# LPG in Agriculture and Farming

## Making the Green Sector Greener

## Innovation & Technology

**2022**

## World LPG Association (WLPGA)

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

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

## Acknowledgements

This report has been developed by a small working group of WLPGA members and staff.

There could be views expressed in this document not necessarily shared by all contributors.

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- George Nikolaou, NaTcogroup/Liquid Gas Europe
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# LPG in Agriculture and Farming

## Making the Green Sector Greener

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## Chapter One

# Introduction

This report reviews the recent trends in the use of LPG in the agriculture sector and related applications. The aim of the report is to promote the understanding amongst the LPG industry and beyond, of the technical possibilities, applications, and market potential of LPG for agricultural use.

The report scope includes:

- A scan of the market for agriculture applications**.**
- Engines and machinery that use or can easily be converted to use LPG as a fuel.
- Identification of market barriers and drivers to increase LPG penetration in the sector.

Besides providing a bird's-eye view snapshot of the sector as a whole, a key objective of the report is also to identify concrete opportunities for the LPG industry to pursue.

This report contains:

- **A fact sheet** giving an overview of the current technologies, the main players, and the market status.
- **An overview of the applications** (crop farming, livestock, power generation, etc.), and identification of those of particular interest to the LPG industry.
- **A roadmap** exploring the market outlook. The main barriers that inhibit growth and the drivers for future growth.
- **Recommendations** for WLPGA association members on how to overcome the barriers and maximise the market opportunities.

## Chapter Two

# Executive Summary

Agriculture is one of the most widespread activities in the world and plays a crucial role in food production and food security, environmental protection, landscape preservation and rural employment. Agricultural activities vary largely throughout various regions and countries in terms of:

- Scale and intensity of activities.
- Crop and livestock combinations.
- Ways and means of commercialising of the farm production including logistics.
- Level of automation and mechanisation (small-scale farmers/agriculture, commercial farming/plantation agriculture, self-sufficient farming, organic farming etc.).

The use of LPG in the agricultural industry is not new, but it is certainly increasing. LPG is a sustainable way of keeping farms operating, and it helps to promote sustainable development, reduce costs, lower emissions and allows the agricultural industry in general to remain competitive.

LPG is a cost-effective, extremely versatile and complete energy source for agriculture. LPG burns efficiently and cleanly; it does not contaminate crops and food. As farmers seek more environmentally friendly production methods and cost effectiveness, LPG is the clear and responsible choice. It contributes to increased production and quality of farm products. It is used for crop harvesting, crop drying, weed flaming, heating breeding houses, powering farm equipment such as irrigation pump engines and much more. In many respects, LPG is the ideal fuel for the production of food by agriculture and animal husbandry. Farming requires large areas of land, and the problem of energy supply to remote locations is not always easy to solve.

The LPG industry embraces challenges and opportunities to develop growth in agricultural markets and help farmers increase profitability. There are various technologies available for the use of LPG as a fuel in agriculture. The choice depends on the application and availability of technology for the specific application, as well as the regulatory framework, costs and other regional factors.

LPG is truly a diverse and adaptable solution that satisfies various needs across agriculture and user bases.

## 2.1. Key Messages - Fact Sheet

The agriculture sector uses a very diverse and broad range of equipment and engines. There are many possible applications for LPG engines and machinery. This section below describes the variety of these applications, with case studies and best practices. In many of these applications, LPG as an engine fuel is already present, varying amongst countries and regions, while in others it presents a significant opportunity that needs to be developed.

Advances in agriculture and a growing supply have combined to make LPG an enticing option for fuelling farming machinery and other agricultural applications.

Farmers across the world rely on LPG as an **adaptable power source to keep their businesses growing**. LPG allows them to meet the challenge of staying competitive in the modern agricultural environment, whilst maintaining a commitment to **sustainable development.** No other fuel offers a comparable combination of **portability, accessibility and convenience o**f use. LPG is used to increase the production and quality of farm products through crop harvesting, crop drying, weed flaming and other uses.

- LPG as engine fuel is a green, clean burning alternative both to storing and burning.
- It is less expensive than petrol or diesel in many countries.
- It is reliable and available everywhere.
- It is an alternative energy source that is ready now.
- It is a perfect combination with renewable sources of energy.

**In terms of potential applications, the list is vast,** ranging from agricultural uses such as irrigation engines and small (compact) farming tractors to a variety of machinery and also static uses such as power generation. The various agricultural uses of LPG, which were briefly touched upon in the introduction, can be sub-divided into five major groups.

- Agricultural and farming machinery as a diesel fuel substitute.
- Crop farming and protection.
- Livestock farming.
- Drying of cereals, other food crops, grass, and specialties, e.g., tobacco or rubber.
- Flame weeding and soil sterilisation.

While LPG use in agriculture is certainly not something new, some of the applications highlighted in this report are fundamental to the industry. Nearly 80% of farms in the USA use LPG.

LPG is used to **increase the production and quality of farm products** and provides clean, off-grid power for a range of applications. LPG is already ideally suited for field applications that require energy away from the natural gas grid or electricity, where diesel and gasoline are frequently used today. LPG is used for space heating, product drying and the operation of greenhouses with significant energy consumption. Due to its clean combustion, LPG is ideal for a wide variety of applications and its use entails many advantages for **livestock farming**.

Whether used for livestock-rearing, **crop-drying, weed and animal waste disposal or simply fuelling agricultural machinery,** LPG is an essential tool for the contemporary farmer; clean combustion ensures crops, feeds and litter are not contaminated. The $CO_2$ by-product can be diverted and repurposed to increase yields in greenhouses, whilst the moist heat given out by LPG can help induce rapid, even feathering of poultry.

**There are three basic engine technologies available today related to the use of LPG as a fuel for agricultural engines and machinery:**

- Spark ignition (Otto cycle) engines dedicated (mono fuel) engines.
- Spark ignition (Otto cycle) engines bi-fuel petrol-LPG engines.
- Diesel compression ignition diesel/LPG dual fuel engines (HDDF in SHDEs).

**These can also be combined with in micro hybrid electric technologies. Spark ignition engines can be easily converted to run on LPG.**

**Mono fuel dedicated engines** have the advantage that they use only LPG and are equipped with only one type of fuel system and one fuel cylinder, thus saving on costs, although a disadvantage might be the lack of flexibility of fuel option where the LPG distribution network may not offer complete coverage.

**Bi-fuel petrol-LPG engines** are less common in the agricultural sector.

**At present, the variety of available LPG engines for agricultural applications is limited.**
The availability of LPG engines is limited. Some older LPG engines from OEMs have been taken out of their catalogues as they are no longer able to meet the stricter emissions requirements, while newer ones would need significant investments for homologation and certification.

**The main players in the agricultural sector** consist of engine manufacturers and technology developers, as well as manufacturers of equipment, machinery and vehicles that use these engines.

Several players exist in developed countries; some have grown into regional markets. Others are appearing in emerging markets that have the potential to outgrow their current positions as regional giants or niche players.

The number of OEM quality platforms for LPG agricultural applications is growing with partners in the US such as **Greengear (Cavagna group), ONYX Solutions, EnviroGard, John Deere,** and others.

**The role of various stakeholders is instrumental in driving growth.**
All principal stakeholders, from policy makers, regulators, governments, LPG distribution companies, engine manufacturers, OEMs, independent system developers, vehicle manufactures, national and international industry associations, and emissions experts, need to be addressed with coordinated actions.

**Regulations** are also changing rapidly to meet the environmental challenges. Therefore, technology advancements must keep up, which requires further investments.

**Certification regulations are in force**. UN level regulations for OEM and retrofit technologies provide a mandate or model for National Certification and will significantly enhance the availability of high quality dual-fuel systems. Complying with environmental standards and requirements will entail costly technologies, for which end users and other operators may be unwilling to pay the price.

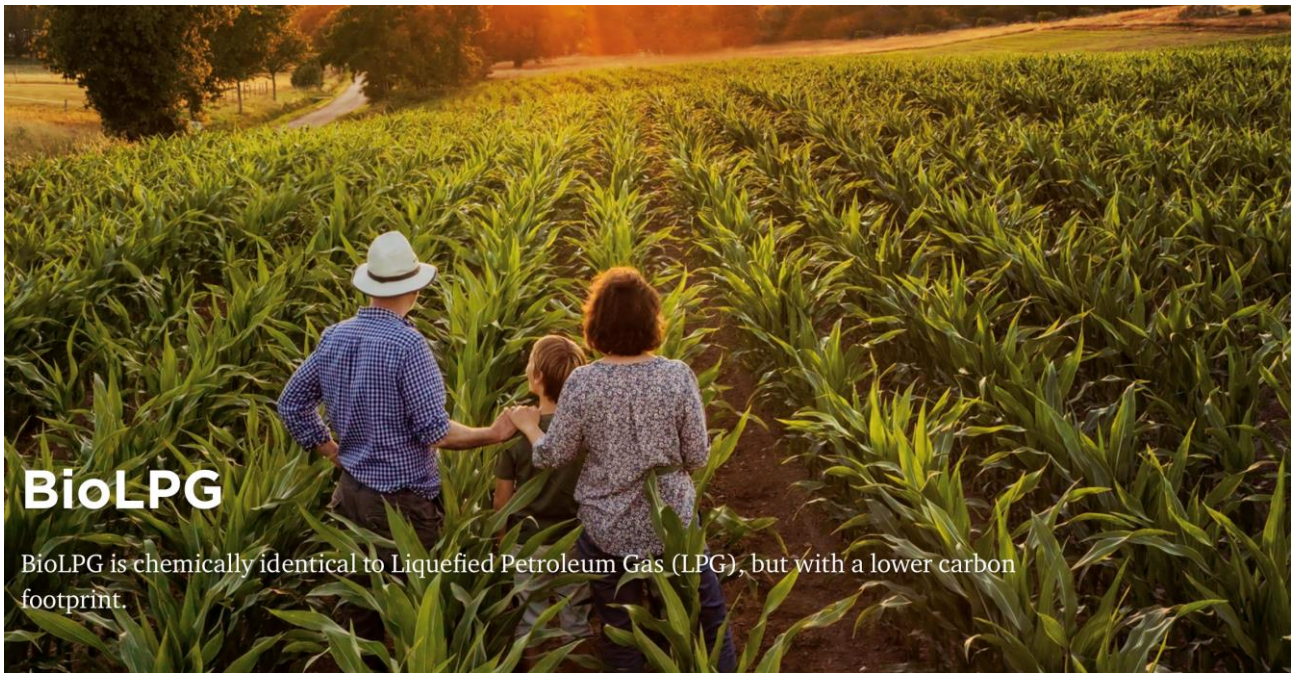
The significant price advantage and flexible supplies of LPG reinforce the notion that LPG can play an important role as a major part of a clean fuel portfolio for the years to come towards reductions of GHGs, NOx and PM emissions.

**Safety** represents a top priority for any professional agricultural engines and equipment. The highest level of safety should be integrated at the design stage of any application as well as during its fuelling, use and operation.

LPG distribution infrastructure offers the most economical solution compared to all other alternative fuels, making the case even stronger for continued growth in this market space, although for very small equipment, additional alternative small fuelling receptacles and distribution methods should be developed.

*Source: Kubota*

**LPG is cleaner when compared to other fossil fuel options as it can be considered sulphur-free and allows for the easy reduction of NOx, which minimises acid rain, carbon emissions, as well as eliminates soot emissions. Solid fuels and fuel oils require supplemental anti-pollution devices to clean combustion products to meet environmental standards. This further lends credence to the argument that LPG is the clean and cost-effective option.**




*Source: SHV ENERGY*

## 2.2. Key Messages – Roadmap

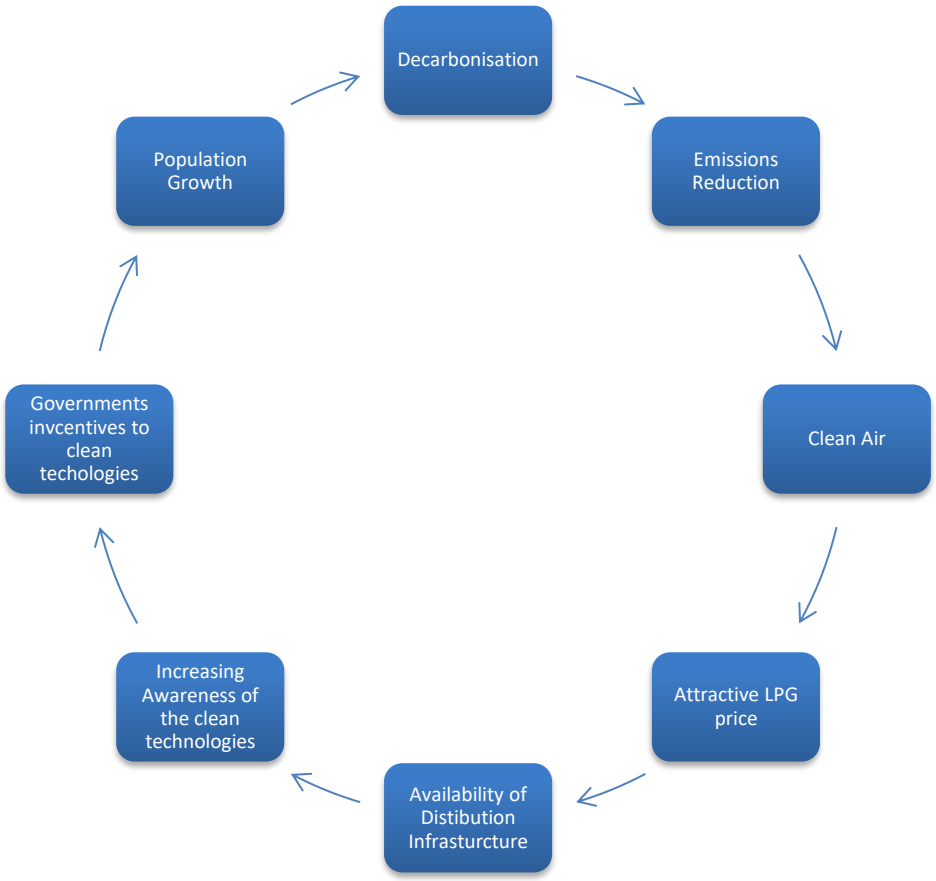
The Global agricultural machinery market, valued at USD 154.44 million in 2019, is estimated to grow at a CAGR of 8.0% until 2025.[1] Tractors accounted for over 50% of the market share in the global agricultural machinery market in 2019.

High demand for agricultural products in developing countries has driven the growth in agricultural machinery.

- The Asia -Pacific region is expected to grow rapidly over the forecast period due to the increase in the population in countries, particularly India and China, followed by Europe and North America.
- The market concentration for global agricultural machinery is consolidated with the presence of a few large players like, Deere & Company, Ltd., CNH Industrial N.V., Kubota and others dominating the market.
- Asia Pacific is the fastest growing and largest market.

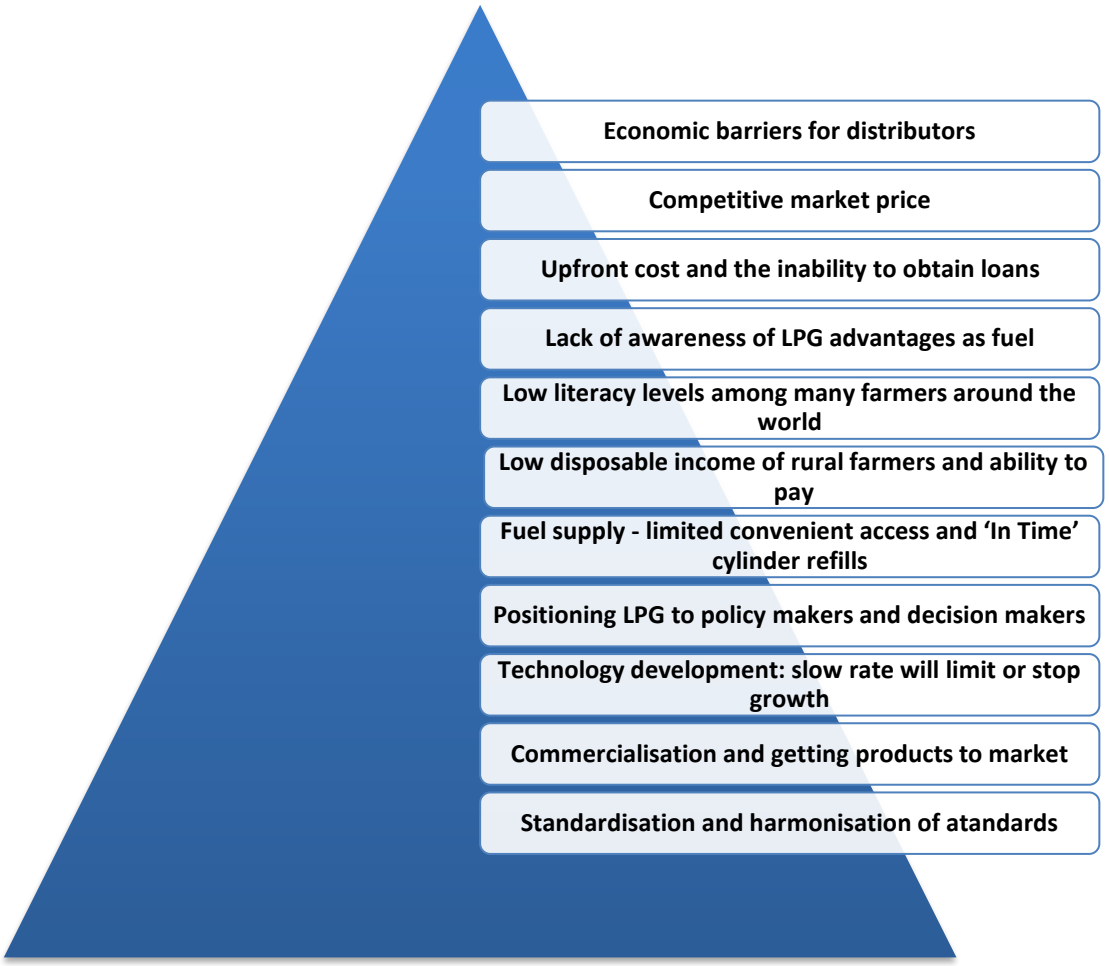
European OEMs are now at critical stages in product development in implementation for EU Stage V in 2020. Bringing their resources together with engine manufacturers and demonstrating their experience in bi-fuel solutions could lead their future vision.

**Drivers for Market Development**




[1] Grand View Research, Inc

**LPG as fuel faces several barriers which need to overcome to achieve greater global penetration**




Agricultural machinery will remain strongest in North America, mainly in the USA and is likely to emerge more slowly in other markets.

**Currently, the market for agricultural engines and machinery is highly variable depending on the application and the region**. LPG engines and equipment market are relatively well established in the USA. It is developing slowly elsewhere, most notably in Europe and Asia. The number of OEM quality platforms for agricultural applications is growing in the USA for companies looking to save money on fuel costs as well as make their operations more sustainable.

LPG is already ideally suited for field applications that require energy away from natural gas mains or electricity, where diesel and petrol are frequently used today. However, since LPG is a clean fuel, it can replace diesel and petrol in engine use, while generating a fraction of their emissions. In such applications, the LPG industry will have to justify a switch to LPG technologies based on cost, productivity, or environmental performance.

## 2.3. Key Messages - Recommendations

LPG can play a major role in this changing environment and re-establish itself in the position that it deserves as an ideal alternative clean fuel. However, the present trend is not in its favour. To reverse the trend and encourage growth in the LPG fuelled agricultural market and the applications that use them, significant step changes are needed.

**Sustainable economics for LPG companies**: It is critical to achieve acceptable economic returns in order to ensure sustainable supply in such markets.

**Competitive market price:** It is essential to have market related prices for LPG closely linked to the comparative efficiency, convenience, cleanliness and other benefits of LPG. These features and benefits need to be carefully and persistently explained to customers to build market share and customer loyalty.

**Customer, user economics and return on investment (ROI)** are probably the most important drivers from user's side. This is in terms of both up-front investment in new LPG machinery, and also running costs. Incentive schemes, financial packages and the lowering of engine costs by OEM integration of LPG options in original product designs will all contribute to lowering up-front investment. Efficient and reliable engines and competitive fuel pricing through LPG logistics and distributor schemes and government incentives, contribute to low running costs.

**Raising awareness of the existence of agricultural applications and their market potential is the first major challenge.** The way LPG agriculture engines and machinery are perceived by the market is critical to their success.

**All market players need to work together in a coordinated way to overcome the barriers and create opportunities in the agricultural sector.**

**Policy/regulatory framework** is key. It needs to be ensured that LPG fuelled engines in all their configurations, static or mobile, are included in regulatory framework and incentive schemes. Global standards and certification regulations for OEMs and retrofit technologies are also necessary to ensure safe and reliable LPG fuelled engines and compliance with emissions requirements.

**Technology development on LPG engines** has been progressing at a very slow rate. If this does not change rapidly, enormous opportunities will be lost and LPG may even disappear in some parts of the world as an agricultural engine fuel option. Investment in Research and Development (R&D) is needed and this is probably the most important enabler for the growth of the LPG agricultural engine market. As a large variety of applications may use the same type of engine, an intelligent grouping of applications and their potential per engine type will lead to prioritisation and focus.

OEMs with already available technology should be contacted by associations and major distributors for facilitation of the introduction of existing engines to other regions and countries, including homologation, certification, etc.

The LPG industry must embrace several challenges and opportunities to develop growth in agricultural markets and help farmers increase profitability. **LPG allows them to meet the challenge of staying competitive in the modern agricultural environment whilst maintaining a commitment to sustainable development. No other fuel offers a comparable combination of portability, accessibility and convenience of use.**

## Chapter Three

# Fact Sheet

This Fact Sheet provides an overview of the agricultural market, the major LPG applications in global regions and various market segments. It provides a snapshot of the main players in the global market as well specifies on the most important ones.

### 3.1. LPG - The Smart Alternative, Everywhere You Need It

LPG is a portable, clean and efficient energy source that is readily available to consumers around the world. LPG is primarily obtained from natural gas and oil production but is also produced increasingly from renewable sources. Its unique properties make it a versatile energy source which can be used in more than 1,000 different applications.

**Benefits of LPG**

**LPG offers significant benefits to both the end-user and society as a whole**

**Clean**

*Source: Liquid Gas Europe website*

LPG offers significant environmental advantages. It is characterised by low particle emissions, low NOx (nitrogen oxide) emissions and very low sulphur content, meaning that it does not pollute the air as much as many other energy sources. LPG can therefore contribute significantly to both indoor and outdoor air quality.

**Available**

*Source: Liquid Gas Europe website*

LPG is available right now in quantities that can meet the energy needs of millions of citizens across the world. Looking forward, LPG will remain in abundance globally for the foreseeable future. For many years to come, LPG is an energy source that society can depend on.

**Secure**

*Source: Liquid Gas Europe website*

Due to the dual origins and the fact that it is easily transportable, LPG offers a secure alternative to other energy sources that are part of a grid system. If one source of LPG is unavailable, then it is always possible to supply it from another one. Not only is LPG produced in Europe in large quantities, when it is imported, it arrives from the north, south, east and west.

**Lower Carbon**


*Source: Liquid Gas Europe website*

LPG is a low carbon alternative to conventional fossil fuels. Its combustion emits 33% less carbon-dioxide than coal and 15% less than heating oil. LPG also emits almost no black carbon, which scientists now believe is the second biggest contributor to climate change globally and is perhaps the single biggest cause of arctic warming.

LPG offers inherently high efficiency, an advantage that has been greatly enhanced by the emergence of performance-optimising technology such as condensing boilers and renewable/LPG hybrid systems. In view of the environmental, economic, and strategic benefits associated with a reduction in energy demand, a switch to LPG from other, less efficient alternatives is a smart move for individual end-users and European society as a whole.

## What is LPG Used For?

LPG can be used in several different sectors, such as domestic, commercial, industrial, agricultural and transportation. Wherever heat, light, or power is required, LPG can offer its benefits to both end-users and society as a whole.

## LPG is an important energy source for farmers

Farmers across the USA rely on LPG to keep them growing. No other fuel can offer a comparable combination of

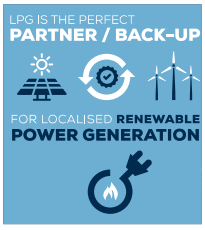
*Source: PERC*

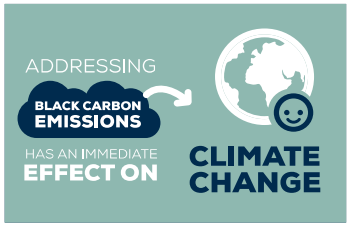
portability, accessibility and convenience of use. As a clean fuel, LPG allows farmers to meet the challenge of staying competitive in the modern agricultural environment, all while respecting the value of nature and maintaining a commitment to sustainable development. Whether used for livestock-rearing and crop-drying applications or simply for fuelling agricultural machinery, LPG is an essential tool for the contemporary farmer.

Whatever the application, LPG is an immediately available alternative, ready to power clean, modern and efficient agriculture all across the world. LPG is used to increase the production and quality of farm products through crop harvesting, crop drying, weed flaming and other uses.

## LPG is an exceptional energy

## The advantages of LPG in agriculture are numerous and significant





LPG use to replace traditional fuels reduces the emissions of several climate- active pollutants and protects forests by decreasing deforestation and if spilled, will not pollute the ground or aquifers.

LPG is an existing fuel in many agricultural operations and offers many benefits:

### Cost Savings

- LPG -powered vehicles and equipment deliver equal or superior performance at a reduced overall cost, cost of operation and maintenance requirements.
- New LPG easier and low emissions filling connection solution in the USA ("Euroconnector").
- LPG engines generally cost 20 - 40% less than diesel engines with comparable power.

### Incentives

- LPG farm incentive programmes in the USA could help with some of the initial cost of purchasing new agricultural equipment. Incentives are available for certain models of irrigation engines, grain dryers, propane generators, swine and greenhouse heaters, and even flame weed control units that are powered by LPG.
- LPG upgrades may also qualify for efficiency programs sponsored by the United States Department of Agriculture (USDA) through the USDA Rural Energy for America Program (REAP).

### Increased Productivity

- LPG offers the longest running range of any alternative fuel option. Due to a higher-octane rating and efficient combustion, LPG engines can use higher compression ratios, resulting in higher power and better fuel efficiency.

### New Business Opportunities

- LPG makes it easy to add extra irrigation or grain dryer whenever a farmer needs it or to relocate where it is most needed.

### Environmental Standards

- Emissions regulations are increasing requirements for more environmentally friendly agricultural machinery, creating new challenges for OEMs. Engines and machinery offering such sustainable technology will enable farmers to win contracts in environmentally sensitive locations with stricter standards.

- Farmers, mainly in the USA, are subject to tightening federal and state environmental regulations. LPG offers farmers a way to meet their energy needs without polluting the air, water, or soil. As farmers seek more environmentally friendly production methods, LPG is the clear choice. It enables farmers to achieve responsible results, that is, farming can be done **organically** and **efficiently.**

*Source: AVANTI GAS*

LPG provides a cleaner, greener and versatile energy source for farmers. Whatever the application, LPG is a viable alternative fuel ready to power modern agriculture all across the world.

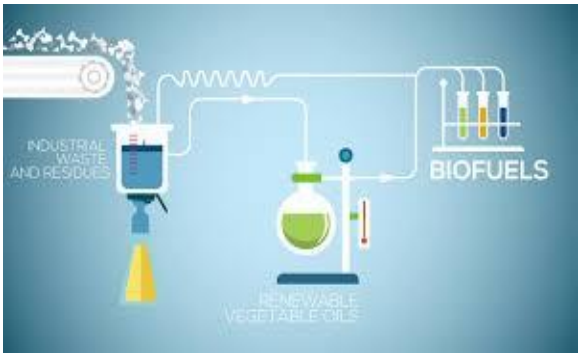
## 3.2. The Bio LPG - Renewable LPG from Biological Agricultural Substances

BioLPG, biopropane, renewable LPG (rLPG) and renewable propane (rpropane) are terms used to describe LPG which is derived from a diverse mix of biological feedstocks and processes. **With the same chemical composition as LPG, bioLPG brings even higher environmental benefits and** can deliver up to an 80% carbon emissions reduction and carries the same low NOx, SOx and PM as conventional LPG.

