat idle from use as at 2021. Our analysis utilises industry capital cost data, and US input-output table modelling to examine the economic effects which could follow a $150 million investment in HVO plant conversion. Based on the linkages between the sectors of the economy which would directly benefit from such an investment and the wider supply chain, our analysis projects that this investment can deliver:

- Over $170 million of gross value-added contribution to the US economy, based on direct economic contributions from the engineering, chemical products, petroleum refineries and construction sectors, and a boost from the wider supply chain linking to these sectors.
- In terms of employment impact, utilising job intensity figures per unit of economic output, and employment multipliers from the Economic Policy Institute, we project that this HVO plant conversion investment would sustain 275 direct full-time equivalents, and a further 236 indirect jobs.
- In total, the 350,000 tonnes of HVO produced by this illustrative plant and 13,500 tonnes of bioLPG can generate 1.32 million tonnes of carbon savings per year when displacing diesel consumption.

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