Produced from renewable sources, including biological oil, crops and fats, and the fermentation of glucose by microorganisms, bioLPG has an even lower carbon footprint than conventional LPG. This product is a potential game changer, showing the industry's investment in new products and its commitment to sustainability.

**rLPG is mostly a co-product in the production of renewable liquid fuels**

Internationally, bioLPG is seen as an eventual replacement of LPG from mineral sources. Already available on the market, is an affordable, convenient and non-intrusive 'drop-in' solution to decarbonisation for a variety of rural off-grid homes and businesses.



*Source: Calor Gas*

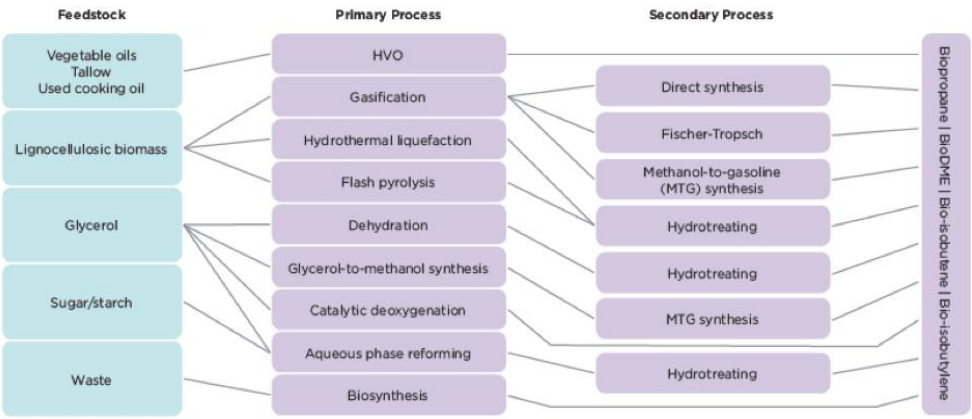
In countries where there is an extensive use of LPG in off grid applications and biogas is available, e.g. the United Kingdom, bioLPG is now being produced and replaces LPG.

There are a few different ways that bioLPG can be made using different types of technology and a variety of thermal or chemical processes. This means that bioLPG can be produced not just as a primary source, but also as a secondary one alongside other bioenergies. Thanks to this, a range of different ways of producing it are being explored and invested in.

**The different ways of making bioLPG**

**Advantages of bioLPG**

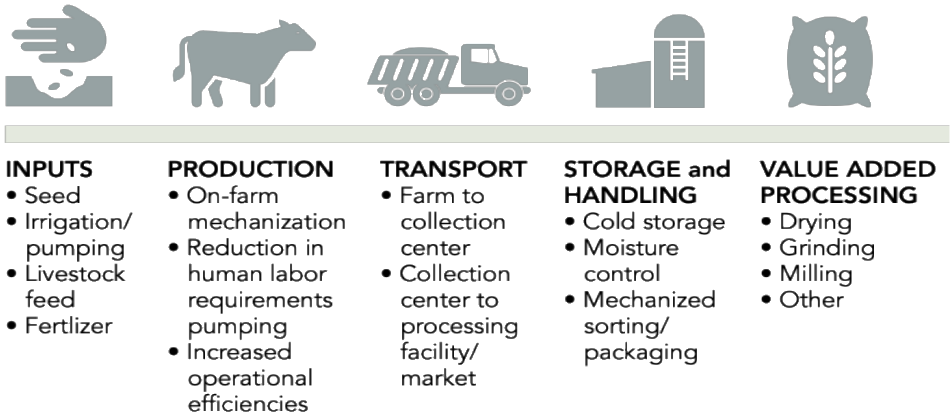
- The carbon footprint of bioLPG is small, with only 60 g CO2e/kWh.
- In addition, the combustion of bioLPG is identical to that of standard propane, which will result in good air quality, as it emits virtually no fine particles. BioLPG fumes will therefore not affect your operator.
- The properties of the LPG are preserved, which will thus make it possible to obtain the same output as that of conventional LPG.
- BioLPG can circulate through the same pipes and gas supply lines as propane, so no modifications are required. As for the storage of bioLPG cylinders, the rules remain the same.
- Maintenance and servicing will also be the same when you decide to work with bioLPG.



## 3.3. Agricultural and Farming Applications

LPG is entwined with most aspects of the agricultural sector. LPG is used to run farms and ranches; to operate trucks and other equipment; to pump water, run ventilation fans, and cool agricultural products; and to provide light for workers, greenhouses, and livestock.

**Opportunities for LPG technology throughout the agricultural value chain**




LPG is used to increase the production and quality of farm products through crop harvesting, crop drying, weed flaming and other uses as below.

Whether used for livestock-rearing, crop-drying, weed and animal waste disposal or simply fuelling agricultural machinery, LPG is the best fuel option for the contemporary farmer; clean combustion ensures crops, feeds and litter are not contaminated. The $CO_2$ by-product can be diverted and repurposed to increase yields in greenhouses, whilst the moist heat given out by LPG can help induce rapid, even feathering of poultry.
*Source: PERC*

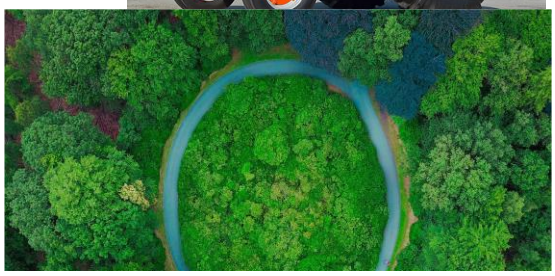
**Typical benefits of LPG in Agriculture**

- Constant temperature control for brooders.
- Flame weeding and pest control without chemicals.
- Handling and processing of meat and other food products.
- Drying products such as cotton, grains, milk products, nuts and tobacco.
- Space heating for poultry sheds, fish farms, greenhouses and nurseries Hot water for sanitation and other uses.
- Cost-effective power generators.
- As a diesel fuel substitute in machinery, to reduce costs and emissions.

### 3.3.1. Farming – Field Work

The World Bank has estimated that the demand for food will upsurge by 70% by 2050 and an $80 billion annual investment will be required to meet the objectives. Agricultural equipment production globally reached around 1.9 million units in 2016. This figure is expected to rise to around 2.2 million units by 2023.

Farm equipment covers an extensive range of equipment engaged in several stages of agriculture, such as land development, sowing, planting, cultivation, harvesting, and threshing. The range varies from the simplest machinery such as transporters, tillers to fertilisers, plows, harrows, fertilizer spreaders, seeder sand high-end engineered tractors.



Farming machinery is too numerous to be mentioned. As it is mentioned above, there are as many farm machines as there are farm tasks to be done. Each type of farm work has farm equipment used in doing it.

*Source: SHV ENERGY*

Here are some classifications of machines based on the type of farm work they are meant for:

*Source: Grimme Farming Equipment*

- Cultivators include power tillers, ploughs, drags, spikes, chisel ploughs, rockier pickers and others.
- Planters and trans planters used from crop planting.
- Irrigation machinery for watering the field.
- Harvesters which include thresher, combine machinery, conveyor belts, cotton pickers, corn, cane and bean harvester, gleaner, farm machines gravity wagons, swathers and diggers.
- Haying machines and loaders, which include rakers, balers, bale movers, mowers, backhoes and other transporting machines.

#### 3.3.1.1. Farming Tractors

Tractors are used intensively in farming to accomplish all of the field work on a farm, including tillage, secondary tillage, planting, mowing, hauling and transportation.

LPG agricultural tractors are not new to the market; the first ones were manufactured and sold in the USA in the late 1940's. However, even though new models with different characteristics had emerged over the course of several

decades, in the 1970's, diesel engines took over, and LPG was gradually phased out as a fuel for farm tractors. LPG fuelled tractors can change the perception of environmentally

responsible agriculture especially in organic farming. The development and adoption of heavy-duty LPG engines for these tractors could be for the farming industry a significant step forward towards more economical, more efficient, and more environmentally friendly operations.

## Advantages

- Quieter in use than diesel alternatives.
- Performance characteristics are usually superior to electric and other diesel alternative equivalents.
- Environmentally friendly, LPG has a smaller carbon footprint than diesel and petrol.
- Clean, LPG produces fewer engine deposits than petrol and diesel fuel, resulting in lower maintenance costs and extended engine life.
- Affordable and cost effective.

## Engines

**KUBOTA -WG3800-E4**

**DEUTZ G 2.2 and G 2.9**

**Yanmar 4TN88G Industrial LPG Engine**


DEUTZ has developed its G 2.2 and G 2.9 series, water-cooled 3- and 4-cylinder spark plug ignited LPG engines 35 – 73hp, for tractors that comply with EU level V.

INDUSTRIAL DUALFUEL ENGINE

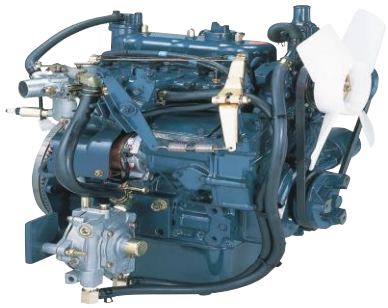
**KUBOTA WG SERIES (3-cylinder)**

# WG752-GL-E3

EPA Phase 3 | CARB Tier 3

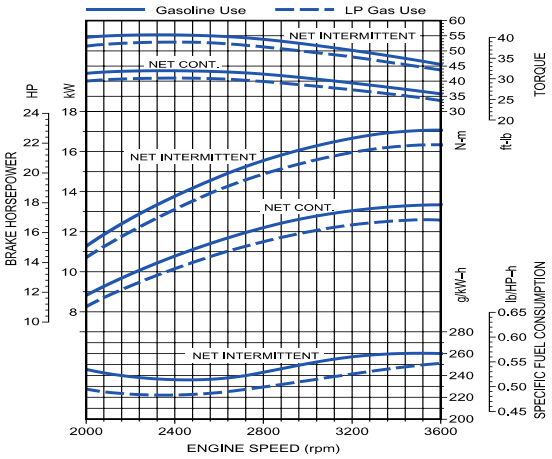
## RATED POWER

**18.3kW@3600rpm (GAS)**
**17.5kW@3600rpm (LPG)**



Photographs may show non-standard equipment.

## PERFORMANCE CURVE




## FEATURES and BENEFITS

### Emission

- Kubota's WG752-G/GL-E3 engine has been designed to comply with two of the strictest emission regulations: EPA Phase3 and CARB Tier3.

### Fuel Flexibility

- Installation compatibility between SI and CI engines is a good solution for customers who need fuel flexibility for their products. The Kubota WG Series has a gasoline version and a dual fuel (gasoline and LPG) version. Also available is a DG Series(*) natural gas version.

(*)The DG Series is compliant with the EPA Phase3 emission regulation only.

### Durability and Reliability

- Kubota's WG Series small SI engines are designed after the Kubota Super Mini Series diesel (CI) engines, which are known worldwide as reliable industrial engines. The new WG Series engines provide an easy transition from the previous Tier models by leaving the same footprint while still offering excellent performance.

### 3.3.1.2. Combine Harvester & Rice Transplanters

Combine harvesters and rice transplanters have helped the mechanisation of rice transplanting and harvesting.

*Source: Kubota*

They are used for simultaneous harvesting and threshing of crops such as rice, wheat and pulses.

### 3.3.1.3. Farm Work – Utility Vehicles

Utility vehicles, also known as cargo all-terrain vehicles (CATV), or simply, “utes,” are ideal for farmers, family farmers, ranchers and growers that suit them for the demands of agricultural work. The LPG option offers lower running costs, lower whole life costs and better cold weather performance than electric power. A utility vehicle is a vehicle, generally motorised, that is designed to carry out a specific task with more efficacy than a passenger vehicle. With diesel powered vehicles under scrutiny from environmental campaigners, the LPG fuel option for a utility vehicle will be welcomed by those who want to go ‘green’. LPG offers clean power without the downtime and cost associated with electric power and batteries.

**Example: EnviroGard – John Deere Gator**

EnviroGard in partnership with John Deere developed application specific kits to convert John Deere utility vehicles to LPG. EnviroGard LPG Conversion Kits help operators save on fuel costs, reduce fuel system maintenance, and lower emissions. Their patented technology provides an optimal balance of power, performance, and fuel economy. These use the SAM Safe Air Monitor, which is a safety device that many indoor applications are using to monitor carbon monoxide.

**Advantages**

- Reduces fuel costs by up to 30%.
- Significantly reduction in emissions.
- It reduces fuel system maintenance.
- Application specific design.
- Maintains EPA engine certification.


**Case Study: LPG Power for Kubota RTV500 Utility Vehicle**

Euromec has launched an LPG fuel option for the Kubota RTV500 utility vehicle. Under the front bonnet is a refillable LPG tank, plumbed and wired into the vehicle’s main systems. On the dashboard, controls tell the operator how much


fuel is available; the RTV can be switched to petrol if LPG is not available. Refilling the LPG tank is easy using the nozzle mounted just under the front bumper. Apart from using the refillable LPG tank, the RTV can also use LPG from a bottle. In the front right-hand corner of the load area, a simple bottle mount and fuel line make fitting and changing a gas bottle simple. The LPG option offers better running costs, whole life costs, and cold weather performance. It has the added benefit of 100% availability as it does not need recharging. Operators also benefit from the LPG choice; cab heaters are available and much more effective. More power means gritters, pressure washers and attachments work harder for longer.

#### 3.3.1.4. Loaders

Loaders are specialised machines that allow the operator to load and unload their products or goods. Often, the LPG powered skid steer loader is a modified version of the diesel-powered unit. The extreme flexibility of this machine allows it to be operated in almost any environment. This is especially useful in situations where low emissions are required but the remote location of the work area would prevent the use of an electrically powered equivalent. This self-sufficient loader has the ability to work without the need for an external power source.

**Example: AVANT 525 LPG Compact Loader**

The Avant 525LPG is equipped with a Kubota 23 hp LPG engine. Avant 525 LPG is ideal for indoor jobs where a compact yet powerful machine is required and where use of diesel or petrol engines is not possible.

Avant 525 LPG compared to diesel models:

- Less emissions with no particle matter pollutants.
- Quieter engine operation.

*Source: Avant Equipment*

#### *3.3.1.5.* Forklift Trucks[2]

LPG forklift trucks present an invaluable alternative to both diesel and electric counterbalance forklifts, and the low emissions from LPG, mean LPG forklift trucks can be used almost anywhere, most importantly in food and other hygiene-sensitive environments. LPG forklift trucks are also highly suited to working in remote locations. The portability of LPG allows them to be easily transportable, thereby making LPG forklift trucks the trucks of choice in remote places.
Refuelling of LPG forklift trucks has several advantages over other alternatives; replacing an empty LPG cylinder with a full one is a quick procedure, versus battery recharging or change-overs associated with electric trucks.


LPG forklift trucks are the preferred choice for various reasons, including, competitive pricing, environmental friendliness, suitability for inside or outside usage, and convenience for round-the-clock work.

**Features**

- Quieter in use than diesel alternatives.
- Produce significantly less air emissions than diesel powered forklifts.
- Exhaust catalytic converters work more efficiently on higher temperature LPG spark ignition engines, than on diesel compression ignition engines.
- Performance characteristics are usually superior to electric and diesel-powered equivalents.

[2] WLPGA report LPG for Forklift Trucks

- Travel speeds, rates of acceleration, and lift speeds usually outperform their electric/diesel rivals, because of better power to weight ratios and more responsive engines.


**Benefits**

- **Affordable and cost effective:** LPG forklifts are significantly less expensive than their diesel equivalents and the use of LPG as a fuel is often more economical. They require less maintenance as they have less carbon build-up than petrol and diesel engines. Spark plugs and engine oil last much longer, contributing to these engines lasting up to twice as long as petrol engines.
- **Effective:** LPG as a fuel source provides constant power to consistently lift, push and pull loads throughout the forklift's work shift. It allows for uneven surfaces and steep inclines to be tackled and also for operation times.
- **Fast**: LPG forklifts achieve higher acceleration and travel faster than their electric counterparts.
- **Strong and silent**: LPG forklifts are stronger than electric forklifts and significantly quieter than a diesel forklift.
- **Reliable**: They have the ability to push heavy loads at full capacity, faster, and for a longer amount of time than electric forklifts and maintain consistent, 100 % power throughout operation, with faster ground speeds than electric forklifts.
- **Quick to refuel**: It takes less time to fill an LPG tank than to switch or charge a battery. CNG powered trucks may take six hours to refill after as little as two hours of operation, and electric forklifts can take up to eight hours to recharge. It takes only five minutes to change an LPG cylinder or refill the tank.
- **Versatile:** Forklifts powered by LPG can be used in both indoor and outdoor applications, unlike their electric counterparts. They can even operate in temperatures as low as -20$^{o}$C.
- **Environmentally friendly**: LPG has a smaller carbon footprint than diesel and petrol, whilst it produces fewer PM10 particles (associated with respiratory problems) than diesel, and, if fitted with a 3-way catalyst, LPG forklifts are lead and soot free. LPG forklifts also transport their fuel in a sealed, pressure-tight system, eliminating a major source of secondary pollution found in petrol and diesel fuelled forklifts. Overall, LPG forklifts produce can produce up to 19% fewer emissions than petrol forklifts and 7% fewer emissions than diesel forklifts.
- **Clean**: LPG produces fewer engine deposits than petrol and diesel fuel, resulting in lower maintenance costs and extended engine life. Properly maintained LPG-powered forklifts emit far fewer carbon monoxide, nitrogen oxide, hydrocarbon, and particulate matter emissions than comparable petrol or diesel-powered forklifts. LPG-powered forklifts carry their fuel in a pressure-tight, sealed system that avoids any spillage or evaporation into the atmosphere, thus being suitable to be used in semi closed warehouses.
- **Safe**: LPG forklift tanks, fuel lines and carburetion components meet strict specifications. Built-in safety devices automatically shut off the flow of fuel in case of an accident. There is no risk of spillages or contamination with LPG as it vaporises.

**Main LPG forklift manufacturers**

| | | | | |
|---|---|---|---|---|
| BT | Hyundai | Mitsubishi Forklift Trucks | Bad Boy Mowers | Husqvarna |
| CAT | Hyster | Toyota Industrial Equipment | Bobcat Company | John Deere |
| Clark | Jungheinrich | UniCarriers | Dixie Chopper | & R Products |
| Crown | Komatsu | Utilev | Exmark | Scag |
| Doosan | LiuGong | Yale | Ferris Mowers | Toro |
| Hamech | Nissan Forklift | Kawasaki Motors | Gravely | |

### 3.3.1.6. Mini Transporters

The mini transporters are able to make precise movements on rough paths and transport cargo on difficult terrain with steep slopes. The platform has non-slip strips and front eye bolts to secure the cargo for ease of handling and loading.

### 3.3.1.7. Tillers

Properly preparing the soil with a tiller is a great way to start successful planting. There are LPG conversion kits for existing petrol or diesel units. These kits are user-friendly and easy to install.

**Example**

Greengear LPG Tiller offers ultimate manoeuvrability and balance with the power of a full-size model. Handlebar-mounted throttle control with durable cast aluminium gear driven transmission.

### 3.3.1.8. Weed Flamers

A variety of methods are available for the control of weeds by farmers. Amongst farmers, chemical spraying is common. However, chemicals can be expensive to use, difficult to apply in wet or windy weather, and very important, many pollute the water and the soil itself. Chemical spraying can also delay crop harvesting. Growers may also face herbicide restrictions because of environmental regulations or sensitive crops.

As we move into 2022, it has never been more important for society to work in ways that are not only efficient, but also sustainable. LPG promotes both of these to enhance all aspects of farming, creating greater production and better peace of mind, while at the same time reducing costs and emissions.

Furthermore, as interest in organic farming continues to increase, consumers have begun to demand organic foods from more sustainable production methods. Organic farmers, who cannot use conventional herbicides, often rank weeds as their number one challenge. Weed control alternatives are often time consuming and cost prohibitive for these farmers.

A common alternative to chemical spraying is mechanical cultivation, where repeated machine cultivation runs can temporarily control weed growth. However, this requires several runs in a season and promotes soil erosion, exacerbating other environmental problems. Frequent tillage also results in soil moisture loss, which is a critical issue for farmers who regularly have to deal with restrained water resources.

*Source : Calor* Gas

Increased legislation and consumer pressure are forcing growers to look for alternative methods to chemicals, many of which are now banned or severely restricted.

Flame weeding, burning of weeds (also flame cultivation) is the killing of weeds with intense heat produced by a fuel-burning device, LPG burners or torches either hand-held or tractor-mounted.

As LPG is nontoxic and does not contaminate ground water, it is an acceptable non-chemical weed control option in organic production. LPG weed flamers or torches negate, in an eco-friendly manner, the need to treat crops with acid. Flamers which use a concentrated flame to damage or kill weeds, have generally become a popular alternative to using chemicals for weed control, desiccation and as a soil hygiene tool. They enable growers to keep on top of weed pressure, reduce yield losses and save considerable weeding costs.

*source: PERC*

Recent advancements in LPG weed flamer technology have made the process easier and quicker than ever before. This adds an **effective and economical weed control** method to the organic farmer's toolbox.

An LPG weed flamer or torch, uses LPG-fuelled flames to transfer heat to weeds over a short exposure time. It uses different amounts of LPG and pressure to vary the heat created by its concentrated flame. The user sprays the flame near the weed leaves or stalks. The flame does not char the leaves, but instead quickly heats the water inside the plant cells. Because plant cells are filled mostly with water, the pressure from this quickly heating water causes the cells to burst.

Without a way to move water and nutrients from roots to leaves (disruption of photosynthesis), the weed dries out and wilts. This is usually accomplished in under two seconds, without injury to planted crops.

Future weed re-growth will also be stunted, but permanent elimination of the weed depends on the degree of damage inflicted in the initial spray, as well as the depth of the weed's root system. Some studies have shown weed flamers to be most successful with a repeat application. A repeated application when the new growth is approximately 1-two inches long and the root structure is still weakened will further weaken and eliminate the plant. Post emergence burning works very well in crops with energy stored in tubers or bulbs such as potatoes and onions.

LPG flaming can control several different weeds on a variety of crops, and it offers a time-saving, soil-friendly alternative that reduces moisture loss and can be repeated as needed during the growing season. It is highly effective on young, annual weeds. Perennial weeds with taproots or woody stems may require re-flaming or additional cultivation. Broadleaf weeds are more readily killed by flaming than grasses.

In highly intensive cropping systems, high levels of heat applied via LPG burners not only destroy post-harvest debris but also kill weeds and any fungal spores on or near the surface. This can help create a sterile seed bed and minimise the disease pressure on the following crop.

*Source: BPN Butane Propane*

**Features**

- LPG weed flamers are available in a range of sizes designed to suit different needs. Small hand-held or 'walk-behind' versions (handheld wands), powered by smaller LPG cylinders, are ideal for tackling troublesome, hard-to-access areas.
- Market-farming equipment options also include push-wheeled multiple-torch flamers mounted under a flame hood. These small-scale units are easy to operate and very convenient for flaming on farms with many small, sequential plantings of crops.
- For farmers and growers with large businesses and high acreage, tractor-drawn weed flamers enable maximum ground to be covered in minimum amount of time. This highly efficient method features a mobile LPG tank strapped to the tractor, allowing a large area to be treated in one go without the need for refills. These kits are available in multiple-row models, with or without a flame hood; other options include a complete toolbar setup with accompanying cultivator attachments for between-row mechanical cultivation.
- Recent technological advancements have also seen the development of hooded weed flamers. These consist of regular LPG flamers but with torch hoods that better focus the flames, protecting them from the elements and enabling them to kill weeds more effectively and while reducing fuel consumption. A split-hood configuration allows more mature crops to flow through the machine undamaged, while an adjustable torch mount enables a wider range of treatment capabilities.

**Advantages**

Organic growers are excited about flaming because, in many cases, it works as well as herbicides because it can be done when fields are too wet to cultivate and does not bring dormant weed seeds to the surface.

- Flaming is faster than tilling and significantly less expensive than both hand weeding and organic herbicides.
- It more than doubles the level of weed control obtained when weeds cannot become resistant to flame, as they can to some herbicides.
- It does not damage the soil or cause erosion as other alternative weed control methods can.
- Stale seed bed management (encouraging weeds to grow, then burning them before sowing the crop) and pre-emergence weed control (sowing the crop but burning weeds before the crop emerges) can reduce overall weeding costs by up to 75%.
- It allows farmers to return to the field immediately after treatment, in contrast to herbicide application. There is no lost productivity due to delayed chemical application.
- Farmers will only use about 5-15 gallons of LPG per acre, depending on the desired extent of weed control.

- It preserves soil and water quality, prevents soil erosion, and conserves water.
- LPG as a fuel provides a cleaner, more controllable power.
- LPG burns cleanly with no harmful residues left on the crops.
- Flame weeding does not pose safety risks to people in the surrounding area because it avoids the drift hazards associated with chemical treatments. It can be used close to areas used by the public as well as near livestock and fauna.
- It eliminates worries about handling and storing chemicals as well as their propensity to leach into waterways. They can be used near water courses.
- Its use is not dependent on wind and rain. They operate in all weather conditions.

#### 3.3.1.9. Irrigation Systems

Irrigation is an energy-intensive farming operation. LPG-powered irrigation engines are becoming more efficient all the

*Source: PERC*

time and when compared with diesel or gasoline can, this can provide farmers with an immediate savings in fuel costs. Advanced LPG-fuelled stationary irrigation engines offer increased efficiency and reliability with reduced maintenance requirements.

Portable LPG engines are a convenient and economical way to drive irrigation pumps. These engines can also be disconnected from the pumps and used for other power needs, such as generating electricity, powering mechanical grinding mills, and driving various types of manufacturing equipment.

**Advantages**

- LPG usage frees farmers from the task of transporting the fuel while eliminating diesel thievery in isolated locations.
- LPG-powered irrigation engines produce up to 18 percent fewer greenhouse gas emissions than petrol and diesel alternatives.[3]
- It reduces maintenance costs by decreasing deposits on engine components and thus extending engine life, fewer oil and filter changes.
- It ensures reliable irrigation without grid-related power interruptions.
- There is no risk of spillage or groundwater contamination.
- Quieter running.
- Farmers who switched to new LPG irrigation engines reduced their fuel consumption per hour

[3] Gas Technology Institute

- by 43% and reduced overall fuel costs per hour by 75%.[4]
- EPA and CARB certified. Farmers who switched to new LPG irrigation engines in the USA saw overall reductions of the order of 40% in fuel consumption, 75% in fuel costs and 48% in maintenance costs.

**PSI engine on the Irriland irrigation**

PSI engines are commercialised and homologated for Europe.

**Manufacturers**

More than 15 LPG-powered irrigation engines are now available in the USA from 1.5 lt to 21.9 lt.

| | | |
|---|---|---|
| Anderson Industrial Engines | Gas Equipment Company | Power Solutions Inc. (PSI) |
| Bell Power Systems | Graham Ford, Inc. | Powertech Engines Inc. |
| Buck's Engines | Husker Power Products | Southwest Products |
| CK Power | Industrial Irrigation | SRC Power Systems |
| Don Hardy Engines | KEM Equipment | Tradewinds Power Corp |
| E.C. Power Systems | Kubota Engine | Western Power Products |
| Engine Distributors Inc. (EDI) | Northern Power Products, Inc. | Weichai America |
| Engine Power Wisconsin | Origin Engines | Zenith Power Products |
| Flint Power | Pivot Power | Power Solutions Inc. (PSI) |

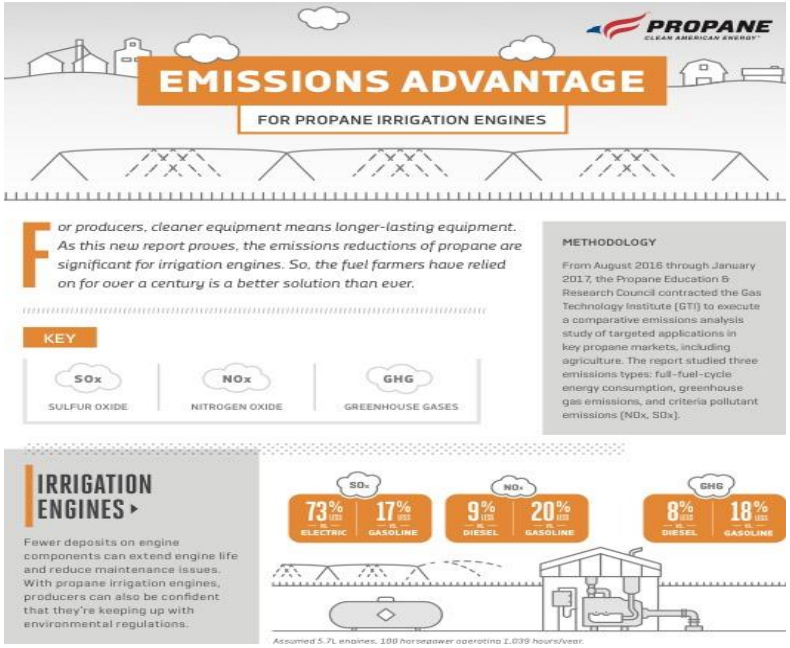
**Case study – Comparative Emissions[5]**

The case study studied three emission types: full-fuel-cycle energy consumption, greenhouse gas emissions, and criteria pollutant emissions (NOx and SOx). According to the study, the emissions reductions of LPG are significant for irrigation engines. So, the fuel that farmers have relied on for over a century is a better solution than ever.

Fewer deposits on engine components can extend engine life and reduce maintenance issues. With LPG irrigation engines, producers can also be confident that they're keeping up with environmental regulations.

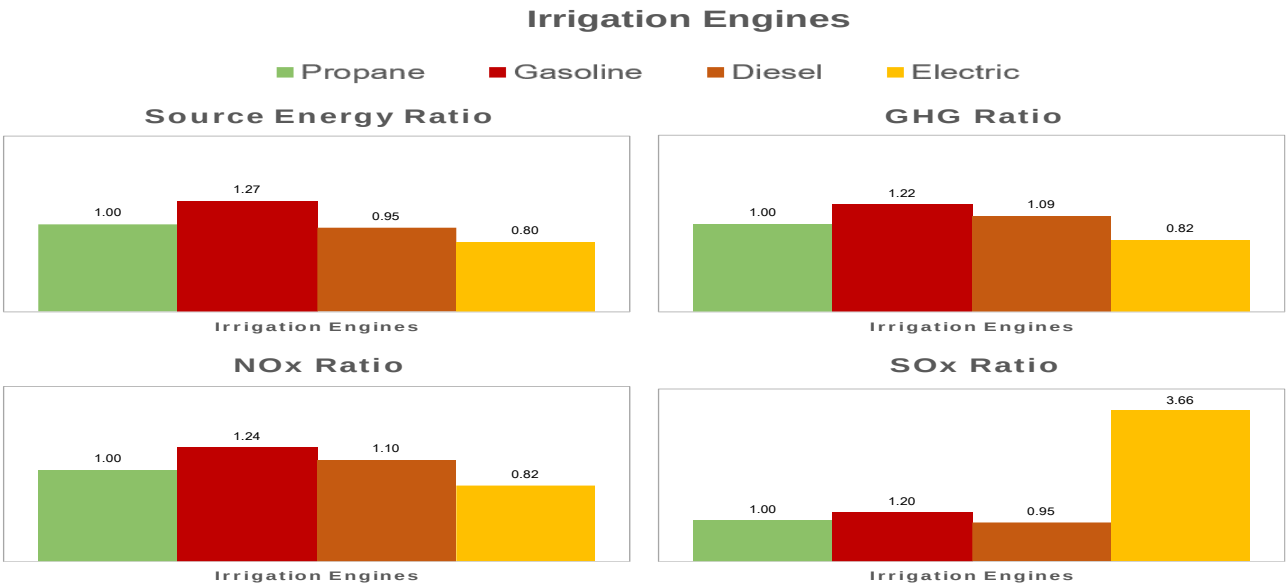
[4] PERC
[5] Conducted by Gas Technology Institute (GTI) for PERC[5]

- **Sulphur Oxide** (SOx)
  73% less vs. electric
  17% less vs. petrol
- **Nitrogen Oxide** (NOx)
  9% less vs. diesel
  20% less vs. petrol
- **Greenhouse Gas Emissions** (GHG)
  8% less vs. diesel
  18% less vs. petrol



| Irrigation Engines | Annual Fuel Use (gge) | Site Energy Use MMBtu | Source Energy Use MMbtu | Source Energy Ratio | Total CO2e (kg) | GHG Ratio | NOx Ratio | SOx Ratio |
|---|---|---|---|---|---|---|---|---|
| Propane | 8,811 | 989 | 1,137 | 1.00 | 67,005 | 1.00 | 1.00 | 1.00 |
| Gasoline | 9,195 | 1,032 | 1,439 | 1.27 | 81,626 | 1.22 | 1.24 | 1.20 |
| Diesel | 8,130 | 912 | 1,085 | 0.95 | 72,723 | 1.09 | 1.10 | 0.95 |
| Electric | 2,676 | 300 | 910 | 0.80 | 54,743 | 0.82 | 0.82 | 3.66 |

**Notes:**
1. Irrigation engines 5.7L displacement, 100 hp, operate fully loaded 1039 hrs/yr (Propane's Advantage 2009)
2. Irrigation relative fuel consumption based on University of Florida performance standards
3. Electric GHG emission factors from SEEAT, other fuels based on EPA NonRoad Vehicles. NOx and SOx emission factors based on SEEAT

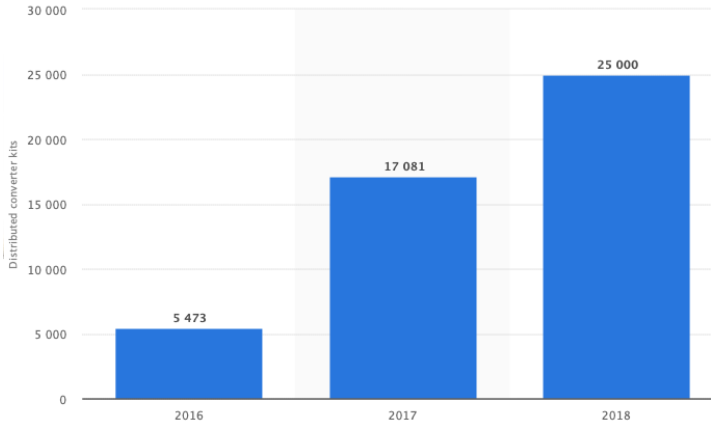



### 3.3.1.10. Small Scale Fishers

LPG is a very attractive fuel in the fishing sector. Its undeniable environmental benefits make it an ideal fuel for use in environmentally protected areas, lakes and rivers but also largely in fishing fleets where water contamination from the marine fuel can have severe adverse effects. The use of LPG as an engine fuel is particularly popular in boats operating in salmon fishing farms. Besides its environmental benefits, in many countries, the use of LPG in the marine segment provides significant cost- saving opportunities for fleets and other boat operators.

**Indonesia distributed LPG conversion kit for small scale fishers**

In 2018, the Ministry of Energy and Mineral Resources in Indonesia distributed 25 thousand units of LPG conversion kits to small-scale fishers all over Indonesia as a part of the governmental program for the conversion of petrol to Gas in the Transportation Sector (Program Konversi BBM ke BBG).




Distribution of starter kits for the Conversion to LPG for Target Fishermen of 2020 Programme was carried out in October 2020. In the Coordination Meeting about the Plan to Distribute LPG Conversion Packages for Target Fishermen of 2020 held in Yogyakarta on Friday 2nd October, the Senior Expert for Litigation and Security of National Vital Objects of Ministry of Energy and Mineral Resources. At the Conversion to LPG for Fishermen is a mandate of Presidential Regulation No. 38 of 2019 on Provision, Distribution, and Pricing of LPG (Liquefied Petroleum Gas) of 3 kg Cylinders for Fishing Vessels of Target Fishermen and Water Pumps of Target Farmers.

There are key benefits of LPG conversion that fishermen should know.

- **Competitive Price**. Using LPG as fuel reduces operation costs by 30-50% compared to using oil fuel (solar diesel). Savings can reach as high as 80% at several locations.
- **Easier maintenance.** The distributed packages contain several components, including engine, converter kit, long axel, propeller, two LPG cylinders containing three kg of gas each, and other supporting accessories (reducer, regulator, mixer, etc.). Simple assembly and a cleaner fuel make maintenance easier and the machine serviceable compared to using oil fuels.
- **A safe energy alternative.** The gas is compressed and stored in a highly-pressurised tank with a shutoff valve, so it is a safe alternative for both users and boats.
- **Lower emissions**. LPG has cleaner combustion than oil fuels because its carbon chain is shorter than oil fuels. Due to the short carbon chain, LPG has a high-octane number, and as a result, emits less $CO_2$ gas than oil fuels.
- **Support the fishing economy.** This assistance is given to small-scale fishermen who own a fisherman's ID card, use environmentally friendly fishing gear, have a fishing boat measuring less than five gross tons with a machine output of less than 13 Horsepower (HP), and those who have never received similar assistance from either the national government or the regional governments

*Source : Ministry of energy and mineral resources republic of Indonesia.*

### 3.3.2. Crop Farming - Crop Protection

In horticultural markets, the particular advantages of using LPG in conjunction with well-engineered equipment are of paramount importance. Burning LPG produces a highly controlable humid heat with no harmful by-products. This is used to maintain temperature controls during the cold months and eliminate the risk of frost damage to plants and flowers.

#### 3.3.2.1. Greenhouses

Greenhouses are buildings or structures where plants are grown and they range in size from small sheds to industrial-sized buildings. They are another area in agriculture where LPG provides vital solutions.

The most notable application is in space heating, where LPG greenhouse heaters provide the necessary heat and humidity that aid crop development and also prevent crop damage during the winter months. The growth processes of many fruits and vegetables in glasshouses and polytunnels can be improved by using LPG. In addition to being flexible and highly controllable, LPG powered systems can, in fact, provide the added advantage of releasing CO2 as a by-product. The correct balance of CO2 is the key ingredient to a successful horticultural crop.

Greenhouse heaters are heating appliances tailored for use in a greenhouse environment. Almost all greenhouse gas heaters run on LPG which has always been the most popular choice for heating requirements. These heaters are ideal for protecting plants all year round, particularly during cold winter spells and are even beneficial during poor summers to ripening fruits.

Designed for safe and efficient operation, the gas greenhouse heater will provide a desired amount of heat in all greenhouse environments.

**Features**

The majority of gas greenhouse heaters come in high-quality, robust, stainless-steel casings to ensure their status as long-term investments. They are also available in various coloured finishes, including green, which will blend with greenhouse environments. The gas greenhouse heater is made to the highest of safety standards, with safety cut-off features and a flame failure device, a major benefit for this type of heater to ensure they burn safely.

They are convector heaters, meaning that they work efficiently by collecting the coolest air, heating it and expelling it at high speed. LPG greenhouse heaters are designed to give a moderate increase in temperature to a large volume of air rather than a higher increase to small quantities.

They are fitted with thermostats to enable temperature control, push button ignition and flame failure devices. Most of these models are manually ignited, and then switched off by turning the valve on the gas bottle. Greenhouse gas heaters are available in various sizes to suit all domestic greenhouses, and can even extend their use to conservatories, providing heat where there may not be a central heating system. Given the powerful heat that these appliances produce, they can also be used in larger commercial greenhouses.

**Advantages**

The LPG greenhouse heaters burn safely, and are more economical to run than other gas alternatives such as paraffin. These heaters provide further economic benefits when they are incorporated with thermostats, which detect the ambient temperature. The heater is automatically switched off when it has reached the desired temperature, and then switched on again when the temperature has fallen. The thermostat will operate more accurately if the heater is raised off the floor of the greenhouse, as this will reduce the effect of the cold from the floor.

**$CO_2$ generation for plant growth enhancement**

An added advantage is the production of $CO_2$ which can be repurposed to stimulate photosynthetic processes for the housed crops. The enrichment of greenhouse atmospheres with carbon dioxide, is based on the fact that $CO_2$ is the raw material for the photosynthesis process, i.e., the formation by plants of starch and cellulose from water and $CO_2$ in the presence of chemically active radiation. Since optimum $CO_2$ content for growth is about 0.2%, whereas atmospheric air contains only 0.03% $CO_2$ enrichment is often desirable.

While it is generally possible to increase yield and quality and reduce the maturing time of greenhouse crops by enriching the atmosphere, other influences have to be taken into account and careful control over temperature, moisture, light and impurities introduced by carbon dioxide is essential. In particular, the presence of sulphur in a fuel used to generate $CO_2$ is undesirable and generators using non-gaseous fuels must be fitted with a sulphur absorption device.

Furthermore, since each species of plant has an optimum growth temperature, that may vary over the course of its development, the heat produced in $CO_2$ generation must only be used to raise greenhouse temperature to the optimum and not beyond. Complete combustion must be ensured since carbon monoxide, ethylene, formaldehyde and the other partial oxidation products are known to cause damage to greenhouse crops. Improved crop yields ascribed to $CO_2$ enrichment have been reported for a wide range of plants, including tomatoes, cucumbers, lettuce, carnations, fir saplings, carrots and many others.

#### 3.3.2.2. Snow Blowers

An LPG snow blower is a machine for removing snow from an area where it is not wanted, such as a driveway, or pavement.

Snow blowers range from the very small, capable of removing only a few inches (a few more cm) of light snow in an 18 to 20 in (457 to 508 mm) path, to the very large, mounted onto heavy-duty winter service vehicles and capable of moving 20-foot (6.10 m) wide, or wider, swaths of heavy snow up to 6 feet (1.83 m) deep. Snow blowers can generally be divided into two classes: single-stage and two-stage. On a single-stage snow blower, the auger pulls snow into the machine and directs it out of a discharge chute. On a two-stage snow blower, the auger pulls snow into the machine and feeds it into a high-speed impeller, which in turn directs it out of a discharge chute.

**Greengear LPG-Outdoor-Powered-Equipment-Snow-Blower-ASPNR 7.0E**

The ASPNR 13.0E LPG self-propelled snow blower is equipped with a 4-stroke engine that produces 13 HP. It features traction wheels, a working light, lower slides that are adjustable, manual and electric start, icebreaker blades and snow chains. The turbine is two-stage with control of the direction of the jet of snow.

#### 3.3.2.3. LPG Torch for Melting and Snow

LPG Torches is also useful application during heavy winter periods, which is ice and snow melting. This equipment is mostly found as single torch units, but there can also be models available that feature multiple torches, with more than one fire nozzle.

**Features**

The LPG Torch consists of a hose/inlet connection, a heating nozzle unit with protective cover, a pilot lever, a flame adjustment valve and a standard LPG cylinder and regulator.

**Advantages**

- Requires only LPG, no oxygen is required.
- Portable and economical to run.
- Robust construction, safe, efficient and easy to use.
- Uses any standard LPG cylinder and LPG regulator, typically used on standard LPG equipment.

### 3.3.2.4. Log Splitter

The Greengear GLSPCLG81 is a log splitter with a 4-stroke AXO 210 engine powered by LPG. The engine's power is 4.8 kW with a thrust power equal to 8 tons. It has a control blade lowering which activates only when both levers are tightened on the truck, for optimum safety. Displacement in 208 cc and can displace petrol or diesel fuelled engines in rural areas where Log splitters are usually used.


### 3.3.2.5. Cold Storage of Fruit in Nitrogen

An interesting use of LPG in horticulture is the cold storage of fruit under a protective atmosphere consisting essentially of nitrogen. To prevent decay of stored fruit at what would otherwise be an optimum temperature (0-5), it is necessary to reduce the oxygen content of storage space between by 2 and 4%. This is done by burning LPG in a 'generator' located externally to the storage area. The products of combustion are carbon dioxide, nitrogen and some excess oxygen. These gases are piped through an absorber-cooler containing lime, in which the atmospheric temperature is reduced, and the carbon dioxide removed, leaving only the nitrogen which is then led into the cold storage room. The optimum gas composition is maintained by burning more LPG and recirculating the atmosphere through the scrubber. Apples in particular are responsive to this sort of treatment and commercially made gas generators have been used for cold stores holding up to one million bushels (36,000m$^3$).

### 3.3.2.6. Frost Protection (variety of crops including grapevines, deciduous trees and citrus)

Each year millions of acres of fruit orchards, vineyards and other crop fields risk being subjected to freezing temperatures and it is approximately 5-15% of the world's crops are damaged by cold temperatures.

This has emphasised the need for farmers to engage in activities to mitigate the effects of subzero temperatures. These frost/freeze protection methods are based on preventing or replacing radiant heat loss.

The investment in some form of frost protection or combination of systems may mean the difference between a zero and total crop loss. Heating is a method for frost protection that has been relied upon for centuries. LPG is an exceptional energy source for heaters because of its portability and its ability to provide powerful heat with a smaller environmental footprint.

**Orchard and Vineyards Heaters**

Orchard heaters are commonly used in various areas of the world to prevent frost damage to fruit and fruit trees.

There are several advantages to using heaters that alternatives do not provide. Most heaters are designed to burn fuel and can be placed as free-standing units or connected by a pipeline network throughout the crop area. Experience has however shown that a large number of small fires burning throughout the orchard provides better protection than a few large fires concentrated in spots.

Traditional heaters have been found to be less user-friendly and can lose up to 85% of the heat produced due to radiation into the earth and sky (known as the "stack effect").

LPG's high heat content, combined with the unique designs of modern heaters, ensures that a greater percentage of heat radiates directly into the crops, thus increasing the efficiency of crop protection.

**Features of heaters**

Heaters provide frost protection by direct radiation to the plants around them and by causing convective mixing of air within the inversion layer.

Protecting with heaters is technically dependable and growers preferred heaters until pollution problems and high costs of fuel relative to the crop value made the method too expensive for many crops. Now heaters are mainly used to supplement other methods during extreme frost events and for high-value crops.

Most of the energy from heaters is released as hot gases and heated air that mainly warm the ambient air by convection. Radiant energy from the heaters
travels directly to nearby plants that are in direct line-of-sight of the heaters.

There are three types of heaters suitable for use in horticulture.

- Direct fired heaters provide economical and efficient frost protection during the cold months, but can also supply fresh unheated air for summertime ventilation.

- Indirect fired and unit cabinet heaters are capable of increasing the heat by 10-15° without damaging crops.
- Radiant energy is more efficient than heated air, and the radiation emanates best from a hot, solid surface (e.g., a steel smokestack of a heater). Radiant heaters directly warm a precise location by radiating infrared heat. No heat is wasted nor do they circulate dust, so they are ideal when a clean atmosphere is required. A portion of the

combustion is converted to sensible heat as heated air and gases from the flame. As this heated air rises and mixes within the inversion, it can warm the leaves, fruit, and branches.

All of these heating systems are compatible with LPG, which means the farmer gets a reliable, clean burning energy supply.

### Advantages

- LPG provides a clean-burning and efficient option for orchard heating compared to diesel-fuelled heaters. In contrast to diesel spills that pose a significant risk to surrounding orchard trees by contaminating water and soil, LPG vaporises into the air and is nontoxic and insoluble in water, eliminating any risk of soil or water contamination.

LPG-fuelled heaters also offer major operational benefits over diesel-fuelled heaters:

- **Ease of use:** LPG flow rates are controlled by a single pressure regulator.
- **Reduced ignition time:** In standardised tests commissioned by the PERC, it was discovered that LPG burners required one hour to ignite compared to two hours for diesel burners, which must have their air-vents adjusted by hand to achieve the proper setting.
- **Reduced shut-off time:** Closing the valves to the sub-main supply lines for the LPG burners only took five minutes, while diesel burners required one hour.
- Networks of connected heaters have the advantage of the ability to control the rate of burning and shut all heaters down from a central pumping station simply by adjusting the pump pressure.

### AgHeat LPG heater

Models like the AgHeat LPG heater possesses a pyramid shape that allows more heat to be directed to the air surrounding the crop than vertical pipe designs.



### Wind Machines

A less well known but very cost- effective method for frost protection is the use of wind machines. These work with nature to pull warmer air down into the orchard or growing field to raise temperatures and save crops. These machines are available in models that consist of LPG powered engines.

Wind machines are one of the most cost-effective methods for frost protection under radiation freeze conditions.
The principle underlying their value is that during the day, the sun warms the soil and plants and then at night, this lighter warm air rises, leaving a colder mass of air near the earth's surface. This higher, warmer air is called a temperature inversion.

Wind machines capitalise on the inversion development in a radiation frost and work with nature to pull the warmer air down into the orchard or growing field to raise temperatures and save crops. The effect is essentially that of a large fan which mixes the air within and above the orchard so that the average air temperature near the ground is raised.

The wind machines are used on a wide variety of crops including grapevines, deciduous trees and citrus.

Growers typically install wind machines when trees are seven to eight years old, and can use them for over 30 years.

**Features**

Wind machines generally consist of a steel tower with a large rotating fan near the top. There is usually a two- or four-blade fan with a diameter typically varying from 3 to 6 m. The typical height for fans is about 10-11 m above ground level. However, lower heights are used for lower canopies. Power to operate the fan usually comes from an engine mounted at the base of the tower. The principle of the system is to move heavy cold air to prevent stratification, and allow the warmer inversion layer air to replace the colder air near the ground. To be most effective, wind machines should be started before the temperature drops below freezing. Depending upon the field layout and contour, a single large tower machine will effectively protect up to about ten acres with a 10$^{o}$ degree temperature inversion differential at 50 feet. As the inversion strength (differential) weakens, the area of protection becomes less.

There are three types of wind machines available on the market:

- **Tower machines** are the most common type. With a blade that is positioned at a slight tilt from perpendicular to the ground, they are designed to draw warm air from above down and mix it with the colder air at the surface as the head rotates around the tower.
- **Tower-less machines** that are designed to blow the cold air near the ground upward to mixing it with the warmer air above and circulating it back.
- **Ground-level mobile machines** (frost fans) that blow cold air out of the site and permit warmer air from above to replace it can be effective, depending on the strength of the inversion and contour of the site. These units are positioned near the highest point on a site in a natural air drainage pathway to improve the cold air flow.

An effectively installed wind machine can even provide sufficient frost protection when used in conjunction with uniformly scattered orchard heaters.

The combination provides adequate protection for even the coldest locations. The wind machine will protect the grove for some of the nights by itself, but for the very cold nights, the heaters are available to add heat and thus provide positive protection. Usually, the heaters are lit whenever the wind machines cannot maintain the temperatures above the danger point. This combination method has the advantage over heaters used alone, in that it is cheaper, while providing complete protection. When these two methods are combined, the required number of heaters per acre is reduced by about half

**Advantages**

- More economical than orchard heaters. Wind machines use only about 5% to 10% of the energy per hour required by heaters.
- Adequate protection against local radiation frosts when temperatures go only two or three degrees below the damaging point.
- Useful in increasing air movement in groves where dead air occurs.
- Increased effectiveness of heaters.

#### 3.3.2.7. LPG Refrigeration System for Tulips

Hanenburg-Hettinga is a leading agricultural company with a main focus on tulip growing. As expansion of the site was needed, the family owned business reviewed how to do this in the most environmentally friendly way.
*Source: Geerlofs*

Geerlofs installed a refrigeration system with LPG. The refrigeration system was indirect, meaning the use of LPG was limited to the machine room and in the building water and glycol was used as a means to bring the cold to the stores. Both the compressors as well as the fluid pumps were equipped with frequency-controlled motors to enable variable speed drive. The system is future proof, already taking into account a possible extension with two additional cold stores later. The system has taken into to using a climate computer during the summer months.

#### 3.3.2.8. Soil Steam

**Replacing pesticides with steam and increasing harvests**

**Case study – Soil Steam International**

Soil Steam has created the world's first device for killing weeds with steam. It lets farmers improve harvests and storage time by using fewer pesticides and fertilisers. Industrial farming across the world uses large amounts of pesticides to stay productive and avoid food waste. However, pesticides also carry great health and environmental risks, which organisations such as the OECD and the EU work to reduce.

This trade-off between risk and reward for pesticides and productive agriculture creates huge challenges for farmers and communities.

**Efficient operation**

Soil Steam International has developed a patented technology that makes it possible to steam soil in open fields. The method kills 95% of all fungi, weeds, seeds and nematodes in the soil, without the need for pesticides.

Soil Steam International is the first company in the world to operationalise the technology for efficient use down to soil depths of **30 cm**. **A single treatment is effective enough to last for up to five years.** The company's machines can cover between 600 and 1 500 square metres of farmland per hour, depending on the temperature and moisture of the soil.

**Soil Steaming reduces food waste**

The use of pesticides must be reduced. At the same time, farmers must continue to produce food in a sustainable manner. Soil steam is very effective in fighting all weeds, seeds, fungi and nematodes in the soil. The vegetables get less competition for nutrition, water and sunlight, and a 50% larger crop. Many vegetables can also be stored for much longer. This means that more and healthier food, can be produced at a lower cost and food waste is reduced.

*Source: Calor Gas*

*Source: Soil steam international*

Steaming of the soil gives up to 50% more growth, and some vegetables can be stored for up to six months longer. This means more food per m2 and less food waste.

## Advantages

- Killing weeds with steam not only reduces the need for pesticides.
- It also reduces the need for fertilisers, since crops absorb much higher levels of nutrients from the soil once weeds are removed.
- Soil steaming is increasing storage time for many vegetables. The steaming process kills fungi in the soil – a major reason for vegetables rotting in stock.
- Soil steaming can increase harvests by up to 40%.
- The treatment is particularly effective for berries, fruit, vegetables and flowers.

The technology has been tested by experts in both Norway and Germany and the reports show that 95-100% of all weeds, seeds, fungus and harmful pathogens are killed.

- Both pictures here are taken during summer 2018. Chinese cabbage is shown to the left and carrots to the right.

- On the picture with Chinese cabbage the line between steamed and not steamed soil is seen. Cabbage is on both sides of the pictures, but you on the right-hand side are not seen because of all the weed in the not steamed area. It is covered with weed.
- To the right, a carrot field is seen which has been steamed. There is no weed there, and there not used any chemicals.
- The cabbage farmer got 15% bigger harvest on the steamed soil, while the carrot farmer got a 40% bigger harvest.

## A carrot farmer increases income by 55%

- Normal harvest 70 tons per hectare, new harvest minimum 100 tons per hectare.
- When killing fungus in the soil with steam we increase storage time by 100%, and reduces waste by 60%.
- Farmers get paid for 88 tons instead of 49 tons (55% more) after waste. Soil steaming is profitable year one, and lasts for five years.

## Business case - Value Proposition

| COST AND EFFECT | | | | | | | |
|---|---|---|---|---|---|---|---|
| WAYS OF GROWING | METHOD | COST/HECTARE | WEED | WEED SEEDS | SOILBORN FUNGUS | NEMATODES | AIRBORNE FUNGUS |
| TRADITIONAL FARMING | CHEMICALS | CA EUR 2 K | OK | - | - | - | OK |
| USA FUMIGATION* | CHEMICAL GAS | CA EUR 10 K | OK | - | OK | OK | - |
| ECOLOGIC FARMING | MANUAL WORK | CA EUR 10 K | OK | - | - | - | - |
| SOIL STEAMING | CLEAN STEAM | CA EUR 6 K | OK | OK | OK | OK | - |

| ENVIORMENTAL IMPACT | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| WAYS OF GROWING | | | | CHEMICALS IN FOOD | SOIL | WATER | AIR | HARVEST |
| TRADITIONAL FARMING | CHEMICALS | CA EUR 2 K | OK | NETGATIVE | NEGATIVE | NEGATIVE | NEGATIVE | NORMAL HARVEST |
| USA FUMIGATION | CHEMICAL GAS | CA EUR 10 K | OK | NEGATIVE | NEGATIVE | NEGATIVE | NEGATIVE | 15-40% INCREASE |
| ECOLOGIC FARMING | MANUAL WORK | CA EUR 10 K | OK | NEUTRAL | NEUTRAL | NEUTRAL | NEUTRAL | 40% DECREASE |
| SOIL STEAMING | CLEAN STEAM | CA EUR 6 K | OK | NEUTRAL | NEUTRAL | NEUTRAL | NEUTRAL | 15-40% INCREASE |
| * Fumigation is illegal outside USA | | | | | | | | |

### 3.3.2.9. Insect, Bug, Bird & Rodent Control

Pests come in various shapes and sizes and cause discomfort and inconvenience to farmers. Farmers all over the world search for specially designed devices that can dissuade birds from eating recently planted arable crops.

## Bird and Animal Scarer

One of the most popular types of bird scarers used by farmers is the LPG powered gas gun, which produces a periodic loud explosion. These stationary guns utilise the explosive power of LPG ignition to create a loud shot-like sound to scare away birds and predators. The volume of the noise depends on the size of the canon and sometimes it is also adjustable. The interval between detonations can be adjusted from e.g. 40 seconds up to 30 minutes. The mechanism is simple. A carefully-controlled mixture of air and LPG is periodically blown into a semi-open pot, which is the combustion chamber.

LPG powered scare guns can keep birds away from every kind of fruit and vegetable field, in fish farms against herons, from garbage disposal sites (for hygienic reasons), or from structures, buildings, roofs etc. where bird excrements can cause damage. In some parts of the world they can also be found employed as a scare to keep away elephants, monkeys, wild boars and other wild animals from destroying agriculture harvest and other vegetation.

Also, for farmers who work hard to keep their crops, seeing the damage caused by moles, voles or other burrowing pets can be terrible. They seek to find reliable methods to evict these critters for good without using harmful chemical. LPG provides also a solution to this in the form of LPG rodent control blasters.

### Features

- Random modes can have variable and programmable random features, which means that no same timed pattern will ever repeat (birds adapt quickly to any sound that does not randomize its magnitude, pitch or time interval and can make it ineffective after some time).
- Maximum portability, lightness and easy to carry
- No reliance on heavy batteries.

### Benefits

- Cost Efficient: A standard 10kg or 5-gallon/20-pound LPG cylinder can emit up to 20000 - 30000 blasts depending on size.
- Safe & Environmentally Friendly: Powered by clean and economical LPG no chemicals, no poisons, or traps used
- Weather Resistant: Functions even in dire weather conditions, day and night.
- Once set up, it operates unattended.

## LPG Fogger

LPG thermal foggers produce a dense fog that will permeate foliage, cracks, crevices and other insect and rodent hiding places. The device burns LPG gas to heat a heat assembly element, that vaporises an insecticide from its liquid form that is pumped through the heat assembly, and sprays it out as a fog.

They are better suited for outdoor usage, and create a dense cloud of fog with tiny particles, that can penetrate very small places such as cracks in the floor, walls, gaps between furniture and warehouse equipment etc. This is a very effective and easy to use device, that can quickly collapse insect and rodent populations, leaving a safe pest free environment, with much less pesticide residues, if any, compared to other pesticide processes. LPG foggers, sometimes also called mosquito foggers, are amongst the best insect and pest control and repel systems to use to remove insects from the garden or the backyard.

**Features**

The LPG fogger is a one-piece unit, with the insecticide solution tank built into the body of the fogger and cannot be detached. Most fogging units are light with a handle on top for carrying the fogger and do not have a carrying strap. A fogging trigger is usually located under the handle and when pressed, pumps insecticide from the solution tank into the coil to vaporize the liquid and output it as a fog.

The burner unit is located at the front of the fogger and consists of a coil that is heated up with LPG and vaporizes the fogging solution. A basket around the coil provides protection from accidentally touching the hot coil. A nozzle located at the end of the burning assembly releases the insecticide into the air as a cloud of fog.

- The heat assembly unit is located at the front of the device.
- Insecticide storage container at the base of the device.
- An LPG canister can be attached to the device.
- Some models feature an automatic ignition unit, but the heat assembly element may also be lit with an external device.

**Advantages**

- There is very little, if any, pesticide residue after fog disperses.
- It produces a dense fog with tiny particles, which can therefore penetrate very small places.
- Advantage of portability as the small LPG tank is usually attached to a fogging device.

#### 3.3.2.10. Sterilisation and Parboiling of Rice Bran

An important potential use for fuels in the production of rice is the sterilisation of rice bran. This is the product of milling brown rice is an endeavour to produce as white a polished rice as can be achieved. The bran which constitutes over 10% by weight of the harvested crop contains rice oil, vitamins and other valuable constituents, which can be extracted, but is subject to rapid fermentation in hot climates unless sterilised immediately after milling. Rapid steaming of the bran prevents deterioration (at the rate of 1% decomposition of rice oil per hour) that would otherwise take place.

Another improvement in the utilisation of rice crops is the parboiling of the freshly harvested ‘paddy’ rice. This results in the migration of vitamins and minerals, which could otherwise be stripped together with the bran and polishings, into the rice kernel, thus improving its nutritional value. Both bran sterilisation and parboiling are made easy by the use LPG fired equipment.

#### 3.3.2.11. Accelerated germination of seeds

A final interesting application of heat is the accelerated germination of seeds exposed to high temperatures before planting, or occasionally the opposite effect. Both phenomena are being investigated and can be used to insure faster growth on the one hand or more efficient hybridisation, i.e. simultaneous flowering of species which would otherwise not cross-fertilise, on the other. So far, this treatment has been applied to sorghum and rise.

### 3.3.3. Livestock Farming (production and animal health)

**Space heating and constant temperature control for poultry sheds and brooders**

Building heat: during cold snaps, LPG provides heating solutions for livestock and poultry. LPG heaters provide a constant heat and clean air for livestock. Even during the long, cold winter months, when building heat is more energy intensive, LPG will heat buildings effectively and efficiently. LPG also delivers the consistent heat needed for healthier animals.

#### 3.3.3.1. Poultry Rearing

A reliable energy supply is a matter of life and death for poultry farmers. Birds thrive on consistent levels of heat and a stress-free environment in which to grow healthily. LPG produces the moist heat necessary to promote rapid growth as well as the feathering of chickens. Moreover, thanks to the clean properties of LPG feeds or broods do not run the danger of contamination.

*Source: Calor Gas*
*Source: Calor Gas*

#### 3.3.3.2. Pig Rearing

The use of heat in the breeding and raising of pigs is becoming established in most moderate and cold climates. It can be demonstrated that there is an optimum temperature for both meat and fat production; if this is exceeded, food intake is reduced. If pigs are reared at lower temperatures, too much of the food is consumed to maintain body heat. Provision of a localized radiant source of heat when rearing piglets allows both sow and litter to choose optimum conditions for growth and comfort.

*Source: PERC*

#### 3.3.3.3. Fish Farms - Aquaculture

Growing fish in the middle of a field in the heartland is certainly not the average agricultural use, but in this case, it certainly has grown in sales. LPG not only provides the LPG to warm the building that houses the fish tanks and office, but also to warm the water in which the fish live. And the business is growing, just like the fish it raises.

Fisheries are generally rural-based businesses, so most sites are only served by limited electricity and in order to run mains electricity to many lakes, it would cost an extortionate amount of money that most businesses are not prepared to pay. Especially when there is an easy alternative.

LPG water pumps are very innovative. During times of prolonged warm weather with little rainfall that dissolves oxygen within the water, it can decrease at a rapid pace and could (in the worst-case scenario) completely deoxygenate. This could cost a fishery thousands of euros in just a matter of hours and put the business back years in order to replenish fish stocks to similar levels.

## AgVantage Fish Farm- Case Study

A Fish Farm company (Nelsons) decided to expand the business and focused on changing the seafood industry in the USA, creating a safe and dynamic domestic supply of fish rather than continuing to depend primarily on imports.

While the company started out by growing a hybrid striped bass, they've switched to barramundi, a favorite eating fish in Australia and Southeast Asia. The barramundi is hatched in Australia, and each week the Nelsons travel to Minneapolis


Propane heats the water in the dual-current, climate-controlled, recirculating freshwater tanks that keep the fish active.

VeroBlue Farms raises barramundi, a fast-growing and favorite eating fish in Australia and Southeast Asia.

AgVantage FS fills four manifolded 1000-gal. tanks every three to four weeks for the VeroBlue fish farm facility.

to pick up thousands of the half-inch fingerlings. The fingerlings are transported to the Nelson facility and grown in dual-current, climate-controlled, recirculating freshwater tanks that keep the fish active and swimming upstream. The system runs on air, is low-maintenance, and requires little energy. The fish grow very quickly in this system and are sold when they reach around two pounds.

Keeping the water temperature at the required 26°C-28°C is critical. Four manifolded LPG tanks are positioned in front of the facility every three to four weeks, depending on the weather. During 2016, two fish farms contracted a combined 60,000 gallons; for 2017, 100,000 gallons have been contracted. Monitors ensure that the fish farms have an adequate supply of LPG, and help the LPG supply company eliminate unnecessary trips to check on their supply.

That success is due to the cost-effective benefits of LPG. But it also has a lot to do with the fish farms' comfort level with the individual who delivers that LPG.

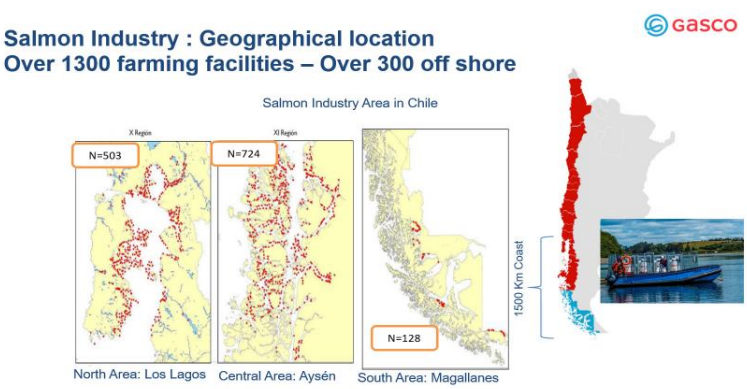
## LPG For Power Generation on Salmon Farms in Chile

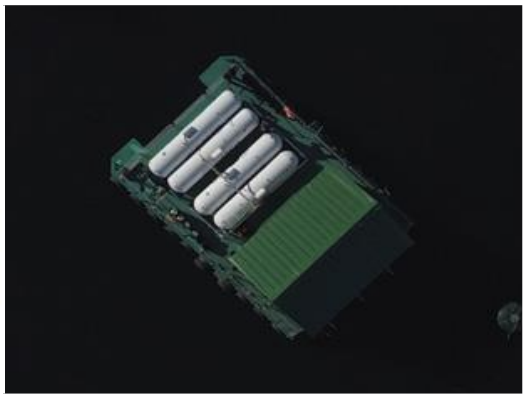
### The Project

- Gasco is promoting the replacement of diesel used for electricity generation in salmon farming by switching to an LPG based energy solution, with an estimated consumption of 130 tons of LPG per year. The project has been implemented by the Salmones Aysén company and is operational in a farming centre located in Huito, which is in the southern part of the country. Chile is the second largest producer of salmon in the world after Norway, and this power generation system proves that it is possible to cultivate salmon in a more sustainable, economic and safe manner by replacing diesel with LPG. Salmones Aysén has within its corporate objectives the implementation of innovative and environmentally friendly processes and procedures, so the idea of using an LPG power generation system was seen as a natural fit with overall company aspirations. This was the first of four similar projects that were launched at the end of 2019 in the same region of Chile.

### The Technology

- This power system is composed of a marine platform holding three LPG powered generators with a total capacity of 300 kVA, in a 2x120 kVA + 1x60 kVA configuration. It also includes an LPG dispenser for outboard engines and a storage system that holds 16,000 litres.
- The solution was provided by CETEC in a package that includes a Doosan engine, Standford and Cramaco generators and a soundproof cabin specially built for operations in marine environments. The platform was designed and built locally as well as the storage tanks which are composed of four tanks of 4,000 litres each. The main objectives of the project are to provide continuous power to the feeding and lighting systems.
- Use of night-time LED lights on industrial fish farms has a positive impact on the development of the fish and improves yields. Both the feeding and lighting processes are intensive during the periods that the salmon are growing. They generally complete a harvesting cycle between 12-18 months. In addition, the integrated LPG supply solution for outboard engines allows platform users to save time by avoiding going to land bases to refuel.

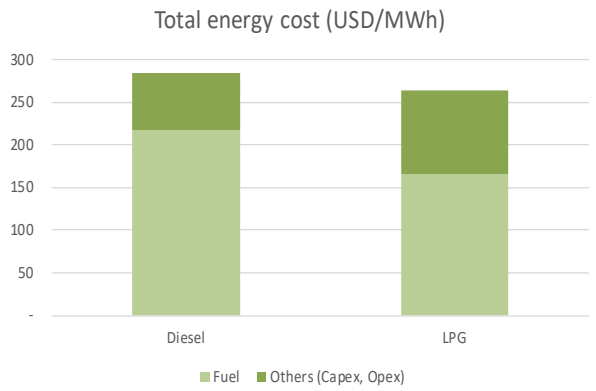



**Benefits for the Country**

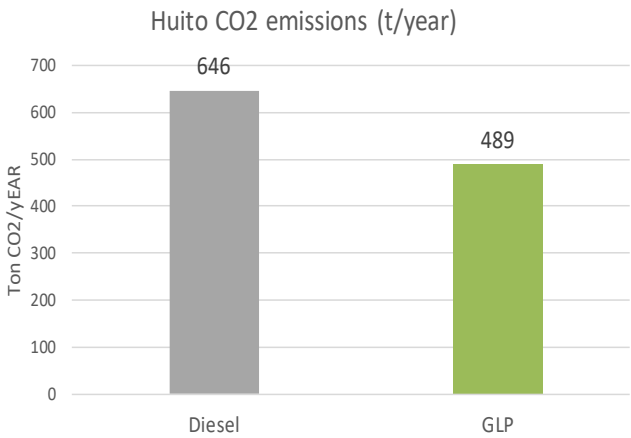
Chile's salmon industry is among the world's biggest in terms of annual export volumes. The main export destinations are China, the US, Brazil, Japan and the European Union. The use of less polluting LPG to produce the salmon allows for a reduction in the product's carbon footprint, as well as improves the industry's operational efficiency. LPG is also cheaper than diesel, increasing the competitiveness of the industry.

It is estimated that of the total energy required for salmon farming (fish, seawater and processing plants), 30% is consumed by marine platforms. So it is important for the industry to use energy technologies that generate a lower impact on the environment. Also, due to its physical and chemical characteristics, LPG reduces the risk of spills into the water and their impacts. Unlike diesel, an LPG leak will completely dissipate virtually removing the risk of bioaccumulation and allowing the industry to use energy technologies that generate a lower impact on the environment. Also, due to its physical and chemical characteristics, LPG reduces the risk of spills into the water and their impacts. Unlike diesel, an LPG leak will completely dissipate virtually removing the risk of bioaccumulation of hydrocarbons in the fish. LPG is also nontoxic, allowing for improved yields and improved safety standards for the industry.



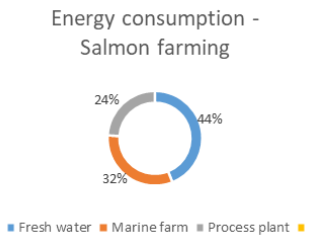

**Advantages for the User**

For Salmones Aysén this project will create a 7% reduction in total costs, including investment, fuel and maintenance. These savings are generated mainly by the 24% reduction in fuel costs. Also, the project will reduce the site's CO2 emissions by approximately 24% as well as control fuel consumption more effectively and remove the risk of damaging and dangerous spills of diesel.




**Timeline (17 months)**

- Project design three months: June - August 2018
- Project construction six months: January - June 2019
- Commissioning four months: July - November 2019



**Greengear Water Pumps for use in Fish Farms**

Greengear offers four different models of Water Pump which mostly used for agricultural use.

**Advantages**

- **Cost savings:** In comparison to petrol and diesel, LPG is, in most cases up, to 40% cheaper. Making a clear financial benefit for businesses.
- **Reduced fuel consumption** with up to a 40% cost saving with no reduction in performance.
- Lower maintenance costs. Servicing periods occur less frequently due to the clean burning nature of LPG and will therefore require service less often than units using petrol or diesel. LPG increases the lifespan of the engine and its parts.
- **Portability:** The water pumps two and three weigh 24 and 27kg's so are easily transportable via a one man lift. Additionally, the cylinders are transported and rolled into position creating no additional manual handling issues.
- **Environmental benefits:** Using an LPG water pump has a wide range of benefits when compared to petrol- or diesel-powered pumps. The environmental impact of any service is considered daily from weed control to bio security and the need to segregate water ingress between the lakes and to a lesser extent bait and fishing weights being placed in to the lakes by anglers. LPG is the cleanest burning fossil fuel and will provide lower emissions to that of its petrochemical counterparts. For most fisheries, who rely on nature to sculpt the surroundings of the lakes, this is seen as a major benefit.
- **Safety:** quick and safe refuelling.
- **No spillages:** As LPG is stored in cylinders under pressure, there is no chance of a fuel spillage whilst refuelling.
- **Noise:** Reduced noise pollution from just 68 dB. LPG powered equipment is quieter than its petrol/diesel counterparts. When running a business this can be a great advantage and many fisheries are near homes (most likely your own home!) so can be beneficial to the neighbours.


*Source: WLPGA, LPG Exceptional Energy*

LPG water pumps have a multitude of uses within the fishery and fisheries management industry. **From draining down lakes prior to fish grading or netting to aeration in times of low Dissolved Oxygen levels and ice prevention during the winter months,** LPG pumps do everything a fishery needs.

### 3.3.3.4. Animal Waste Management

An unusual and relatively novel use of fuels is the processing of animal waste. The production of farm manure from intensive farming is such that simple spreading on farmland is becoming too labour-intensive and also would involve transport over too large a distance in many instances. One way of dealing with the large production of animal waste is to dry and sterilise it prior to application as fertiliser. The concentrated manure can then be returned to the original croplands even if feeding lots and broiler houses are a long way from fields.

A somewhat disconcerting use of dried and sterilised manure is its re-use for feeding. Neither cattle nor poultry extract all available food value and sterilized dried manure can therefore be blended with fresh hay and other feeds into so-called 'wastelage', a perfect feed for cattle, sheep and poultry. This results in considerable savings. Other possible uses for sterilised manure are as bedding for both free-range and factory-farm animals.

Incineration is a notable solution to the disposal of waste. LPG incineration is an efficient, economic, bio-secure solution for the disposal of hazardous waste. It can be used to dispose of many different types of waste and is, in particular, an efficient and desirable option for the safe, bio-secure disposal of diseased animal carcasses.

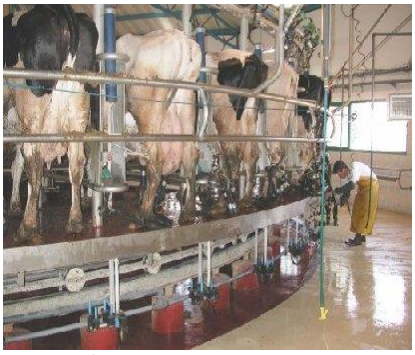
LPG can also be used to control unwanted weeds on farms without the fear of pollution of soil, the environment and ground water. It can also be used in greenhouses as a carbon fertiliser since LPG increases the leaf mass of the plants.

#### 3.3.3.5. Nutrient Management

Nutrient management is a method of managing farm waste - one of the largest concerns of growing livestock confinement operations and other types of agriculture. As a clean burning, energy-rich fuel, LPG is an excellent fuel source for this type of technology. Nutrient management research develops technologies that help farmers maintain proper management of waste materials. These materials are often rich in valuable nutrients that can support or enhance other agricultural production.

#### 3.3.3.6. Sterilising Milk Lines and Storage Tanks

LPG water heaters give dairy farmers hot water on demand at a given temperature. Having reliable hot water is essential on a dairy farm, with a particular need for a continuous flow of hot water that's available fast, as required. Whether it's needed for washing the milking system, keeping the animals clean, or washing equipment, LPG hot water systems are not only more efficient, they offer a continuous flow of hot water. LPG systems are also cost-effective saving dairy farmers up to 25% on their hot water energy.



*Source: Elgas*

### 3.3.4. Drying (crop/serial/fruit and corn, soybeans, grains, tobacco, apples, peanuts, onions, and other crops

LPG is successfully used in a range of crop drying applications for corn, wheat, barley, hops, oats, rye and peas as well as for nut roasting, pig farrowing, and cold as well as warm room chicken brooding.

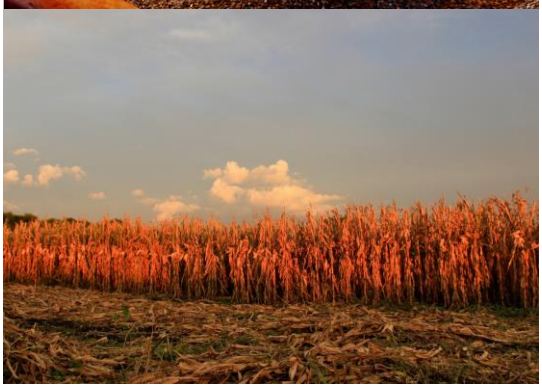
Grain drying is the process of removing moisture from the grain following harvest. Traditionally, crops were left in the field to dry but were at risk of being subjected to mould, fungus growth, frost, and other detrimental conditions. Farming regulations state that crops must reach a certain moisture level to be considered safe for storing. Using a commercial

grain dryer, farmers can harvest at any time and are able to maximize the overall harvest yield. Crop dryers also take considerably less time than waiting for crops to dry naturally.

## Advantages of LPG

Over 80% of crop dryers utilise LPG. Because LPG is portable and stores well, it is an ideal fuel source for farmers in remote locations where alternative fuels are not accessible. Not only is it incredibly versatile, but LPG is also highly efficient; farmers rely on LPG to produce an even heat for drying crops quickly and effectively. Cleaner than diesel and gasoline, LPG will not contaminate the soil or crops in the case of a leak. Overall, the power of a LPG crop dryer is in the time and money saved, as well as enhanced flexibility.

- Saving time and resources.
- Maximises consistency of crop yield.
- Limits the risk of fungal and bacterial growth.
- Minimises crop risks due to weather.
- Enhances flexibility of harvesting.
- Eliminates risk of soil contamination.
- More energy efficient than alternative fuels.
- Achieves moisture content restrictions.
- Produces high output of thermal energy.
- Less equipment maintenance required.



*Source: PERC*

## Case Study

### PROPANE FLAME WEEDING SYSTEM AN INNOVATIVE, EFFECTIVE TOOL FOR ORGANIC TOBACCO WEED CONTROL

A PROPANE CASE STUDY

*Lee Newman has been farming for decades on his family farm near Sumter, South Carolina. The farm includes organic tobacco, corn, soybeans, wheat, and cotton, as well as twelve turkey grower houses. As owner of the operation, Newman is constantly analyzing and searching for the most effective, cost-efficient means of running his farm. Because his products are certified organic, all farming techniques must be carefully and meticulously evaluated in order to meet the specific criteria required of such labeling. The organic stamp also means the farm cannot use many of the conventional farming methods common to non-organic farms.*

Weed control is one such method that requires a non-traditional approach for organic farmers. Conventional farmers can rely on fertilizers and herbicides to effectively reduce and eliminate weeds, but many common chemicals are not acceptable for certified organic farming. Instead, many organic farmers rely on manual labor and cultivation. While these methods can be effective when performed properly, they are also very time- and labor-intensive; so Newman began researching alternative methods for organic weed control, particularly for his tobacco fields.

*"Controlling weeds in an organic environment where you can't use any herbicide is a challenge that tobacco farmers have been struggling with for years and years."*

**Lee Newman**
*Organic Tobacco Producer*

#### TOBACCO FLAME WEEDING: A NEW SOLUTION

"Controlling weeds in an organic environment where you can't use any herbicide is a challenge that tobacco farmers have been struggling with for years and years," said Newman. "I was looking for another way to control the weeds and had this idea come to me that you could probably burn them. So I got online and began researching that idea, and that's when I came across propane flame weeding systems."

#### COMPANY

Newman Farms
Sumter, South Carolina

#### CHALLENGE & SOLUTION

In order to avoid the use of pesticides commonly used in conventional farming, many organic farmers rely on time- and labor-intensive manual removal and tillage to control weeds. When Newman Farms, a certified organic tobacco producer, adopted a propane flame weeding system, they were able to effectively control weeds in tobacco fields while reducing labor time and costs by approximately 40 percent.

#### RESULT

- Propane flame weeding reduces labor time and costs by approximately 40 percent.
- Propane flame weeding is approved for certified organic farming operations.
- Propane flame weeding avoids the disruption of essential soil nutrients, which commonly occurs with cultivation and tillage weed control methods.
- The 4-row propane flame weed control unit controls between 90 and 100 percent of weeds.

*"I have been amazed with the systems' capabilities. Even tobacco farmers who are not certified organic are experiencing benefits from using this method."*

**Lee Newman**
*Organic Tobacco Producer*

Newman contacted his local propane dealer to learn more about propane flame weeding equipment. "I wanted to make sure I understood exactly how this was going to work before diving in. It was hard to believe it could really remove weeds in the way I required." Newman's propane marketer and the staff at Flame Engineering, Inc. convinced Newman to give flame weeding a try.

#### SAVING TIME, MONEY, AND THE ENVIRONMENT

Newman quickly realized just how efficient his 4-row propane flame weeding system was, "I was amazed at its capabilities," said Newman. "When the machine is set up properly to flame weed at the right angle, it will kill 100 percent of weeds."

Before using the flame weeding system, Newman Farms would remove weeds by hand, which was incredibly arduous and time-consuming. "Manual labor is very expensive and required significantly more time," said Newman. "In my experience, it was probably three or four times as expensive to control weeds manually when compared to running this machine."

In addition to reducing labor costs and time, propane flame weeding systems are more environmentally sustainable. As a certified organic farmer, this was another important factor to Newman. Flame weeding methods replace the need to use harmful chemicals while protecting essential soil nutrients. Propane is also a clean fuel with a lower carbon content than gasoline and diesel. Its nontoxic and insoluble in water, making it safe in contact with aquifers, streams, and soil. Newman Farms was already using propane for grain drying and their work trucks. Using this environmentally friendly energy source for an additional farming application was an easy decision.

#### INNOVATIVE, EFFECTIVE WEED CONTROL

While propane flame weeding has been around for years; new, innovative models make the use of heat treatments over chemicals for weed removal more effective than ever. Research supported by the Propane Education and Research Council has shown that weed flaming provides approximately 95 percent effectiveness in weed control for a variety of crops, supporting Newman's own experience with his new flame weeding system. "I have been amazed with the systems' capabilities," said Newman. "Even tobacco farmers who are not certified organic are experiencing benefits from using this method."

#### 3.3.4.1. Grain Dying

Grain drying is an integral part of the farming operation, and LPG is most often used to fuel heated-air drying systems because it is portable, can be easily stored, and is readily accessible in rural areas where natural gas is unavailable.

LPG-fuelled moisture-control technologies prepare crops for harvest and storage and are capable of drying virtually any type of grain. They are available as either batch dryers (where grain is dried in batches ranging from 80 to 1,000 bushels) or continuous flow dryers (wet grain is fed into the dryer in a steady stream) – both types are available in the form of mobile and static grain dryers. Grain drying increases the quality of harvested grain by reducing crop exposure to weather, and it also allows more time for post-harvest field work.

**Features**

General features associated with LPG dryers include:

- A full range of temperature settings caters to a variety of grain types.
- Fully-automated filling, unloading, and shut-off capabilities.
- Quick and easy full-length clean-out doors to facilitate grain changing without contamination.
- Control panels to indicate the operating status of equipment as well as the sources of problems in the event of a shut-down.
- Long operational life and very low maintenance requirements.
- A choice of fuel storage options; LPG tanks or gas cylinders, ensuring the most convenient and cost-effective supply of LPG.

Some features are associated with specific models:

The capacity to operate in three modes:

- Pressure heat and pressure cool.
- All heat.
- Pressure heat and vacuum cool.

*Source: Calor Gas*

The flexibility allows farmers to customise their grain drying cycles. Low-profile vacuum-cooled dryer features a horizontal, modular design with a centrifugal fan for quiet operation. The ability to circulate the grain during the drying process, maximising grain quality and minimising fuel use and operating costs. This eliminates over-drying and maintains optimal grain temperature and efficiency. Features such fans and heaters at both ends of the dryer to distribute heat more evenly resulting in more even drying. Alternating air flow direction increases efficiency and eliminates front-to-back moisture variation and heat loss.

**Advantages**

- LPG is a highly controllable fuel and facilitates effective drying of grain, reducing over-drying (optimum drying conditions are consistently maintained) and producing more evenly-dried, higher-quality grain.
- The complete combustion process further reduces the chance of grain combustion, water ingress or fuel sediment embedment.
- Wheat, maize, barley, rapeseed, peas, potatoes, bulbs and onions can all be dried economically and efficiently. This allows farmers to preserve the quality of their crops and to meet specific market specifications for moisture content for storage and onward sale.
- LPG grain drying technology recycles heated air and converts 90% of the LPG used to energy which enhances efficiency, lower fuel consumption and lower costs. They require as little as 1,650 British Thermal Units to remove a pound of water, compared to 3,500 with older technology.

- They expand the harvest window and reduces crop loss caused by weather and mechanical harvesting when crops are left to dry in the field.
- The environmentally friendly equipment utilises a clean burning fuel and eliminates soot build up.
- It reduces the need for chemical application, produces healthier chemical-free crops, eases the harvest process, and increases food safety and unlike fuel oil or kerosene, LPG will not leak and contaminate the grain.
- LPG grain dryers also limit fungus and bacterial growth and can allow farmers to harvest their crops with some flexibility, more independently of the weather.

#### 3.3.4.2. Fruit Ripening

Dehydration is the process of driving free water from products like fruits, vegetables and nuts at accelerated rates and stabilising them at low-moisture content without damage to the products. LPG is an exceptional choice for fuelling the burners of fruit dehydrators.

We must reduce food waste:

- One third of all food that is produced is wasted. This accumulates to ca. 1,3 billion tons.
- In Norway, 10 – 12 thousand tons of carrots are wasted every year before the vegetables reach the store. The same volume is imported. The fungus from the soil follows the harvest into the warehouse and starts the rotting process quickly.

**Features**

LPG-fuelled dehydrators are available in two basic designs: tray or tunnel dryers and cabinet dryers.

**Tray or Tunnel Dryers**: Tunnel dryers are generally factory-assembled and are relatively inexpensive. Batches of the product are loaded onto trays and fed into the dryer on one end, and the dried product is unloaded on the other end. Tunnel dryers have these typical features:


Gas burner

- Tubular steel frame.
- Heavy gauge sheet metal interior walls.
- Exterior walls with enamelled weather-protection roofing and siding material.
- Multi-speed fan.
- Thermostatic controls for humidity, temperature, and air velocity.
- Medium-sized and full-sized dehydration systems have a maximum drying (tray) area of about 3,700 square feet and 8,000 square feet, respectively. Mobile units that can be transported to a site near the crop are also available.

**Cabinet Dryers:** LPG cabinet dryers are compact dehydrators for small to medium scale production. They are available in a broad range of capacities to serve different dehydration needs and are particularly useful in facilities where space is at a premium.

Typical features include the following:

Gas burners:

- Rugged tubular steel frame and heavy gauge sheet metal.
- Insulated exterior shell finished with industrial enamel.
- Stable platform of trays.

- Multi-speed fan.

Temperature and air flow controls. *Source: WLPGA, LPG Exceptional Energy*

- 
- Large access doors and fixed racks for easy loading, unloading, and cleaning.

**Benefits**

- LPG is nontoxic and safe around food materials.
- Emissions from LPG burners are significantly lower than those from oil-fuelled burners.
- LPG can be stored for extended periods of time, while gasoline or diesel fuel tends to turn rancid.
- In contrast to gasoline or diesel fuel spills, which can contaminate water, land, and crops, any LPG leak vaporises instantly.

#### 3.3.4.3. Tea Production

**Oil companies keen on pushing LPG in tea production replacing coal**
**This could open up a large, untapped market for LPG.**

Tea, the green beverage, demands the cleanest possible processing. Oil companies in India are taking serious steps to replace coal with LPG in tea production, which can ensure a cleaner processing environment for tea. On the other hand, it could open up a large untapped market for LPG. But there are issues to be addressed first for this major shift in the processing system to take place.

The use of LPG in tea garden factories ensures uniform heating during the drying process of tea leaves and thus guarantee the production of quality tea. LPG is also easily available and the cost of transportation would be much less than furnace oil and coal and it would be easy to store.

Tea gardens located in remote areas, which were deprived of piped gas connections could also opt for LPG facilities in their factories. Also, tea gardens located in the green belt especially near Kaziranga National Park, would have no option but to shift to LPG as there are no piped-gas facilities in these areas.

#### 3.3.4.4. Ginning Cotton

Ginning is an energy intensive process. From the field, seed cotton moves to nearby gins for separation of lint and seed. The cotton first goes through dryers to reduce moisture content and then through cleaning equipment to remove foreign matter. These operations facilitate processing and improve fibre quality. LPG is used for cotton drying prior to ginning.

#### 3.3.4.5. Curing of Tobacco and Rubber

Curing is the process used to achieve the texture, colour and overall quality of a specific tobacco type. It takes place in three steps: yellowing to obtain the desired colour at low temperature, leaf drying with fairly high heat and rapid air circulation and killing the stem with high heat and little air movement. It usually involves a heat source that reduces chlorophyll content and converts leaf starch into sugar, while the tobacco changes colour from green to brown, closer to the colour and texture you will find in a typical cigarette.

While some tobacco is normally air-cured or sun-cured, most commonly, heat is introduced into a curing barn or shed through pipes from an exterior furnace. This is known as flue-curing. The curing process for flue-cured tobacco production is by far the greatest energy user (constitutes more than 80% of total energy requirements).

LPG has become the primary fuel used in curing, replacing wood and accounting for almost 70% of production. Almost all bulk-curing barns built are equipped with LPG gas burners. It lights instantly, is easily controlled, and is a constant and uniform source of heat.

Combustion gases have been found to produce tobacco-specific nitrosamines, which are deemed carcinogenic. Producers are now required to retrofit, or change all flue-curing barns to operate only with indirect-fired curing systems. In these systems, direct mixing of flue gases with curing combustion gases is prevented by passing combustion gases through heat exchangers or by allowing
combustion to take place outside of the barn with the resulting heat being conducted into the barn via hot water or steam.

Since some heat loss is unavoidable with indirect curing systems, it is very important for growers to gain as much heating system efficiency as possible in order to control fuel costs. The single greatest reason for burner inefficiency is improper ventilation. Growers have switched from using fuel oil to LPG because LPG systems are more efficient – LPG and air mix better during combustion than fuel oil and air. This allows for a lower excess air setting on the gas burner and improves the efficiency of the system.

**Advantages**

- LPG curers allow for a lower excess air setting on the gas burner, which helps to improve the efficiency of the system.
- With LPG curers, better temperature control system and uniform heat distribution, better energy efficiency than other energy sources can be achieved and fewer leaves are exposed at risk or damaged during curing.
- LPG could be burnt directly in the barn, thus avoiding heat loss through the chimney, as in a normal flue piped system, fewer contaminants are introduced with the combustion gases and it is claimed that LPG tobacco curing leaf quality is, in fact, superior to that of other fuel dried. Combustion gases from other fuels could contaminate tobacco leaves by depositing soot and aromatic materials, sulphur compounds particularly if there is any malfunction in the burner or controls.
- LPG system advantages are the good fuel utilisation, a high degree of flexibility and the initial first cost of the curing equipment.
- LPG curers are environment friendly compared to traditional curers that rely on biomass as a fuel source.
- A high calorific value.
- It reduces frequent equipment maintenance and cleaning.

#### 3.3.4.6. Distillation

Distillation is the process of making spirits from fruit, cereals, plants and vegetables. The two main operations in spirit distillation are the heating of fermented preparations and the condensation of alcoholic vapours. LPG can therefore be used in this process thanks to its flexibility of use, environmentally friendly attributes and high yields of heat. The best cognacs are distilled using this process.

### 3.3.5. Support Activities for Agriculture and Forestry

#### 3.3.5.1. Power in Agricultural Industry

Power is required in the agricultural industry for the operation of machinery and other technologies that enable farms to run as efficiently as possible. LPG is both an economical and efficient fuel, well-suited to powering this type of technology.

Many farms are off-grid, with no access to electricity or natural gas. Due to a lack of investment in modernising infrastructure, power cuts are commonplace and tend to be more frequent. Farmers have a more limited choice of energy solutions. There is currently little awareness about the unique energy needs of agricultural areas. An alternative to a cleaner rural energy mix does exist however.

- Solutions for the future of energy.
- LPG.
- Solar Thermal and PV.
- Wind.
- Biomass.
- Heat pumps.
- Micro-CHP.

As the cleanest available fossil fuel available in rural areas, LPG gives farmers access to modern energy, most notably in Micro-CHP (combined heat and power). Agricultural areas also present obvious opportunities in the field of renewable energy production. Energy-efficient technologies such as LPG heat pumps can also help tap into the considerable potential for energy savings.

**Efficient Micro-CHP systems**

Combined heat and power (CHP) systems (or m-CHP -micro-CHP- in smaller sizes), are relatively new systems that allow simultaneous generation of electricity, power and heat. This process, also commonly referred to as “cogeneration”, allows for heat and electricity to be produced simultaneously using a single fuel source and constitutes an energy efficient solution that can cut both carbon emissions and energy costs by generating electricity on site.

The component of the CHP system that converts fuel to useful work (prime mover) can be an internal combustion engine running on LPG. This prime mover is in turn connected to an electricity generator. Heat exchangers capture the residual heat produced and transfer it for space heating or water heating purposes. LPG-fuelled CHP systems thus produce thermal and power output, addressing both heating and electrical needs for agricultural facilities.

Micro-combined heat and power (micro-CHP) systems are such systems on a smaller scale. They are used mainly in residential developments and small businesses.

**Advantages**

- CHP systems provide heat and generate electricity with higher efficiency and lower emissions than conventional heating and grid-supplied power. Thermal energy generated by the Micro-CHP unit can be used for many different needs, including space-heating, water-heating, as well as pool and spa heating.
- Cheaper electricity: Depending on geographical region, electricity produced on-site can cost less than half of what it would if bought from a power supplied.

- Self-Dependence: Another benefit is that CHP systems offer a degree of independence from external providers.
- Greater efficiency: On-site electricity production also avoids the typical losses that are associated with national/regional transmission and distribution networks effectively making CHP electricity more efficient than grid electricity. This makes CHPs up to 70-90% energy efficient (electric and thermal), significantly reducing carbon emissions.
- Avoided costs: The avoided use of the wider electricity network reduces (in principle) the maintenance requirements of such infrastructure by the electric utilities/network operators, which (in theory) has a positive effect on standing charges. In some countries, this aspect is rewarded through a utility payment.
- Potential additional income: electricity can be fed and sold back to the grid, often at a reasonable price.
- Heat Storage: Excess thermal energy may also be stored, in a buffer, for consumption at a later time (in the order of days).
- Back-up assistance: CHP systems can be quickly fired-up to assist with electricity production at times of peak demand. This helps cut fuel bills. Many parties are now looking into the idea of a 'virtual power plant' of many connected CHPs.
- Controllability/predictability: CHP generation is controllable. It provides electricity on demand, in contrast to other low-carbon but inherently intermittent technologies such as. solar PV or wind power.

## Power/Electricity Generators

LPG has become a viable choice to facilitate the generation of off-grid electricity. For these types of localised power generation, LPG is clean burning and has a carbon footprint that is lower than that of diesel and significantly lower than petrol. The supply of electrical power or power generation, has become paramount to the success of daily agricultural activities.


**Standby generators** are permanently connected to a business and their existing power lines. A standby generator can power critical and sophisticated appliances in a business, including lights, heating/cooling systems, refrigerators, pumps and security systems, amongst others. They ensure an owner's quality of life by keeping the electricity flowing in the event of any power failures that result from either a standard service disruption or a natural disaster, such as a storm.


**Portable LPG generators** offer the benefits of a traditional generator but in a portable form and usually on a smaller scale. These are also available in a variety of sizes, providing flexibility to fit power requirements and location of use.

**Hybrid Generators** are new age generators which combine traditional generator sets with another controllable electric source in order to generate a fuel-efficient, noise reduced and environmentally friendly source of power supply. The controllable source may comprise a fuel cell or another device which generates electricity from a non-electrical power source such as a hydro-electric generator, wind turbine generator, solar powered power source, etc. The batteries in hybrid generator sets are charged by renewable power sources (solar, wind, hydro, etc.) along with the fuel generators during their operation. The power supply is given from the charge stored in the batteries themselves, thus eliminating the need for fuel generators to be operating continuously.

### 3.3.5.2. Sanitation

Sanitation is another aspect of agriculture where LPG lends a hand to fuel efficient technologies. LPG-fuelled steam systems can be used as a means of sanitising the soil and controlling micro-organisms such as soil nematodes, effectively replacing the use of methyl bromide. LPG-fuelled flame technology can be used to sanitise both dairy and poultry facilities. These flame treatments can reduce pathogens and moisture in the sand bedding of dairy facilities or the floors of poultry houses. This can help eliminate the needs for acids or chemical disinfectants.


### 3.3.5.3. Steam Generation

Saturated steam is generated by steam boilers/generators either as main generation plants, or at various process units requiring heat from various sources. Despite modern technology, LPG boilers are still the most common appliances to provide the heat energy to generate steam. LPG is without any doubt the easiest fuel to combust with the least danger of fouling a boiler. LPG has emerged as a fuel source of choice due to its environmentally friendly nature. Apart from costs, sustainability and fuel emissions have now become very important major fuel selection criteria for agricultural applications.

### 3.3.5.4. Water Heating - Cleaning

Agricultural producers use heated water for a variety of jobs, including general cleaning of structures, equipment, livestock, poultry, fruit, and vegetables and to sterilise equipment. Dairy farms use especially large quantities of hot water daily for both cleaning structures and equipment and processing milk products. Most agricultural producers use LPG because of its higher efficiency. LPG powered cleaning equipment such as high-pressure water cleaners, cold water pressure washers and steam LPG industrial vacuum cleaners are vital to effective industrial cleaning due to their high suction rate. LPG powered ultra-high-pressure machines are an effective and efficient application of cleaning remote and tough stains. The reasons for using LPG are not far away. Today, the world is facing climate change and business sustainability issues due to fossil fuel use and green strategies and solutions are needed where LPG offers an opportunity for sustainable cleaning practices for a sustainable environment.

Super powered, LPG fuelled, high pressure washers handle the toughest and most demanding cleaning applications. Pressure washers come in three modes:

- Hot water washers.
- Cold water washers.
- Steam cleaners.

**Advantages**

- More durable and reliable than traditional gasoline or diesel- fuelled machines.
- LPG pressure washers allow savings of up to 70% when compared to gasoline-powered washers.
- The absence of smoke, soot, odours result in cleaner emissions. This combined with reduced noise make the appliances an environmentally friendly alternative.
- They are portable, easy to operate and easy to maintain.
- They produce pressures of upwards of 4000 PSI.

### 3.3.5.5. Water Pumping and Boiling

Apart from solar-powered pumping machines, no other fuel pumping machines have the advantages that LPG machines provide. LPG can be used to pump water especially in rural communities that lack grid electricity. It can also be used in pumping fresh water, river water, corrosive water, impurity water, dirty water, etc. such as irrigation and firefighting. More powerful units tackle agricultural spraying, irrigation, dewatering, emergency water supply and bailing, as well as fire-fighting and pressure boosting. The portability of these machines allows for their use in the most remote and harshest of areas. There are LPG conversion kits for existing gasoline or diesel units. These kits are user-friendly and easy to install.

**Advantages**

- They offer great portability, are easy to operate and are suitable for a variety of applications.
- They have lower maintenance requirements, meaning fewer repairs, greater reliability and a longer engine life.
- LPG water pumps are more durable and reliable than traditional gasoline and diesel-powered water pumps.
- They allow savings of up to 70% when compared to gasoline- powered water pumps (lower fuel costs per operating hour and allow better control of fuel costs).
- LPG has a higher-octane rating than gasoline.
- These water pumps offer cleaner emissions that are soot free as well as smoke and odour-free (LPG can reduce hydrocarbon emissions by up to 70%). LPG use significantly reduces pollution from traditional fuels and is beneficial to users and the environment.
- Suitable for fountains, ponds, and aquariums.

LPG does not go stale, get contaminated or undergo theft like traditional fuels.

*Source: WLPGA, LPG Exceptional Energy*

- 
- LPG also does not undergo spillage, of which 17 million gallons of gasoline are accidently spilled yearly.

### 3.3.5.6. The Use of Cogeneration in Agriculture

Modern stockbreeding is an activity that highly pollutes the environment when harmful CH4, N2O and NH3gas content are emitted into the atmosphere. Anaerobic digestion of organic waste significantly reduces harmful methane gases in its content. The most effective way to manage organic wastes, such as manure from cows, pigs and poultry, on the farm is anaerobic digestion technology when biogas is generated. Agricultural biogas is the gas that is produced during anaerobic digestion as well as the digestion of a combination of animal waste and agricultural products, which can be used as fuel for LPG engines in cogeneration power-plants. Combustion of agricultural biogas in cogeneration power-plants is an environmentally friendly way to produce electricity and heat.

Organic materials are placed in sealed containers where the bacteria produce biogas during the anaerobic digestion process (normally 65% of methane and 35% of CO2). Usually, agricultural biogas makes up about 10% of the gases causing the greenhouse effect. Methane evaporating from the organic waste handled in agriculture can be collected for the use in LPG engine cogeneration power-plants to produce electricity. The farms using this technology perfectly arrange their own organic waste without polluting the environment and produce a sufficient amount of electricity and heat for the domestic needs of their farms. Larger agricultural holdings sell the excess energy to local electric power networks.

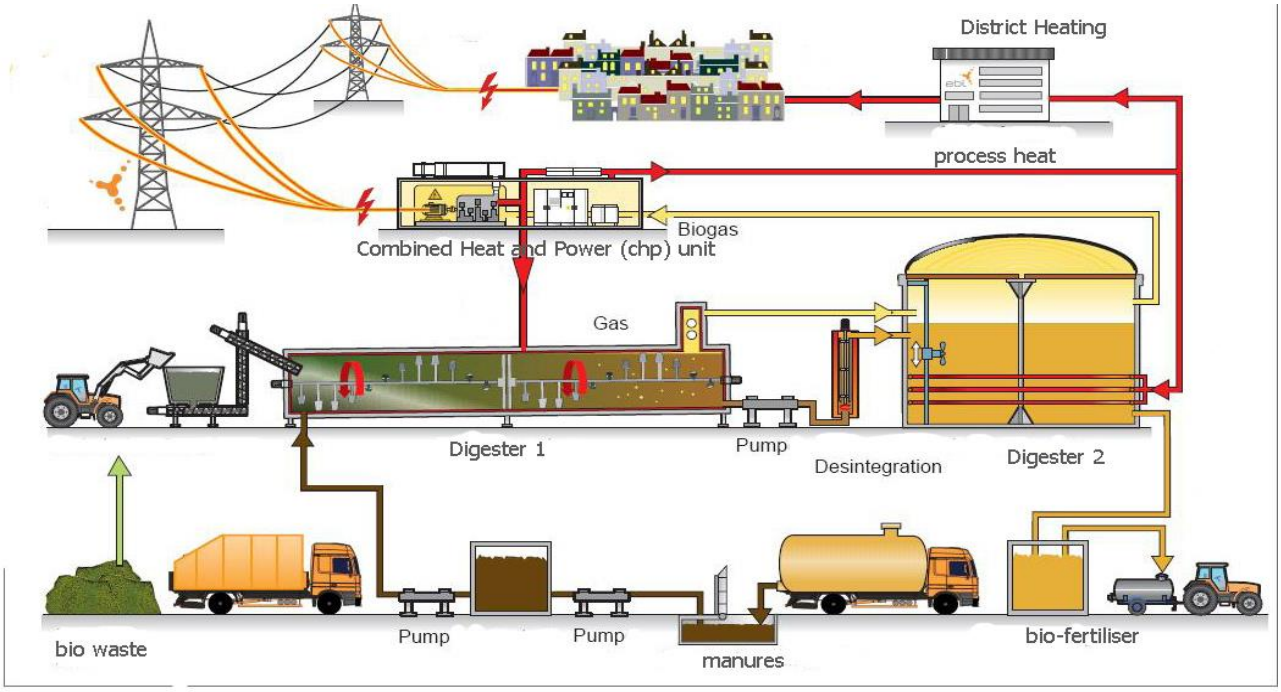
Cogeneration of agricultural biogas is usually applied on:

- Pig breeding/feeding farms.
- Livestock feeding and milking farms.
- Poultry farms.

- Plant-growing and stockbreeding farms (mixed type).

In normal agricultural biogas plants methane and CO2 are generated during the decomposition of organic waste. To speed the process, the waste is heated to 38 °C - 56 °C. For the aeration of waste blowers are used.

Typical scheme of the operation of agricultural biogas processing facility of cogeneration power-plant:




*Source: http://www.fabbiogas.eu/*

Anaerobic digestion process reduces the harmful effects of waste and reduces chemical release of oxygen. This helps to protect the aquatic flora and fauna, as minimum content of separated oxygen is required for the survival of fish and other aquatic and microorganisms of underwater world. The bacteria involved in anaerobic digestion process eliminate unpleasant odour causing compounds. Furthermore, during the process the eggs of flies causing many diseases are destroyed. A greater part of organic nitrogen contained in waste is converted into ammonia. These are fertilisers widely used in agriculture.

### 3.3.6. LPG partnering with Renewable Energy

Renewable energy and LPG are a winning combination. The introduction of LPG enables farmers to progress up the energy ladder toward more sophisticated appliances, thereby creating an energy consumption market and enabling farmers to utilise modern energy. This helps to establish a cost-effective transition to renewable energy supplies by building a solid base of modern energy users throughout a community. LPG can provide a practical and reliable back-up supply or hybrid energy source to compensate for the intermittent nature of renewable energy during those times when there is insufficient wind or solar power.

## 3.4. Agricultural Engine Technologies

Engine types used in non-road equipment and vehicles vary by engine size and application.

Internal combustion (IC) engines, including both spark ignition (SI) and compression ignition (CI) engines provide locomotion, and/or to generate electricity. In contrast with CI engines that operate on diesel fuel, SI engines most often run on petrol and a small number of models are designed to use LPG.

Spark-ignition (SI) engines, mainly fuelled with petrol and LPG, are commonly used in lawn and garden equipment and land-based recreational vehicles. The non-road spark-ignition (SI) industry includes a wide variety of handheld and not-handheld equipment. Not-handheld equipment are powered mainly by four-stroke petrol engines; handheld equipment is powered mainly by two-stroke petrol or LPG engines.

Compression-ignition (CI), or diesel, engines are widely used in equipment applications typical of the construction and agriculture sectors as well as, other industrial applications.

Regulatory pathways in the United States and European Union have differed for non-road CI and SI engines, with standards for CI engines implemented prior to those for SI engines in both regions.

Engine sizes used in common non-road applications can span several orders of magnitude, from small (< 19 kW) engines used in lawn and garden equipment to larger engines used in generator sets and off-highway trucks. Some applications, such as skid steer loaders or refrigeration units, utilise a relatively narrow range of engine sizes. In contrast, engine sizes can span a hundred of kilowatts for equipment such as small agricultural tractors or excavators. In both U.S. and EU regulatory programmes, emission standards are set according to engine power, with the stringency and timing of emission standards varying across engine power classes.

There are various categories of engines and SHDEs related to the use of LPG as a fuel. These engines find their use in both static and also mobile/transport applications and could be categorised as below:

- Spark ignition (Otto cycle) mono LPG fuelled engines.
- Spark ignition (Otto cycle) Petrol/LPG bi-fuel engines.
- Compression ignition diesel/LPG dual-fuel engines (LPG/HDDE).

Almost all the tractors and power tillers are operated by diesel engines. Diesel engines are used for operating irrigation pumps, flour mills, oil ghanis, cotton gins, chaff cutter, sugarcane crusher, threshers, winnowers etc.

**Small spark-ignition** engines are typically petrol or LPG engines found in lawn and garden machines (hedge trimmers, brush cutters, lawnmowers, garden tractors, snow blowers, etc.), in light-duty industrial machines (generator sets, welders, pressure washers, etc.) and in light logging machines (chainsaws, log splitters, shredders, etc.).
These engines **rated at or below 19 kilowatts**.

**Engines types in different applications**
A summary of the **engine types** used in agricultural sector is also given below.

### Agriculture and Forestry

- **Two-Wheel Tractors**
  Tractors are used in agriculture (and forestry) as universal working machines. Very small one axle/two wheels tractors only have a few kW power output (about 5 to 15 kW) and are equipped with two-stroke or four-stroke petrol, LPG or with diesel engines.

- **Farm tractors**
  Two axles/four-wheel tractors (there are also some articulated-wheel and crawler-type tractors which fall under this category) are nearly all exclusively diesel-engine powered and have a power output of between 20 and about 250 kW.
- **Others**
  Under this heading falls all other agricultural equipment, e.g., sprayers, manure distributors, mowers, balers, tillers, swatchers. They are mainly diesel engines, but two- and four-stroke petrol engines are also used in these machines. The power output is in the range of 5 to 50 kW.
- **Professional chain saws/clearing saws**
  These are chain saws for professional use; all are two-stroke petrol-engine driven with a power output of about 2 to 6 kW.
- **Others**
  This heading covers machines such as tree processors, haulers, fellers, forestry cultivators, shredders and log cultivators. They are mainly diesel engine equipment; some use two-stroke engines.

### 3.4.1. Spark Ignition (Otto cycle) LPG Fuelled Engines

Spark ignition dedicated mono LPG fuelled engines operate much like petrol engines. The primary advantage of these engines is that they use 100% LPG as fuel. Without additional petrol or diesel systems on board, machinery that uses such engines carries only one type of fuel and there is no need for a second fuel delivery system.

Such engines had been developed earlier in Japan, the USA and elsewhere. However, development did not continue at the same pace of other type of engines like diesel, petrol or CNG power units. For converting such engines to LPG, there is third party conversion technology available.

**Engine examples**
**KOHLER**

**COMMAND PRO EFI PROPANE PCV740**
KOHLER® Command PRO EFI LPG engines are cleaner-burning.

Features:

- Saves significantly on fuel, with less downtime for refuelling.
- Produces over 50% fewer hydrocarbon emissions, helping to reduce smog formation.
- Advanced sensor technology allows engine to optimise performance by automatically adapting to operating conditions.
- Starts like a car - just turn the key and go.

**Envirogard GKFX730V**
23.5hp Air-Cooled V-Twin 4-Cycle Vertical Shaft

Features:

- Vertical shaft OHV LPG engine.
- EPA & CARB certified.
- Patented LPG fuel system installed on engine.
- Dual stage canister air filter.
- Suitable applications include lawn mowers, construction equipment.
- High efficiency oil cooler.

**Envirogard GKFX600V**
**19hp Air-Cooled V-Twin 4-Cycle Vertical Shaft**

Features:

- Vertical shaft OHV LPG engine
- EPA & CARB certified
- Patented LPG fuel system installed on engine
- Dual stage canister air filter
- Suitable applications include Ztr lawn mowers, construction equipment
- High efficiency oil cooler

**Envirogard GKFS600V**
**18.5hp Air-Cooled V-Twin 4-Cycle Vertical Shaft**

Features:

- Vertical shaft OHV LPG engine
- EPA & CARB certified
- Patented LPG fuel system installed on engine
- Suitable applications include walk behind lawn mowers, construction equipment, floor polishers
- Indoor emission shutdown system (optional)
- Automotive grade catalytic muffler for indoor use (optional)
- High efficiency oil cooler

**Yanmar**

New models: Industrial gas engines: 4TN88G, 4TN98G

Yanmar recently developed two models: 4TN88G: maximum output 45.0kW and 4TN98G maximum output 63.0kW which run on LPG and are compliant with U.S. EPA Tier 2, CARB Tier 4 and EU Stage Ⅴ emissions regulations.


Furthermore, Yanmar has plans to introduce bi-fuel specification models that can run on both LPG and Petrol. These LPG engines produce very little PM (particulate matter), and are comparatively quieter than diesels. This makes them ideal for work indoors and in enclosed areas, where environmental concerns are a major consideration.

| Model | Displacement | Output | Emissions compliance |
|---|---|---|---|
| 4TN88G | 2,2 L | 45,0 kW | U.S. EPA Tier 2, CARB Tier 4 Fase V dell'UE |
| 4TN98G | 3,3 L | 63,0 kW | |

**Kubota WG series**

The WG1903 is a newly created 1.9 Litre, 3-cylinder model designed for use with LPG, petrol, natural gas and dual fuel capability.

Engine specifications:

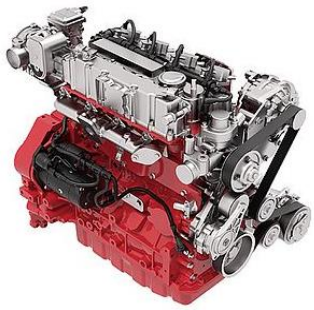
| | |
|---|---|
| **Engine model** | **WG1903-GL** |
| **Emission regulation** | **EPA Tier2 / CARB Tier3 / EU Stage V ready** |
| **Type** | **Vertical, water cooled 4-cycle SI engine** |
| **Fuel type** | **LPG / Petrol** |
| **Cylinders** | **3** |

The WG1903 has been available since 2019.

The Kubota D902-T is an all-new compact premium model within the New Super Mini (NSM) Series. The new model has been ready for EU Stage V since 2019 and forms part of an extensive range of Kubota power solutions.

**DEUTZ G 2.2 and G 2.9**

The newly designed **DEUTZ G 2.2** and **G 2.9** are water-cooled 3- and 4-cylinder spark plug ignited LPG engines 35 – 73hp.



**Bigas – Cavagna Group Enerkit - Conversion Technology**

Enerkit Line, engineered by Cavagna, is an innovative line of gasoline to LPG conversion systems for small engines. The target market includes a wide range of applications, from trimmers and blowers to lawnmowers and snow throwers, from freestanding power generators and water pumps to ride-on mowers and industrial vehicles such as forklifts. Enerkit is committed to supporting the increased usage of LPG fuel. Be it at home or outdoors, LPG promotes a healthier and greener way of life.

By replacing the carburettor, Enerkit enables all engines to easily convert to LPG. Conversion offers the consumer the immediate benefits of protecting the environment and saving money. In addition, Enerkit provides lower odour emissions, reduced engine maintenance, and greater convenience. Enerkit's simple, clean connection to an LPG cartridge or cylinder eliminates spilled gasoline.

- Enerkit BASIC, designed for mono-fuel 2 and 4-stroke engines from 20 cc to 450 cc, is based on an innovative LPG carburettor. With Enerkit, the carburettor is installed between the air filter and the intake manifold, as in the traditional gasoline carburettor. Enerkit BASIC offers three models: it can be used in handheld tools such as trimmers powered by cartridges; walk

behind/recreational equipment such as lawnmowers powered by cartridges or small cylinders; and freestanding equipment such as generators powered by cylinders.

- The Enerkit PLUS line converts 250 cc to 850 cc 4-stroke engines (such as forklifts, ride-on mowers, and industrial sweepers) to LPG. In order to power these engines, two configurations have been developed: mono-fuel and bi-fuel. The innovative mono-fuel system, for installation by OEMs only, integrates the functions of gas supply in the LPG mixer, eliminating the carburettor and the fuel tank. The bi-fuel configuration, primarily for aftermarket conversions, uses a traditional gas mixer inserted between the air filter and the gasoline carburettor. ENERKIT PLUS is available in vapour-phase and liquid-phase withdrawal.

| | K21 | | K25 | |
|---|---|---|---|---|
| | Non-electronically controlled | Electronically controlled | Non-electronically controlled | Electronically controlled |
| Displacement (cc) | 2065 | 2065 | 2488 | 2488 |
| Bore x Stroke (mm) | 89.0×83.0 | 89.0×83.0 | 89.0×100 | 89.0×100 |
| Fuel | Gasoline & LPG | Gasoline & LPG | Gasoline & LPG | Gasoline & LPG |
| Compression ratio | 8.7 | 8.7 | 8.7 | 8.7 |
| Rated power output (kW) | 31.2 | 41 | 35.6 | 46.9 |
| Rated engine speed ($min^{-1}$) | 2200 | 2700 | 2250 | 2700 |

**Briggs & Stratton** commercial power engines are available for LPG conversion through LPG power systems. The conversions are available for certain Vanguard and Commercial series engines. The EPA-certified conversions are available for 11 Vanguard and Commercial Series engines, ranging in displacement from 205cc single-cylinder horizontals up to 993cc BIG BLOCK V-Twin engines. These certified converted engines allow equipment manufacturers to offer LPG to customers looking to take advantage of the benefits of LPG-powered equipment.

### 3.4.2. Spark Ignition (Otto cycle) Petrol -LPG Bi-Fuelled Engines

This is one of the largest categories in the smaller LPG engine segment. Bi-fuel petrol-LPG engines exist in the market either as OEM engines or as conversions from existing petrol models.

**Engines**

Global Component Technology Corporation (GCT) is a wholly-owned subsidiary of UniCarriers Corporation, which is a group company of Mitsubishi Heavy Industries Forklift, Engine & Turbocharger Holdings, Ltd. (M-FET). One of their main products is the K type, a 2.0-liter class, spark-ignited, in-line four-cylinder engine mainly for forklift trucks and gas heat pumps (GHP).

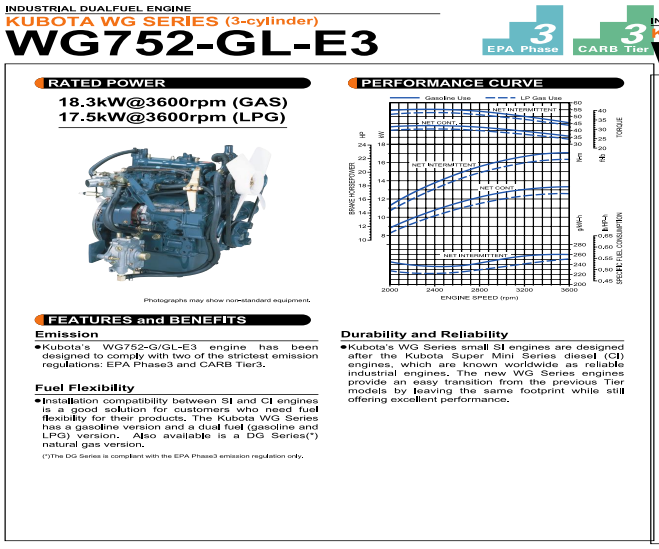
There are three variations of engine displacement (1.5-liter, 2.1-liter, and 2.5-liter), and they utilize common packaging to enhance efficiency for installation on vehicles. These engines are supplied to many foreign forklift truck manufacturers, as well as all domestic forklift truck manufacturers other than Toyota Motor Corporation, including Mitsubishi Nichiyu Forklift Co., Ltd. and UniCarriers Corporation, which are M-FET group companies.

**Specifications of engines for forklift trucks**

**KOHLER COMMAND PRO CH395TF**

Command PRO gaseous fuel engines are designed to run on either petrol, natural gas or LPG. This professional line of carburetted LPG and natural gas engines eliminates bad petrol issues and skips fuel-system winterisation.

**KUBOTA**



INDUSTRIAL DUALFUEL ENGINE
KUBOTA WG SERIES (3-cylinder)
WG752-GL-E3

3 EPA Phase 3 CARB Tier

RATED POWER
18.3kW@3600rpm (GAS)
17.5kW@3600rpm (LPG)

Photographs may show non-standard equipment.

PERFORMANCE CURVE

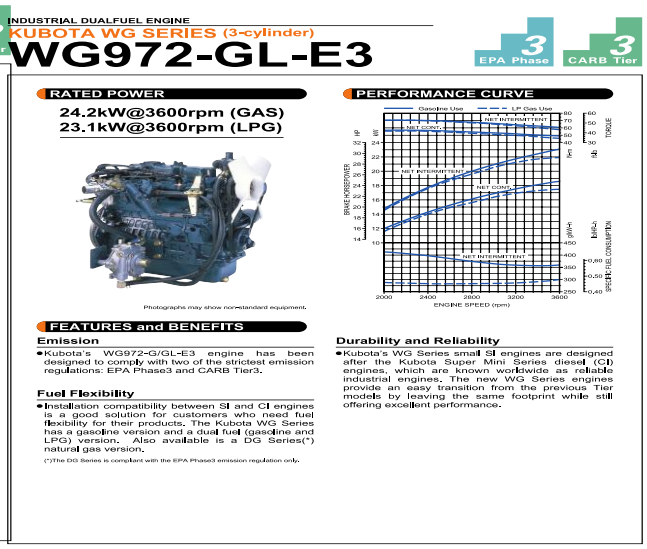
FEATURES and BENEFITS

Emission
- Kubota's WG752-G/GL-E3 engine has been designed to comply with two of the strictest emission regulations: EPA Phase3 and CARB Tier3.

Fuel Flexibility
- Installation compatibility between SI and CI engines is a good solution for customers who need fuel flexibility for their products. The Kubota WG Series has a gasoline version and a dual fuel (gasoline and LPG) version. Also available is a DG Series(*) natural gas version.

(*)The DG Series is compliant with the EPA Phase3 emission regulation only.

Durability and Reliability
- Kubota's WG Series small SI engines are designed after the Kubota Super Mini Series diesel (CI) engines, which are known worldwide as reliable industrial engines. The new WG Series engines provide an easy transition from the previous Tier models by leaving the same footprint while still offering excellent performance.



INDUSTRIAL DUALFUEL ENGINE
KUBOTA WG SERIES (3-cylinder)
WG972-GL-E3

3 EPA Phase 3 CARB Tier

RATED POWER
24.2kW@3600rpm (GAS)
23.1kW@3600rpm (LPG)

Photographs may show non-standard equipment.

PERFORMANCE CURVE

FEATURES and BENEFITS

Emission
- Kubota's WG972-G/GL-E3 engine has been designed to comply with two of the strictest emission regulations: EPA Phase3 and CARB Tier3.

Fuel Flexibility
- Installation compatibility between SI and CI engines is a good solution for customers who need fuel flexibility for their products. The Kubota WG Series has a gasoline version and a dual fuel (gasoline and LPG) version. Also available is a DG Series(*) natural gas version.

(*)The DG Series is compliant with the EPA Phase3 emission regulation only.

Durability and Reliability
- Kubota's WG Series small SI engines are designed after the Kubota Super Mini Series diesel (CI) engines, which are known worldwide as reliable industrial engines. The new WG Series engines provide an easy transition from the previous Tier models by leaving the same footprint while still offering excellent performance.

### 3.4.3. Compression Ignition Diesel-LPG Dual Fuel Engines

These are engines that use a mix of diesel and LPG as a fuel and are mostly modified diesel engines to accept a certain proportion of LPG in the fuel mix, typically of the order of 30% to 55%.

Diesel engines powered by LPG are an excellent way to reduce pollutant emissions while improving energy performance. The high auto ignition endurance of LPG requires specialised fuelling methods. Of all the possible LPG fuelling methods, the diesel-gas method is the most common solution for retrofitting existing diesel engines for following reasons:

- It is easy to implement even on already in-use engines.
- The engine does not need important modifications.
- The LPG-air mixture has high homogeneity with favourable influences on the combustion efficiency and
- Over the level of pollutant emissions, especially nitrogen oxide emissions.

The theoretical and experimental investigations into operation of a LPG fuelled heavy duty diesel engine at two operating loads, 40% and 55%. For 55% engine load is also presented the exhaust gas recirculation influence on the pollutant emission level. The impact of the diesel fuel with LPG substitution ratio on the combustion parameters (rate of heat released, combustion duration, maximum pressure, maximum pressure rise rate), energetic parameters (indicating mean effective pressure, effective efficiency, and energetic specific fuel consumption), and pollutant emissions level was determined. These diesel engines are converted to dual fuel diesel blend through specific systems, kits that allow the replacement of a certain quantity of diesel with LPG. Making use of parameters such as engine speed, turbo pressure, amount of diesel injected, position of the accelerator pedal, engine torque and coolant temperature, the systems determine the optimum balance between diesel and LPG.

The key components of these alternative fuel systems are specially designed for the specific engines and their installation is relatively easy. Their dedicated diagnostic software enables fine tuning of the diesel blend system for optimal performance and emission reduction.

Dual fuel diesel-LPG operation has certain advantages compared to diesel only and spark ignition (SI) engines, higher thermal efficiency resulting from faster burning, less harmful emissions and high fuel power density. Harmful emissions due to diesel and greenhouse gases can BE significantly reduce (10-15%). However, this is very dependent on the application and use offering the highest advantages at constant loads. Diesel-LPG dual fuel engines have good thermal efficiency at high output but the performance is less during part load conditions, although this problem can be mitigated with various techniques.

Such conversions can present technical problems as well, particularly with the availability of specific fuel supply systems fuel injection control and engine optimisation to ensure that the engine performance is maintained and the exhaust emissions are indeed minimised. If this technology, is proven advantageous, it can be best achieved with OEM solutions, since modern diesel engines, Euro 5 and more recent, have very complex and sophisticated electronic controls that any changes in the operation of the engine may cause "ECU recovery" of the vehicle. Furthermore, many recent regulations do not allow changes to engine components without new approval, resulting in expensive, complex and time-consuming procedures, much like the homologation of a new engine.

### 3.4.4. Agriculture and Farming Stationary Engines

Hybrids are part of the latest developments in engine and vehicle technologies. A hybrid system is one that uses two different energy sources and it is typically referred to as a hybrid electric system which combines a conventional internal combustion engine with an electric motor.

LPG Hybrids have the potential to set a new standard for fuel economy and environmental performance and technological options for LPG hybrid conversion are now available.

The batteries that the electric motor uses are recharged by the engine. Although standard diesel is the most common fuel used to power the conventional internal combustion engine, petrol, ethanol and CNG hybrids have also been developed.

However, combining the best automotive technology, electric hybrid drive with the cleanest and most economical commercial fuel, LPG engine technology can yield spectacular results. The petrol-electric hybrid drive is already of the most economical engine configurations on the market.

Such a vehicle can have two energy sources, LPG and an HV battery (LPG-electric ). In addition, this, can be combined with two options of transmission solutions, parallel hybrid drive or serial electric drive:

**Parallel Hybrid Drive**

This configuration consists of an internal combustion engine working together with an electric motor both connected to the transmission system.

**Serial Electric Drive**

The new generation of hybrid configurations are in reality only electric, since they use an internal combustion engine as a “Range Extender” generator. Only the electric motor is connected to the transmission.

Fuel system technologies are key in engine development. The technology around fuel delivery in petrol and diesel engines has developed significantly over the years. Consequently, such technologies, also related to LPG use as an engine fuel, have evolved and several such advanced systems are today present in the market. However, not all are equally applicable at present to SHDEs.

The most common fuel system technologies available today are listed below:

#### 3.4.4.1. Venturi systems

Also, known as converter and mixer or vacuum type systems, these are mechanically the simplest of all systems and can be made to work without any electronics. They consist of the three basic elements: fuel tank, converter (vaporiser/regulator) and mixer. While no longer conforming to the newest emissions regulations, they can still be used to convert older carburetted engines or other machinery.

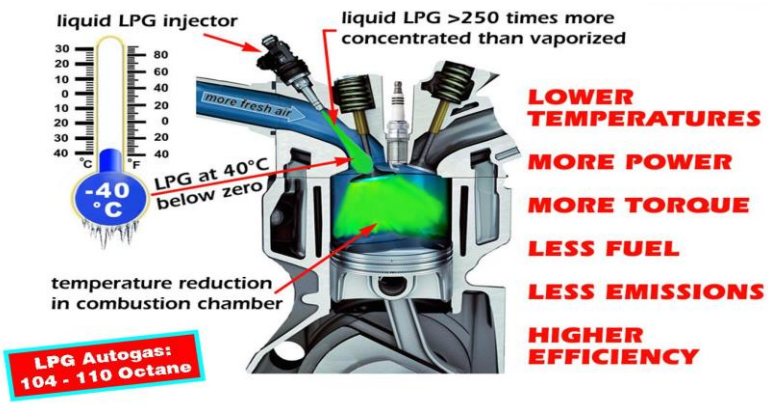
#### 3.4.4.2. Vapour Port Injection

This system uses a converter like that in the converter-and-mixer system, but the gas exits the converter at a regulated pressure and it is then injected into the air intake manifold via a series of electrically controlled injectors, allowing for more accurate metering of fuel to the engine than is possible with mixers, improving fuel economy, increasing power

and reducing emissions. The injector opening times are controlled by the LPG control unit, which works in a similar way to a petrol fuel-injection control unit. Most vehicles of recent vintage use this type of fuel system.

#### 3.4.4.3. Liquid Port Injection (LPI)

This type of system delivers the liquid fuel directly into a fuel rail at high pressure via a liquid LPG injector in much the same manner as a petrol-injection system. As the fuel vaporises in the intake, the surrounding air is substantially cooled; this increases the density of the intake air and can potentially lead to substantial increases in engine power output, improving engine efficiency and performance. The system is controlled by an electronic control unit (ECU), a dedicated computer that regulates the various components, working in tandem with the vehicle's own petrol computer to optimise the injection timing.




*Source: Image by X-Tech*

LPI systems have proven that they can achieve better fuel economy and power as well as lower emissions than VPI systems and are gaining popularity today.

It is to be noted that advanced fuelling systems for modern engines today require the LPG fuel to be of high and consistent quality to protect the LPG pump and injection components from damaging impurities.

**Examples**

Forklifts are crucial to running efficient and effective manufacturing and warehousing plants. Initially, counterbalance forklifts were fitted with internal combustion (IC) engines using diesel or LPG. Electric forklifts produce zero emissions during use and are noiseless, permitting indoor application but they also have shortcomings as they are not ideal for outside use so operators require different forklifts for indoor and outdoor use, with forklifts costing from €25,000 to €90,000.

**Nexen Transport** has developed a novel hybrid counterbalance forklift truck using both an IC engine and electric power to deliver excellent performance in both indoor and outdoor use for large logistic entities with both indoor and outdoor operations such as freight, logistics, retail and wholesale companies.

**FlexiHyLift** will deliver a new range of intelligent, environmentally friendly, highly efficient, versatile and cost-effective counterbalanced forklift trucks with benefits including:

- Light, modular power pack with a lithium ion battery with super capacitor capability and is re-chargeable through the hydraulic system of the forklift.
- Can be switched from IC power to battery power during indoor and outdoor use respectively.
- High-energy efficiency and cost effectiveness owing to the novel modular, hybrid power pack. The power pack recovers energy during the IC engine operation through a small, highly efficient IC range extender engine.

## 3.5. Main Players – Manufacturers

The main players segment consists of engine only manufacturers, technology developers, as well as manufacturers of equipment, machinery and vehicles that use these engines. Several players exist in developed countries. The number of OEM quality platforms for agriculture applications is growing with partners in the USA, Europe, Japan and others.

**Manufacturers – Examples of Engine and Equipment Developers (further information can be found in the specific application segments)**

**LPG Conversion Kits OEMs**

**Greengear**

**Enerkit** can convert any small engine to LPG, from outdoor power equipment to off-road vehicles.
Two types of Enerkit are available:

The Enerkit Plus is suitable for engines from 250cc to 1000cc, for products like riding mowers, turf vehicles, industrial equipment, etc.


The Enerkit Basic is suitable for engines from 20cc to 450cc, for products like lawnmowers, power generators, water pumps, pressure washers, etc.


**Propane Power Systems,** LLC supplies LPG conversion kits for Briggs & Stratton and Vanguard Engines. They have engineered a system that beats strict emissions standards and enables them to lower fuel costs and engine maintenance.

Briggs & Stratton commercial power engines are available for LPG conversion through Propane Power Systems, LLC. The conversions are EPA-certified and are available for 11 Vanguard and Commercial Series engines, ranging in displacement from 205cc single-cylinder horizontals up to 993cc Big Block V-Twin engines.

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## 3.6. Safety

The development of any new technology, especially if it involves engines and machinery requires the uppermost attention and consideration of safety implications. LPG, like any other engine fuel, can be entirely safe as long as the equipment is designed correctly with all safety aspects considered and the operation is carried out equally in the same manner. New technologies require a thorough assessment of all potential safety risks.

## 3.7. Training

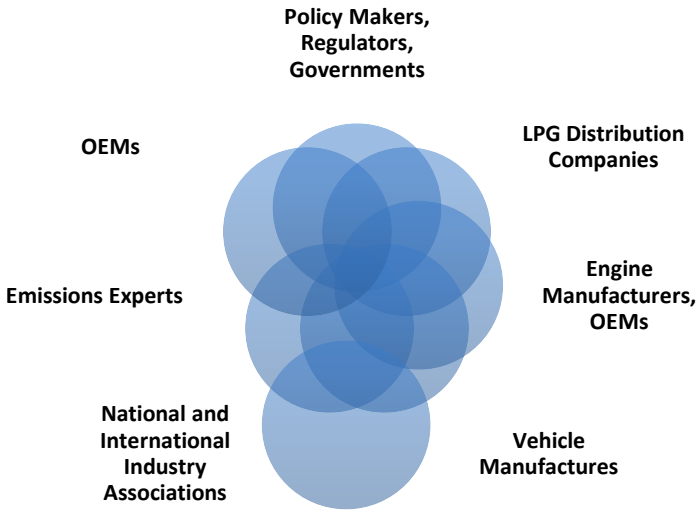
Training of personnel in new technologies, new equipment and particularly in areas where safety is of prime concern is key. This is the case when LPG is introduced as a new alternative fuel in any equipment or operations. Adequate training is a prerequisite before any such new engine and equipment is put into service.


## 3.8. Quality of Fuel

The manufacturers of all types of engines have specific requirements for the quality of the fuel used in their engines. Currently, the quality of LPG used as an engine fuel can vary significantly from country to country or even within regions in the same country. As a result, in order to qualify and maintain LPG as a leading alternative fuel for transportation and for industrial machinery today and for the future, it is becoming increasingly important to ensure to manufacturers, OEMs, a constant composition and quality of the fuel, as well as improved controls in the distribution chain to keep it free of impurities and contaminants. The further development of the market for LPG fuelled engines depends on the availability of OEM engines and vehicles, and this in turn depends on the availability of reliable, good quality fuel in the market.

## 3.9. Main Stakeholders

The role of the various stakeholders is instrumental in driving growth of Agricultural market, helping products commercialise and raising customer and policymaker awareness. Key stakeholders include:



## Chapter Four

# Environmental Aspects

Agriculture is essential for humankind; it provides the food we eat, serves as the livelihood of millions of people worldwide, and manages a large share of the landscape. In doing so, however, greenhouse gases (GHG) are released, making agriculture also a source of emissions that contribute to climate change. Since agriculture depends on natural resources and the climate to provide a suitable environment for crops to grow, climate change threatens to cause major disruptions for agriculture in the future. Adaptation in agriculture must therefore be prioritised alongside efforts to reduce emissions from the sector and maintain food production. Balancing these competing interests presents a significant policy challenge.

*Source: SHV ENERGY*

*Source: ttv-gmbh.de*

**Drivers shaping the use of LPG in Agriculture**

As the environmental protection agenda has morphed into the more inclusive goal of sustainable development over the last four decades, clean technologies (CT) have become an important tool, including in agriculture.

**Air Pollution and Climate Change**

Protection of the environment and improvement of air quality are important objectives of today's regulators.
Global warming is of concern to all. Therefore, a clean fuel like LPG which can power agricultural machinery without contributing to climate change has to be worth considering.

Pollutants concerned in agriculture: $PM_{10}$, $PM_{2,5}$, $NO_X$, $NH_3$ and phytopharmaceutical products.[6]
Main origins:

- Livestock farming: Buildings, storage and manure spreading, grazing.
- Farming: Sludge, fertilisers and phytosanitary products spreading, swilling.
- Silviculture: Specific excavators.
- Other origins: Combustion plants, air conditioning, tractors, open-air burning of crop residues.

Compared to most hydrocarbons, LPG has a low carbon to hydrogen ratio. This means that it will generate lower amounts of harmful $CO_2$ when it burns. It also has a higher calorific value per mass unit than other common fuels, so its flame burns hotter, delivering higher efficiency.

According to the UN International Panel on Climate Change, LPG is not a greenhouse gas and has been assigned a global warming potential factor of nearly zero. Direct emissions of LPG therefore do not contribute to climate change.

*Source: Calor Gas*

[6] https://www.europarl.europa.eu/meetdocs/2014_2019/documents/envi/dv/agriculture/agriculturefr.pdf

Air pollution affects the health of humans, as well as plants, animals and even buildings. Most pollution is
*Source: Calor gas*

caused by the burning of fuel and, as governments and organisations around the world now recognise, LPG can help improve air quality.

## Reduced Emissions

There are over 300 million acres of land used for agricultural purposes throughout the USA. While farming is a necessary industry, it accounts for a large portion of air and water pollution. Because of this, farmers are looking for more sustainable and eco-friendly farming practices. In an effort to reduce their carbon footprint, farmers have turned to LPG as an alternative fuel source for irrigation engines, dryers, and other farming equipment.

**LPG powered farming equipment emits roughly 15% less greenhouse gas emissions than diesel counterparts and 24% fewer greenhouse gasses than gasoline structures. With fewer produced emissions, LPG is a clean-burning fuel source that reduces the agricultural industry's carbon footprint.**

## Financial Incentives

Farmers have the ability to reap the rewards of LPG incentives. There are a number of financial incentives in place by the government for farmers who use LPG based technology and equipment. The Propane Education and Research Council (PERC) leads the charge in testing the efficiency of these programs for farmers. PERC makes it easy for farmers to see the effects of switching to LPG fuelled systems, both ecologically and financially. As the demand for sustainable farming grows, so does the use of LPG.

## Poverty and Wellbeing

Access to modern energy provides the productive capacity for stimulating economic development and reducing conditions of poverty while improving health, air quality, productivity, comfort and education. By delivering cleaner, modern fuel in the form of LPG, and creating sustainable markets for its use, LPG provides rural areas with the means to generate a wide range of productive farming processes in order to deliver vastly improved living conditions.

Because it is portable, clean, safe and extremely efficient in generating heat, LPG is a major step up on the energy ladder and presents an excellent option for delivering energy services in rural areas where few viable alternatives exist. These characteristics demonstrate immediate value to communities by providing a more efficient and cleaner means by which to farm lands and produce food.

LPG is a resource that generates multiple productive services developing micro-economies and generating income at the community level. Access to LPG in these rural communities also extends to the creation and/or modernization of small production enterprises like agriculture. As an example, rural America has a long history with LPG stretching back 100 years. Over 50% of rural Americans use LPG in their homes, and another 40% also use it in their farming operations with over a million tons of LPG per year used in American farm country.

## 4.1 Regulatory Framework [7]

The relationship between agriculture and climate change is twofold, agriculture is a contributor to greenhouse gases and is a sector affected by the impacts of climate change.

**Energy Input in Agricultural Production**

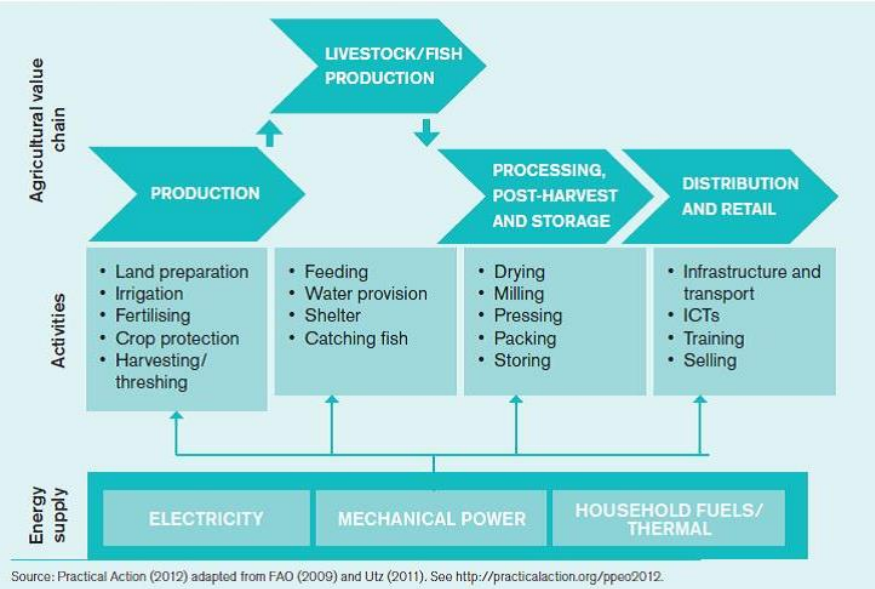
The potential for climate change mitigation and hence for decreased GHG emissions lies in every single step of the agricultural value chain, with its diverse direct and indirect energy inputs. Energy is used at every stage: from production through processing, post-harvest and storage to distribution and retail.

Direct and indirect energy inputs are equally necessary in agricultural value chains but they occur at different steps. Farms and processing plants apply direct energy at the operational level. Additional energy consumed for production, processing and commercialisation of products is categorised as a direct energy input, as is energy for irrigation, land preparation and harvesting.

Direct energy in irrigation systems has the potential to lower emissions. Indirect energy is applied through the use of machinery, pesticides and fertilisers.

**Energy Input in the Downstream Sector**

The downstream sector in agricultural value chains includes processing, post-harvest, storage and cooling. These activities can easily consume large amounts of energy.



Source: Practical Action (2012) adapted from FAO (2009) and Utz (2011). See http://practicalaction.org/ppeo2012.

Tobacco production in Zimbabwe is an example: the (heat) curing process accounts to over 50% of the total on-farm energy demand. The use LPG can replace other fuels in this heating process.

There are several measures to preserve food. Cooling is one option for preserving food quality; however, its carbon footprint is far from insignificant. For some products, the total carbon footprint can amount to 10% and that's only taking their refrigerated storage into account. If electricity inputs, the manufacturing of cooling equipment and lost refrigerants are considered, it is clear that GHG emissions from the refrigeration process are skyrocketing.

Energy consumption does not stop with the on-farm food operations and measures to preserve product quality. Wet-milling of corn accounts for up to 15% of total energy consumed by the food industry. When the best technologies are not used, food processing plants produce with an energy intensity that is up to 50% higher than necessary. By utilising thermal and mechanical vapour compression, the milling of wet corn could save up to 15-20% in its energy-intensive dewatering, drying and evaporation process.

[7] Food and Agriculture Organization of the United Nations

## Environmental Protection

### EU Regulation sets stricter Eiesel Engine Exhaust Emissions

Over the last twenty years, engine exhaust emissions from agricultural machines have been reduced significantly in line with applicable EU legislation. A modern agricultural tractor emits about 95% fewer nitrogen oxides (NOx) and particulate mMatter (PM) than a comparable machine did twenty years ago.

Exhaust emissions from all off-highway combustion engines (including farm tractors) are estimated by the European Commission to contribute approximately 15% of nitrogen oxides (NOx) and 5% of particulate matter (PM) to air pollution in Europe. For off-highway diesel engines, European emissions standards apply to engines used in non-road mobile machinery (NRMM).

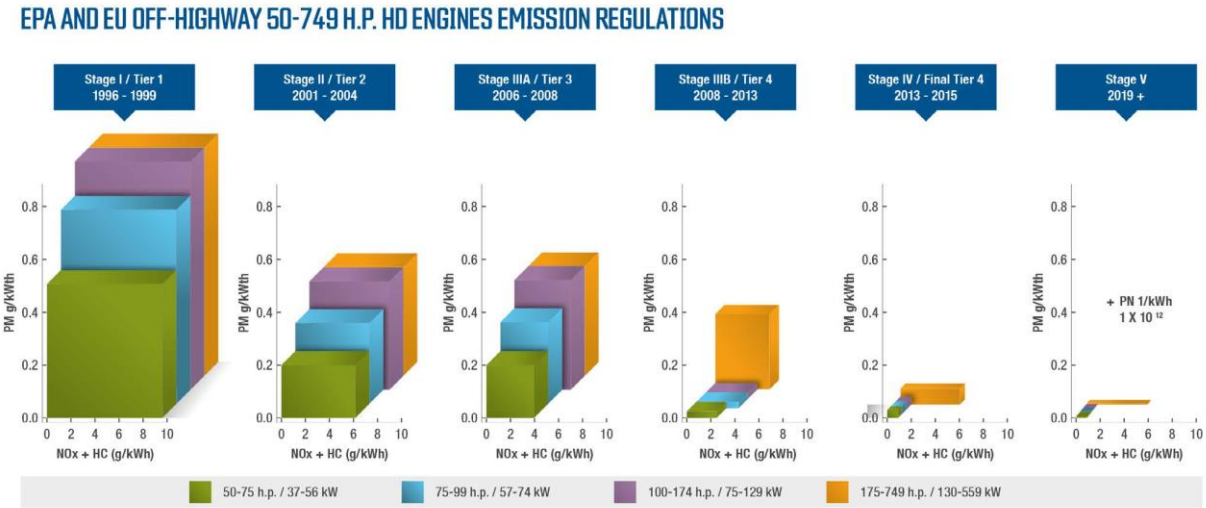



***Fig 1:*** *EPA and EU off-highway 50-749 h.p. HD engines emission regulations*

### Clean Agricultural Machines – What's New?

From 2019 onwards, a further reduction in diesel engine emissions has been applied as new limits, the so-called 'Stage V' requirements, became effective. This new regulation introduced particulate number limits and emission limits for the smallest and biggest engines used in agricultural machines (<19kW & > 560kW). With this step, EU environmental requirements for agricultural machines became the strictest in the world. This requires major changes to tractors and other agricultural machinery as new engines need to be installed in these vehicles. It is important to underline that the European agricultural machinery industry currently produces a broad range of different machines with diesel engines (such as tractors or combine harvesters).

**Stage V introduces particulate number (PN) limits for the first time and mandates carbon monoxide (CO), hydrocarbon (HC), PM and NOx limits across a much broader range of engine kW power ratings. PM limits are also now 40% lower versus Stage IV for engines rated between 56-560 kW.**

While the Stage V standard applies to many markets, the most substantial impact is on diesel engine models widely used in construction and agriculture, with all equipment facing compliance irrespective of engine power output. For a farm tractor with an engine size between 130 and 560kW, PM reductions of 72% and HC+NOx reductions of 94% show how strict legislation has become and reinforce the important role farm tractors have to play in a more sustainable, safer and cleaner future.

## NRMM including agricultural machinery

Non-Road Mobile Machinery (NRMM) is a broad category which includes mobile machines, and transportable industrial equipment or vehicles that are fitted with an internal combustion engine such as combine harvesters. The EU has decided to introduce this NRMM regulation now it is a very timely piece of legislation, fully in line with a broader trend – particularly evident in Europe and the USA – towards wider and stricter environmental controls. With this general trend, confirmed by the implementation of the EU's air quality policy, we are seeing a systematic reduction in the tolerated levels of harmful substances such as nitrogen oxides. At the same time, the legislative net is tightening to include more and more emission sources. Thirdly, policy-makers are looking to include new chemicals and chemical species within the scope of new and amended regulations. NRMM reflects all three dimensions.

European legislators are gearing up for stricter emission standards for off-road machinery, are tightening the net around sources of emissions other than automotives. At the end of 2016, they released a new "Regulation of the European Parliament and of the Council on requirements relating to gaseous and particulate pollutant emission limits and type-approval for internal combustion engines for non-road mobile machinery". The new measures aim to progressively reduce emissions from non-road mobile machinery and phase out polluting equipment.

Agricultural tractors fall under a separate directive (EC/167/2013) and must meet the emissions limits from the previous NRMM directive (EC/97/68). Tractors should adopt the revised NRMM emission limits as soon as the proposal is adopted and not remain under the old directive limits.

Other countries are regulating non-road machines, and this proposal aligns quite closely with US Tier 4 limits for most pollutants (HC, NOx, CO, PM) that have been phased-in from 2008 to 2014. Most countries are basing their legislation on the US and EU standards. It is important for Europe to set ambitious targets that would then be adopted all over the world.

One of the bigger challenges that manufacturers may face – and one that will not be so easy to resolve – results from discrepancies between US and EU legislation. Regulatory fragmentation complicates life for global players, in particular, who are keen to harmonise production processes and testing standards worldwide.

Today's US Environmental Protection Agency (EPA) standards are generally stricter than current EU standards. The new EU Stage V would have the effect of aligning both frameworks to an extent, but would also establish some key differences between the two geographies. The most important of these would be the addition of the particulate number to EU regulations. Currently not within scope in the US, this provision would require manufacturers to fit a particulate filter to vehicles or equipment. This would mean that global producers would have to put different processes in place in order to distribute their products worldwide.

Looking beyond the growing pressure for a globally harmonised standard, it is likely that US legislation will also be stepping up its efforts in the NRMM sector. The scope of the regulation expanded from only regulating liquid-fuelled engines to also including gaseous-fuelled engines.

Requirements relating to gaseous and particulate pollutant emission limits and type-approval for internal combustion engines for construction, agricultural, materials handling, garden machinery, municipal equipment sectors and generator sets.

The regulation applies to engines of any power, any ignition system and any fuel, regardless of whether they are variable or constant speed, which are installed or intended to be installed in non-road mobile machinery unless excluded from the scope of the regulation. This regulation also applies to the non-road mobile machinery to which these engines are fitted to the extent that engine exhaust emissions are concerned.

**Emissions Stage V – Regulation (EU) 2016/1628 in Summary**

# Emission Limits – Land based non-road mobile machinery


| CI engines < 56kW & Engines >56kW | | Directive 97/68 | | | | | | New NRMM proposal | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| emissions in g/kWh | | Stage | CO | NOx | HC | PM | PN | CO | NOx | HC | PM | PN | A |
| **CI engines 0 - 8 kW** | variable & constant | - | - | - | - | - | - | 8 | 7,5 | | 0,4/0,6 | - | 1,1 |
| **CI engines 8 - 19 kW** | variable & constant | - | - | - | - | - | - | 6,6 | 7,5 | | 0,4 | - | 1,1 |
| *CI engines 19 - 37 kW* | variable & constant | IIIA | 5,5 | 7,5 | | 0,6 | - | 5,0 | 4,7 | | 0,015 | $1x10^{12}$ | 1,1 |
| *CI engines 37 - 56 kW* | variable | IIIB | 5,0 | 4,7 | | 0,025 | - | 5,0 | 4,7 | | 0,015 | $1x10^{12}$ | 1,1 |
| | constant | IIIA | 5,0 | 4,7 | | 0,4 | - | | | | | | |
| *Engines 56 – 130 kW* | variable | IV | 5,0 | 0,4 | 0,19 | 0,025 | - | 5,0 | 0,4 | 0,19 | 0,015 | $1x10^{12}$ | 1,1 |
| *Engines 56-75 kW* | constant | IIIA | 5,0 | 4,7 | | 0,4 | - | 5,0 | 0,4 | 0,19 | 0,015 | $1x10^{12}$ | 1,1 |
| *Engines 75 – 130 kW* | | | 5,0 | 4,0 | | 0,3 | - | | | | | | |
| *Engines 130 – 560 kW* | variable | IV | 3,5 | 0,4 | 0,19 | 0,025 | - | 3,5 | 0,4 | 0,19 | 0,015 | $1x10^{12}$ | 1,1 |
| | constant | IIIA | 3,5 | 4,0 | | 0,2 | - | | | | | | |
| **Engines P > 560 kW** | variable & constant - Gen-Sets | - | - | - | - | - | - | 3,5 | 0,67 | 0,19 | 0,035 | - | 6,0 |
| | variable & constant - others | - | - | - | - | - | - | 3,5 | 3,5 | 0,19 | 0,045 | - | |

Limit values in line with US legislation
Limit values more stringent than US legislation

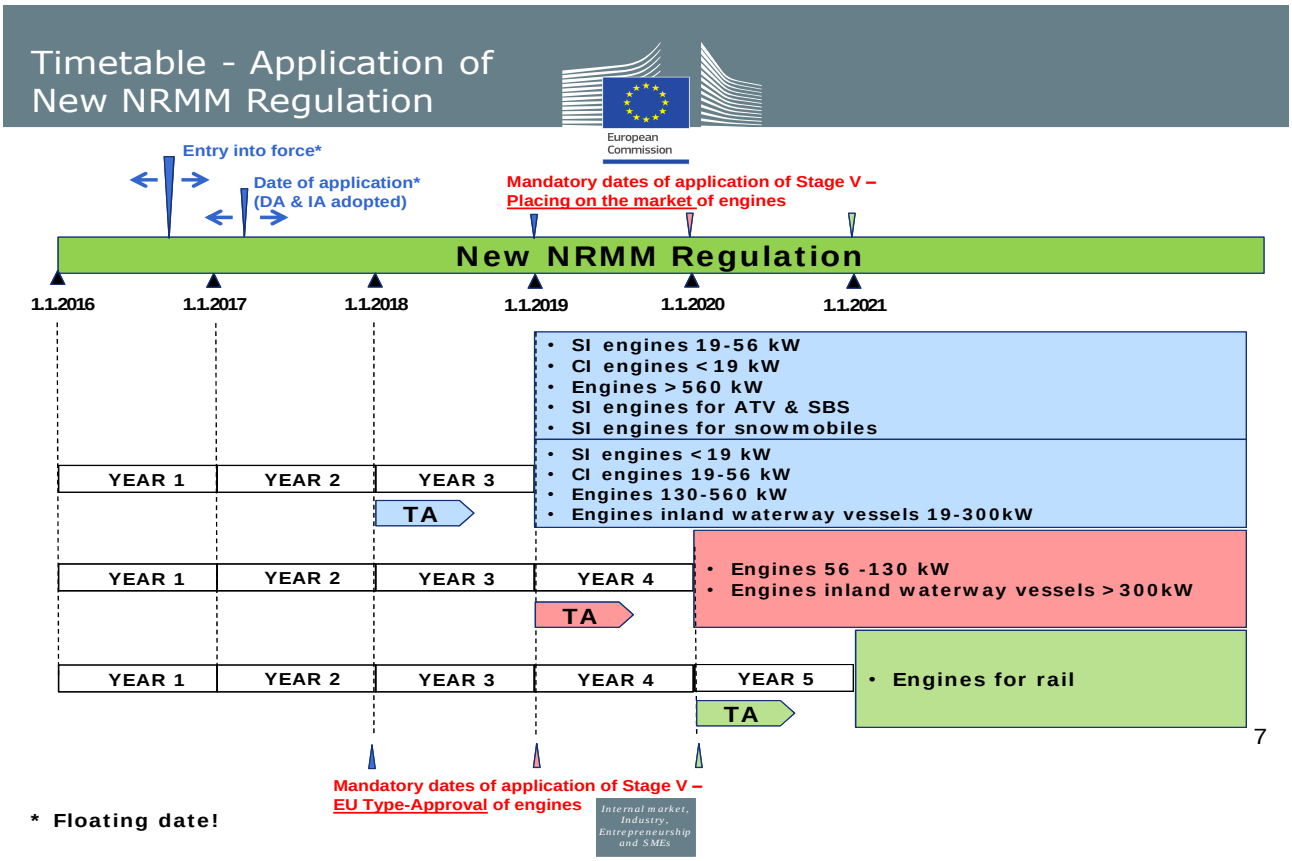
# Land-based NRMM
## (CI <56kW & Engines >56kW)

European Commission

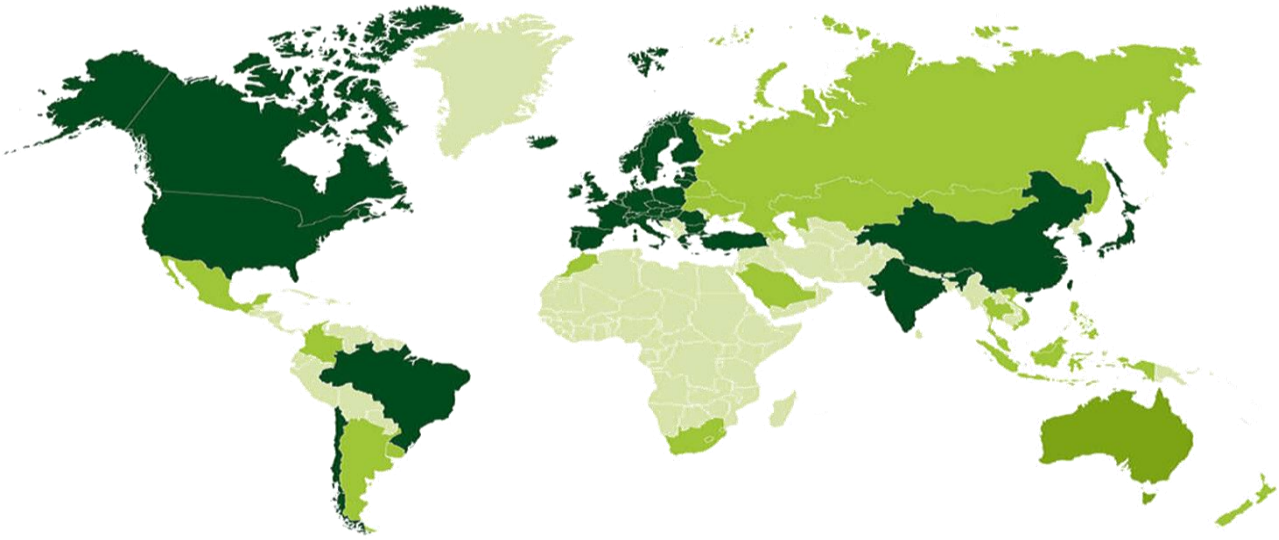

| CI engines < 56kW & Engines >56kW | | Directive 97/68 | | | | | | New NRMM proposal | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| emissions in g/kWh | | Stage | CO | NOx | HC | PM | PN | CO | NOx | HC | PM | PN | A |
| **CI engines 0 - 8 kW** | variable & constant | - | - | - | - | - | - | 8 | 7,5 | | 0,4/0,6 | - | 1,1 |
| **CI engines 8 - 19 kW** | variable & constant | - | - | - | - | - | - | 6,6 | 7,5 | | 0,4 | - | 1,1 |
| *CI engines 19 - 37 kW* | variable & constant | IIIA | 5,5 | 7,5 | | 0,6 | - | 5,0 | 4,7 | | 0,015 | $1x10^{12}$ | 1,1 |
| *CI engines 37 - 56 kW* | variable | IIIB | 5,0 | 4,7 | | 0,025 | - | 5,0 | 4,7 | | 0,015 | $1x10^{12}$ | 1,1 |
| | constant | IIIA | 5,0 | 4,7 | | 0,4 | - | | | | | | |
| *Engines 56 – 130 kW* | variable | IV | 5,0 | 0,4 | 0,19 | 0,025 | - | 5,0 | 0,4 | 0,19 | 0,015 | $1x10^{12}$ | 1,1 |
| *Engines 56-75 kW* | constant | IIIA | 5,0 | 4,7 | | 0,4 | - | 5,0 | 0,4 | 0,19 | 0,015 | $1x10^{12}$ | 1,1 |
| *Engines 75 – 130 kW* | | | 5,0 | 4,0 | | 0,3 | - | | | | | | |
| *Engines 130 – 560 kW* | variable | IV | 3,5 | 0,4 | 0,19 | 0,025 | - | 3,5 | 0,4 | 0,19 | 0,015 | $1x10^{12}$ | 1,1 |
| | constant | IIIA | 3,5 | 4,0 | | 0,2 | - | | | | | | |
| **Engines P > 560 kW** | variable & constant - Gen-Sets | - | - | - | - | - | - | 3,5 | 0,67 | 0,19 | 0,035 | - | 6,0 |
| | variable & constant - others | - | - | - | - | - | - | 3,5 | 3,5 | 0,19 | 0,045 | - | |

Internal market, Industry, Entrepreneurship and SMEs

Limit values in line with US legislation
Limit values more stringent than US legislation

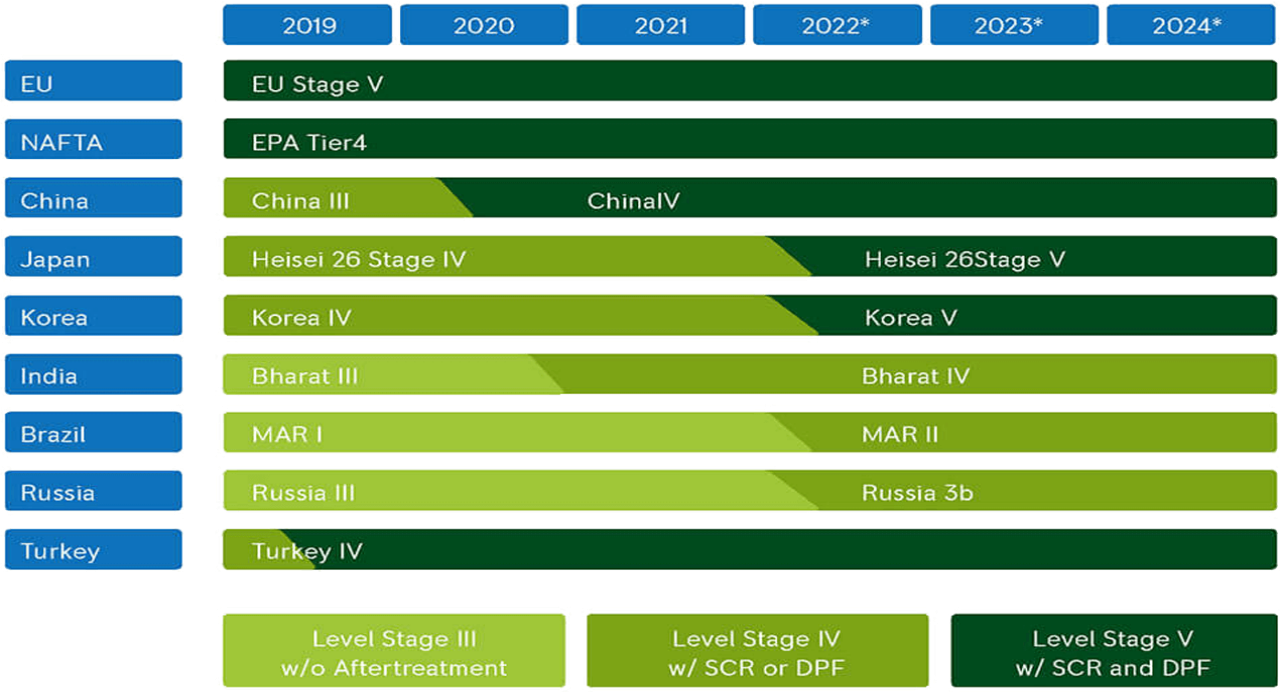



**NRSIEE emissions are regulated in other countries**



Non-road Spark Ignition Engines and Equipment (NRSIEE) emission standards have been introduced in North America (USA and Canada), Japan and China. Chinese emission standards for non-road mobile machinery are generally based on the European emission standards, although they also include small diesel engines which are not included in the European standards. These countries are phasing in stricter limits as awareness grows of the impact of the NRSIEE

emissions, both within country and trans-nationally even at low levels, and advances in technology allow for a lower level of pollutants in emissions from these products.




## 4.2 Engine Exhausts affecting Surrounding Labourers[8]

Small, hand-held engines have an impact on the atmosphere that is accounted for in current emission inventories. But perhaps a more cogent concern is their potential as a source of air toxic exposure to operators. Labourers in the landscape industry frequently operate these devices for extended periods, thus exposing themselves to high concentrations of exhaust gases over prolonged periods of time. Since the exhaust gases consist of large fractions of unburned gasoline, there is a likelihood that workers are being adversely exposed to benzene, butadiene, and other possible toxic compounds contained in gasoline. Toxic compounds produced during combustion may also present a hazard.

Adverse health effects from gasoline-powered lawn and garden equipment emissions are well known. Benzene, butadiene, and formaldehyde are listed among the four-top ranking cancer-causing compounds. They cause lymphomas, leukaemia, and other types of cancer.[9] Ground level ozone (formed by VOCs and NOx in the presence of sunlight) and fine PM cause or contribute to early death, heart attack, stroke, congestive heart failure, asthma, chronic obstructive pulmonary disease, and cancer. Although no studies of grounds maintenance workers were found, studies of gas station workers have shown that regular exposure to gasoline vapours can produce haematological and immunological abnormalities and increase the risk of cancer. In addition, children, seniors, and people with chronic illnesses are especially vulnerable to the negative health impacts of GLME emissions.

**British Columbia Ministry of Forests, Victoria, B.C., Canada** - Use of chain saws and brush saws in vegetation management solutions under dense brush expected to result in significant exposure of workers to exhaust fumes. Benzene and 1,3-butadiene both confirmed human carcinogens, are amongst the substances of concern in two-stroke

[8] EPA

[9] International Agency for Research on Cancer, World Health Organization

engines, as is benzo(a)pyrene (BaP), a suspect human carcinogen. The exhaust contains carbon monoxide, which interferes with oxygen transport to the cells of the body. Formaldehyde, acrolein and nitrogen oxides in exhaust are all irritants and may exert other systemic effects. Numerous other compounds are passed through in unburned gasoline, as combustion products or are formed by reactions in the atmosphere, but there is insufficient information to evaluate them.

Apparently, there are no studies of worker exposure to engine exhaust in brush management. However, data on the exposure of loggers using chain saws provides information that can be used in preliminary estimates of the amount of these toxic substances in the breathing zones of brush control workers. Lifetime added cancer risk from benzene and 1,3- butadiene exposure associated with a typical employment history is estimated to be on the order of one to three chances in 1,000 over the normal background of cancer in the human population. Risk associated with exposure to polyaromatic hydrocarbons, many of which are carcinogenic, or neurotoxic cannot be assessed quantitatively at this time. Carbon monoxide exposure in dense brush is expected to be high enough to produce central nervous impairment, and an increased risk of injury. Formaldehyde and acrolein are strong irritants and contribute to upper respiratory discomfort. A programme of exposure measurement is recommended in order to devise mitigation measures and properly inform workers and policymakers of the potential risks of this kind of work.[10]

One commercial blower running for one hour produces the same amount of pollution as a Toyota Camry driven 1,100 miles. If we run the numbers, a crew running four or five blowers at a time for four to six hours produces the same amount of pollution as two or three Toyotas driven for a full year. But unlike cars, leaf blowers do not drive away. That means all of that exhaust stays in place whether it is in our gardens, playgrounds, or retirement communities. And the exhaust is harmful – the labels on the machines make this clear.

[10]British Columbia Ministry of Forests, Victoria, B.C., Canada

## Chapter Five

# Roadmap

### 5.1. Market Outlook on Technology Developments – Green Sustainable Agriculture

**Meeting Agriculture need for clean energy to feed the Developing World**

According to the United Nations Food and Agriculture Organization, global food production will need to increase by 70% over 2005–2007 levels by 2050 to meet the demand of a growing global population, which is expected to reach 9.6 billion people.

The global agricultural machinery market is projected to witness significant growth on account of upcoming technologies in the industry, coupled with improved economic conditions and rising farm income. These factors are expected to boost industry growth over the next seven years.

Applications that make use of agricultural machinery include soil cultivation, loading, irrigation, traction, power, planting, milking, hay making, fertilising, harvesting and pest control among others. Agricultural machinery includes seeding and harvesting machinery, tractors and other hardware equipment such as mixers, windmills, wool presses and grinders among others. Farm tractors are expected to lead the product segment in this market over the next few years.

The rising demand for this market is propelled by increased investment in new agricultural machinery due to the low-interest-rate as well as a rise in research and development expenditure and economies of scale. Additionally, another major factor that is expected to fuel market growth is the rapidly increasing global population which has led to an increase in the demand for food and other similar products. Governments are also providing subsidies to farmers to invest in better equipment to efficiently meet the needs for higher productivity. Rising food demand globally is expected to have a positive impact on the market.

**Next on the Technology Horizon**

Agriculture machinery technology development is driven by customer needs, legislative conditions like emission and safety standards, energy resources and prices, which are influenced by production/distribution costs and taxes.

Spark ignition engine technology is fully compatible with LPG, and if energy policy promotes these fuels into the marketplace, combustion systems tailored to these fuels will emerge. Extreme-charged, lean-burn, spark-ignited combustion processes are promising in this respect.

### 5.2 Market Status

Agricultural engines and machines are used in various outdoor power equipment like tillers, trimmers, leaf blowers, portable generators, pressure washers, and others. There is high demand for tractors, which is one of the factors that is likely to drive the growth of the LPG engine market. Equipment and engine sales are primarily driven by the increasing demand for agricultural products in various regions.

Developing countries will play a key role in driving demand for agricultural equipment through 2021 and beyond. As their economies and populations expand, the need for agricultural goods (and, in turn, larger and more powerful equipment to harvest and process them) will only increase. Furthermore, industrialized nations – looking to boost crop

yields, reduce production costs, and comply with new emissions standards are expected to spend on new, more efficient machinery.

LPG agricultural machinery represents a tremendous growth opportunity for the industry in terms of LPG fuel potential and new engines and equipment.

The global agricultural machinery market is estimated to grow remarkably in the next few years. All types of agricultural machinery used on fields, including harvesting machinery, haying and forage machinery, irrigation machinery and others have been considered.

Irrigation applications hold a major share in the agriculture machinery market and are estimated to grow at a healthy CAGR of nearly 10% over the next years. Advancements in smart irrigation machinery coupled with on-farm sensor technologies, satellite vegetation imagery, and weather forecasting offer massive sources of big data for farmers to augment the use of inadequate water resources in developing crop yields with improved profits.

Organic farming is fuelling the agriculture revolution in clean fuels such as LPG and increasing investments in technology related to fertiliser application, precision planting, spraying, and irrigation are driving the growth of the agricultural machinery market.

## 5.3 Market Outlook on Regions

The market for engines and equipment is highly variable depending on the application and the region. The agricultural engine market in general is mature and relatively well established in the USA. It is developing slowly elsewhere, most notably in Asia. LPG agricultural machinery currently takes only a marginal share of the market. This varies by region, but overall LPG products make up only 0.5-1% of global machinery to date.

- On the basis of geographical analysis, the Asia-Pacific region held a major share of around 40 %- 45 % among other regions of the agriculture machinery market. Increasing government regulations and government assistance programs to modernise the agriculture process are raising the demand for agricultural machinery in Asian countries such as Indonesia, China, India, and Japan. The established footprints of major agriculture machinery manufacturers in this region will keep this region as the dominant region for the foreseeable future.
- The increasing usage of agricultural implements such as disc harrows, field cultivators, utility and turf, and agricultural machinery used in the production of grains and oilseed crops, as well as their utilisation in livestock operations, is majorly contributing to the growth of the agricultural machinery market.
- According to the American equipment manufacturers, 4WD tractor sales increased 38.2% in January 2019 compared to 2018 in the U.S. Innovative green tractors are in progress to meet the requirements of livestock farmers and hay producers by 2020.

**Global Agriculture Machinery Market: Competitive Landscape**

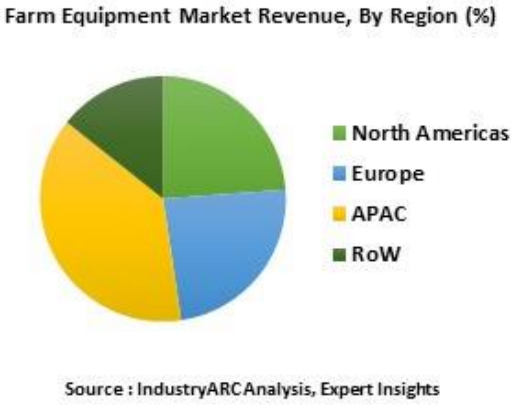
The global agricultural machinery market space is highly fragmented and features a large number of companies competing for a share of the profits. The key market players include Same Deutz-Fahr Deutschland Gmbh, Mahindra and Mahindra Ltd., Kubota Tractor Corp., Kverneland Group, Iseki & Co. Ltd., Kuhn Group, CNH Industrial N.V, Escorts Group, Claas KGaA mbH, Deere and Company, AGCO Corp and Tractors and Farm Equipment Ltd.

The factors that are driving this market are population growth, urbanisation and higher productivity demand due to the shrinking agricultural land throughout the globe, which has led to the growth in demand for agricultural machinery.

Technological advancement for developing more efficient products, while keeping in mind the country-specific requirements and legislation will provide opportunities for future LPG growth in the sector.

## Key Points

- The world's agricultural equipment markets continue to improve.
- The Western European agricultural equipment markets are at a very healthy level for agricultural machinery.
- Potential markets include countries in Europe such as Germany, France and the United Kingdom.
- The North American agricultural equipment markets recorded a high level of agricultural machinery sales.
- Asia's agricultural equipment markets continue to develop positively. Rich harvests and high crop prices led to high incomes, thereby encouraging investments in many regions.
- The huge demand for greater mechanisation in China is in part supported by subsidies. The most important market players here are state farms and contractors, although private enterprises and cooperatives also play a large role. Demand for mechanisation in Asia's key growth regions is expected to increase further in the coming years on account of continuing urbanisation.




- China's stricter emission standards will lead to a slight increase in technological sophistication.
- In China – the commercialisation of alternative fuel technologies is low.
- In Europe, there is high investment in alternative fuel technologies and innovation.

The LPG agricultural engine market is highly competitive. The key players in the market include Deere & Company, AGCO Corporation, CNH Industrial N.V., Iseki & Co., Ltd., and Kubota Corporation.

## Growing Demand for Farm Mechanisation from China and India

The global market for agricultural machinery in general and tractors in particular is driven by the increasing rates of mechanization in developing countries. Tractors accounted for over half of the market share in the global agricultural machinery market in 2019. The trends behind the increase in farm mechanisation in China and India have been increased investments in agriculture as well as the government push towards farm mechanization. The Government of China provides both direct and indirect subsidies on agricultural equipment and machinery purchase to the farmers. The investments in farm mechanisation have been a result of the increase in the number of large agricultural producers and new rural organisations engaged in farming.

North America is expected to account for a significant market share, closely followed by Europe in the global market, owing to the already existing extensively implemented mechanization systems in the region. Market segments of planting and fertilising machinery, and ploughing and cultivation machinery, are also expected to expand at a moderate pace.

Asia Pacific is expected to grow rapidly over the next eight years owing to the increase in the population in countries such as India and China, among others whose primary populations depend on farming to earn their livelihood. Governments of these and other similar countries are focusing on various methods to increase food productivity to meet the needs of the growing population. In this region, the demand for harvesting machinery is most prominent.

Across the globe, the European agricultural equipment market is one of the most developed agricultural markets. The major growth factors for European agriculture equipment are an increase in production output by increasing the level of mechanisation and an optimised supply chain. All these mentioned reasons, contribute to increasing the usage of agriculture equipment, thus driving the growth of the European agricultural market. The European agriculture equipment market will surpass US$ 67 billion by the end of 2025.

Further, with the rapid urbanisation trend, consumers are now seeking better quality food and organic food products. The rising need for such demands is also expected to spur demand for agricultural products which again offers an immense opportunity for the agriculture equipment market to flourish seamlessly over the forecast period. In addition, government administrations across Europe are now providing form of support to farmers, such as loans, subsidies and easy instalment plans for purchasing better agricultural equipment and other farm machinery. These government initiatives further encourage farmers to increase their productivity and cultivation to meet the growing demand of consumers for better food products.

The outlook for LPG markets differs widely by region based on a variety of factors, including differences in weather, types of available markets such as grain drying, irrigation, and mowing, differences in residential housing growth, natural gas market penetration, LPG supply and logistics infrastructure, and other factors.

Several high-level market characteristics are identified which create strong potential for agricultural machinery powered by LPG. These characteristics are used to rate the overall market potential in each global region. If a region has all of these characteristics, the potential market is attractive. If it has several of these factors, the potential is moderate, and if it has none of these characteristics, the potential is weak.

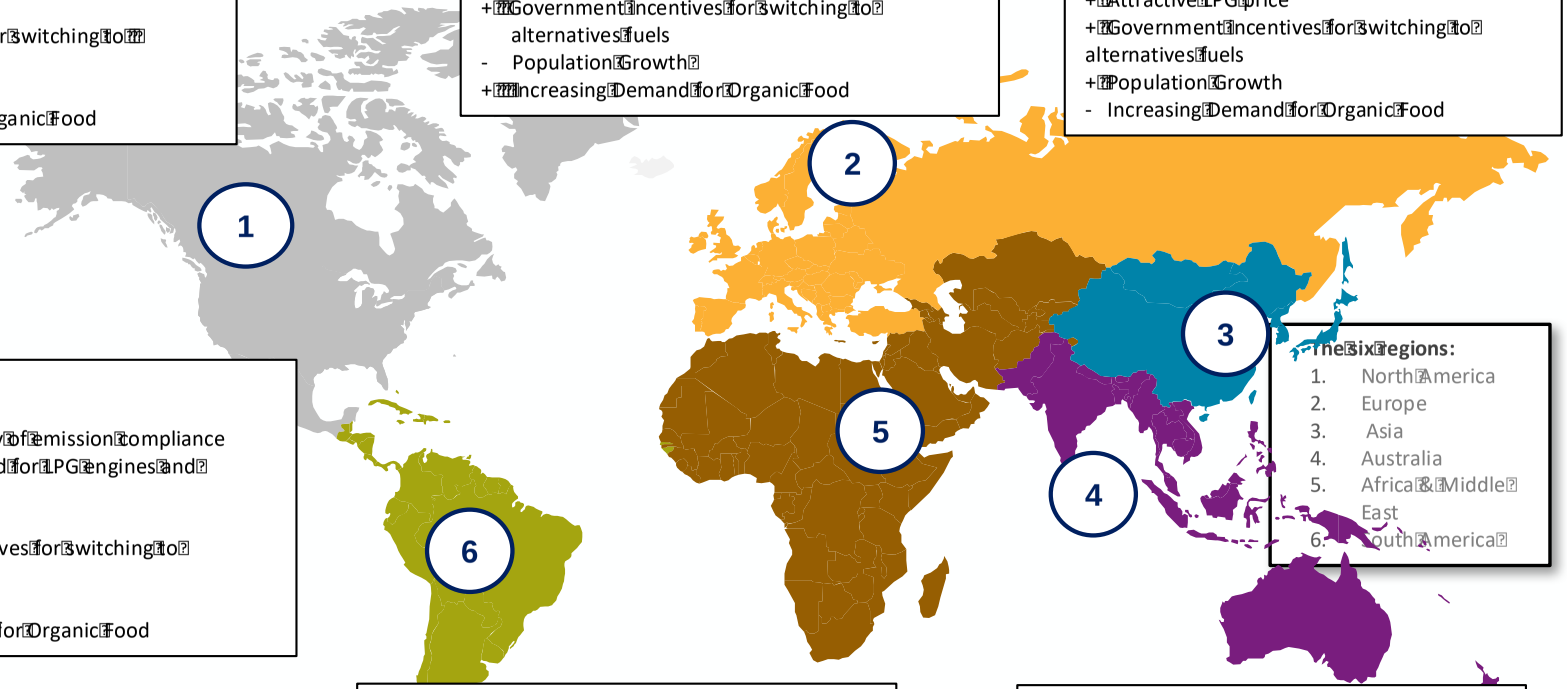
| **Market Characteristics** | **Drivers accelerating LPG growth** |
|---|---|
| New regulations regarding emissions | The stringent emissions standards for agricultural engines in force around the world can easily be met with the adoption of modern LPG systems |
| Cost and Complexity of Emissions Compliance | Replacement of old machinery with new one to comply with new regulations |
| Evolution of demand for LPG engines and machinery | OEMs increase R&D spend and focus on new technologies to meet changing regulations |
| Attractive LPG price | Diesel fuel swings vs. low-cost alternatives |
| Government incentives for switching to alternative fuels | Green grants and tax credits |
| Population growth | There is a demand for more food and more land to be cultivated |
| Increasing demand for organic food | LPG enables farmers to achieve responsible results, that is, farming can be done organically and efficiently |

## Market potential for LPG Agricultural Machinery around the globe based on inherent market characteristics.

**1. North America**
+ New regulations
+ Cost and Complexity of emission compliance
+ Evolution of demand for LPG engines and machinery
+ Attractive LPG price
+ Government incentives for switching to alternatives fuels
- Population Growth
+ Increasing Demand for Organic Food

**2. Europe**
- New regulation
+ Cost and Complexity of emission compliance
+ Evolution of demand for LPG engines and machinery
+ Attractive LPG price
+ Government incentives for switching to alternatives fuels
- Population Growth
+ Increasing Demand for Organic Food

**3. Asia**
+ New regulation
+ Cost and Complexity of emission compliance
+ Evolution of demand for LPG engines and machinery
+ Attractive LPG price
+ Government incentives for switching to alternatives fuels
+ Population Growth
- Increasing Demand for Organic Food




**The six regions:**
1. North America
2. Europe
3. Asia
4. Australia
5. Africa & Middle East
6. South America

**6. South America**
+ New regulation
+ Cost and Complexity of emission compliance
+ Evolution of demand for LPG engines and machinery
+ Attractive LPG price
+ Government incentives for switching to alternatives fuels
- Population Growth
- Increasing Demand for Organic Food

**Attractiveness based on these factors: High to Low**
Asia
North America
Europe
South America
Australia
Africa

**5. Africa and Middle East**
- New regulation
- Cost and Complexity of emission compliance
- Evolution of demand for LPG engines and machinery
+ Attractive LPG price
- Government incentives for switching to alternatives fuels
- Population Growth
- Increasing Demand for Organic Food

**4. Australia**
- New regulation
+ Cost and Complexity of emission compliance
+ Evolution of demand for LPG engines and machinery
+ Attractive LPG price
- Government incentives for switching to alternatives fuels
- Population growth
+ Increasing Demand for Organic Food

## 5.4 Barriers to Growth

There are several specific barriers/drivers, which determine the size of the market opportunity. Key issues are highlighted below.

The Recommendations Chapter proposes suggestions to overcome these barriers.

### 5.4.1 Economic Barriers

Uneconomic business cases are perhaps the most fundamental barrier to rural delivery. Here the high costs of rural distribution in remote areas, low revenue, poor profit margins and unattractive investment have kept back the growth of the rural LPG market.

There are three crucial elements, namely:

- **High costs of rural LPG distribution.** Common factors that generate excessive operating costs to rural areas include attenuated supply chains, long distances and high transport costs, poor road networks, dispersed and inaccessible customer base, high revenue collection costs; need for massive investment in smaller cylinders; and higher cylinder maintenance costs.
- **Low revenue**. Rural households typically consume small quantities of LPG in comparison with industrial and commercial users. Such households are also typically dispersed over large areas. In addition, many rural households are poor with limited disposable income. All these factors conspire to reduce revenue levels.
- **Poor profit margins and unattractive investment**. Rural distribution of LPG to dispersed farms traditionally generates low or comparatively poor profit margins when compared with other LPG market sectors. This negatively impacts the attractiveness of rural LPG distribution as an investment destination for commercial funds.

### 5.4.2 Competitive Market Price and Affordability of LPG

In many countries, the full market or economic cost of LPG is higher than alternative thermal fuels. This negatively impacts both the incentive for poor households to switch to LPG and their ability to pay for a more expensive thermal fuel from limited disposable income of the poor.

### 5.4.3 Upfront Cost-Inability to Obtain Loans

Upfront cost is consistently raised as the single biggest barrier to market entry for new technologies. Cost is the primary decision factor for the majority of farmers. Many alternative fuel or technologies options may have higher upfront investment costs, both in terms of the engines or machinery required. With strict budgetary pressures, many farmers remain focused on immediate costs rather than long-term savings.

### 5.4.4 Lack of Awareness – Limited Media and Reach

Often farmers are not aware of what technology is available. Traditional farmers, especially those in remote rural areas in many areas in Asia or Africa, often cling to tradition and are the slowest to adopt new technologies and modern living practices. Certainly, in Africa there is in many countries a low awareness among farmers about alternative modern fuels, including LPG. In many developing regions of the world there is an absence of media. This is a particular problem in India and parts of Africa. With limited media and that media that does exist having a limited reach to the target agricultural market creates a barrier for supply companies wishing to market and promote their product.

### 5.4.5 Low Literacy Levels among many Farming Areas of the World

There is often a low literacy level among farmers. This is certainly the case in India and Africa. Low literacy presents a range of constraints on introducing and sustaining the safe and efficient use of a new fuel such as LPG by farmers.

### 5.4.6 Low Disposable Income of Rural Farmers and Ability to Pay

In many agricultural areas, not only is income very scarce it is also often sporadic, linked to crop cycles and seasonal work. Thus, serious constraints exist on many rural farmers' ability to pay, both in actual prices required for appliances, but also the regularity of payments necessary for a reliable supply of cylinder refills. There may be certain times in the year or month when such customers simply do not have money to pay for cylinder refills.

### 5.4.7 Fuel Supply - Limited Convenient Access and 'In Time' Cylinder Refills

LPG is often simply not available in close and regular proximity to farms. Without a local and trusted point of sale outlet that can be conveniently accessed by farmers, the product will not be purchased and used.

### 5.4.8 Policy/Regulatory Framework: Need to be on a Level Playing Field with Competing Technologies

If agriculture engines and machinery are to reach potential market they need to be recognised and given fair treatment based on their primary energy efficiencies and carbon saving potential. This is an on-going process in many regions. Regulations need to be finalised for the inclusion of LPG, incentives and regional schemes. These regulations have to consider the use of LPG as a fuel.

Regulations regarding the use of LPG as an engine fuel for various types of agriculture applications and engines vary largely. While the market for engines and machinery is global, international regulations do not exist. Only national type approvals exist and even these are still very few. The national approach is not cost effective and is only sustainable when small volumes of engines are being converted. New international certification regulations are needed, most likely at the UN level, OEMs are to produce engines and machinery in volume then. Such international standards or regulations are also important to help ensure that these systems are safe, reliable and in compliance with emissions regulations.

### 5.4.9 Technology Development: Slow Rate Will Limit or Stop Growth

At present, there are limitations on the range of agriculture applications for which LPG can be implemented. There has been very limited development of LPG engines recently (with the exception of the USA) resulting in a serious lack of LPG agriculture applications. The development of engines for other competitive fuels and technologies has largely surpassed those for LPG. A significant part of the market potential for LPG agriculture is currently based on the expected technology developments, that will widen applicability. If this does not happen as expected, the market potential will be very limited and growth may even stop altogether. Major branch and manufacturers are hesitant about developing LPG versions of their models. This is probably the most important blocker today. R&D investment is absolutely key.

### 5.4.10 Commercialisation and Getting Products to Market: Trained Installers, Distribution/Servicing/Maintenance Networks are required

For conversion systems, new distribution channels and partnerships with OEMs to reach the customer need to be developed or acquired through partnerships with bigger companies. This needs to ensure an effective network and adequate service and maintenance support. It is the critical, convincing performance of FLT salesmen who can influence fuel choice.

### 5.4.11 Standardisation, Harmonisation and Other Barriers are Key for Succeeding in the Market

Standardisation and harmonisation are key enablers, as acknowledged by OEMs and the LPG industry, for the growth of engine markets. They serve as a basis for technology development and reliable and consistent engine performance. Technology should help provide a higher quality of engines and adequate controls to maintain it.

Some other issues can also be considered barriers. They have also hindered growth in the past and may continue in the future if not addressed adequately.

#### Fuel Quality

The large variation in the quality of LPG, in terms of composition and even contaminants, has been the cause of engine performance issues in the past and still is today. This is the case not only amongst countries but also within the same country amongst, distributors and retailers, even with the season. This is a serious concern for engine manufacturers.

#### Aftermarket Conversion Quality

In cases of aftermarket conversions, this can vary significantly, including the suitability of systems used for the specific engine and engine applications.

## 5.5 Market Potential: Target Regions

Currently, strict exhaust gas regulations have been applied to spark ignition type engines for forklift trucks in Japan and North America. In 2019, further stringent exhaust gas regulations were also introduced to Europe.

### Agricultural Machinery

While the macro-economic situation remains tense, conditions for sustained agricultural growth are positive. Steady yields and high crop prices significantly increased farmers' income. Empirical data and recent surveys indicate a stable willingness to invest in mew machinery. **Power generation and irrigation a**re becoming increasingly important agricultural topics.

- The markets in **western and central Europe** will trend toward continued high-level development. While macro-economic prospects were currently muted in light of the euro crisis, steady yields and high crop prices significantly increased farmers' income. Farmers' declining capital expenditure in wind power and photovoltaic plants affords additional free capital for agricultural equipment.
- The agricultural equipment industry is expected to see continuing growth in **eastern Europe**. Despite a significant drop in the production of agricultural products due to the long period of drought during the summer, the agricultural equipment market is expected to grow.
- Many Western manufacturers will see Russia's admission as an opportunity to increase sales.
- Expectations for the **North American** markets remain positive.
- **Asia** is now by far the largest region for agricultural machinery.
- The agricultural equipment markets in **South America** will develop at a high level. Agricultural production values are expected to be up in Brazil and Argentina. High prices and stable input costs result in good incomes and a corresponding high willingness to invest.
- **Asia's agricultural equipment markets** will grow. High crop prices also meant positive agricultural incomes in Asia. However, a tense global economy still provides a degree of uncertainty.

## Chapter Six

# Recommendations

The Roadmap section above identified the critical barriers to market uptake for agricultural machinery with LPG. In this section are presented the recommendations on how each of these barriers can be overcome, and which types of market actors have a role to play.

For more details on the strength of each barrier in each global region, see Section 4.2 above.

The summary table below indicates the varying roles of each type of player in overcoming the barriers to market growth. Each barrier is explained in detail in the text after the table. We differentiate between a "Lead Role" (the actor is critical in overcoming the barrier), and "Support Role" (the actor can support but is not the critical element in overcoming the barrier).

Key: XX = Lead Role; X = Support Role.

| **Barrier** | **Market Actor** | | | |
|---|---|---|---|---|
| | Industry Associations | LPG Companies | Engine Manufacturers/LPG System Developers | Government |
| Sustainable Economics | **X** | **XX** | **X** | **X** |
| Competitive Market Price | **X** | **XX** | **X** | **X** |
| Offer Financing Packages and Incentives | **X** | **XX** | **X** | **XX** |
| Raise LPG Awareness | **XX** | **XX** | **X** | **XX** |
| Establish and Know the Market | **XX** | **XX** | **X** | **X** |
| Trained and Competent Market Support Staff | **X** | **XX** | **X** | **X** |
| Ability to Pay | **X** | **XX** | **X** | **X** |
| Ensure an Efficient Market Chain is Created to Handle the Product | **X** | **XX** | **X** | **X** |
| Policy & Regulatory Challenges | **XX** | **X** | **X** | **XX** |
| Technology development | **X** | **XX** | **XX** | **X** |
| Commercialisation and Getting products to market | **X** | **XX** | **XX** | **X** |
| Standardisation and Harmonisation | **X** | **XX** | **X** | **X** |

## 6.1. Sustainable Economics

From a supply perspective, the agricultural market is relatively costly and difficult to supply in comparison with other market sectors such as bulk industrial and commercial users. It will be essential to ultimately achieve acceptable economic returns to ensure sustainable supply to such markets. Supplying LPG to rural agriculture is, by its very economic nature, a matter of building a sizeable customer base that requires a regular and consistent volume of the product that in turn, will provide the necessary revenue streams for viability and profit. ROLE OF LPG COMPANIES.

## 6.2. Competitive Market Price

Many agriculture customers use diesel that has a low cost to the users. There is little or no financial incentive therefore for such users to switch to LPG. It is essential to have market related prices for LPG closely linked to the comparative efficiency, convenience, cleanliness and other benefits of LPG. These features and benefits need to be carefully and persistently explained to customers to build market share and customer loyalty. Payment methods must also be carefully attuned to local economic circumstances and the way that goods and services are bought and sold. ROLE OF LPG COMPANIES.

## 6.3. Offer Financing Packages and Incentives

- Offering financing packages, via LPG distributors or other players, which could shift the upfront investment & risk away from the end user, this approach could create significant market growth. ROLE FOR LPG DISTRIBUTORS.
- Equipment and other systems must have a cost advantage and be timely in development. A general challenge for the LPG industry is meeting the cost and time requirements of users as they continuously seek to drive costs down and improve productivity. By meeting this challenge, the LPG industry can create a robust, growing market in the agricultural sector. ROLE FOR ENGINES MANUFACTURERS, OEMs.
- Engines manufacturers and system developer new technologies will create cost-reduction potential by improving system efficiencies, with running cost benefits. Market potential of LPG technologies increases significantly when the capital cost of the engine is reduced, vehicle and engine offerings expand, and fuelling availability is facilitated. ROLE FOR ENGINE MANUFACTURERS and OEMs.
- Providing incentives will bring down either the upfront cost or running costs (depending on the structure of the incentive - a grant or a tariff). ROLE OF GOVERNMENT.
- Lobbying to ensure that LPG as engine fuel for agriculture receives a fair incentive rate to be on a level playing field with other competing technologies such as diesel, CNG will ensure that an LPG engine is considered as a preferable option. ROLE FOR INDUSTRY ASSOCIATION.
- Manufacturers of engines, equipment, OEMs, to integrate from the beginning LPG options in their product range to avoid subsequent modifications and added costs ROLE FOR MANUFACTURERS.
- To comply with the new technical provisions, there is a need for sufficient transition time that will provide manufacturers the necessary lead-time. This is necessary to build their machines in compliance with technical requirements and place them on the market on time once the stage V requirements become mandatory. ROLE FOR INDUSTRY ASSOCIATION.

## 6.4. Raise LPG Awareness

Traditional farmers, especially those in remote rural areas in most cultures, often cling to tradition and are the slowest to adopt new technologies and modern living practices. Certainly, in Africa, there a low awareness among farmers about alternative modern fuels, including LPG. Without awareness of LPG, practical knowledge of the product and especially an appreciation of the comparative benefits, it will be impossible to sell LPG to rural areas. Raising awareness of the existence of agricultural applications and their market potential is the first major challenge. The way LPG agriculture engines and machinery are perceived by the market is critical to their success. These engines need to be seen as a carbon

reduction tool (particularly for policy-makers), as reliable and efficient for end-users, and as a revenue opportunity. This is equally relevant for all applications in all regions. We have seen some success in the USA, but in other regions, awareness is still very low.

- Communications initiatives are needed in order to expand LPG's position as a leading alternative fuel and to increase sales. ROLE FOR INDUSTRY ASSOCIATION & POLICY MAKERS.
- Marketing/awareness-raising activities involving, for example, information, dissemination demonstrating real technology performance, applicability and potential, targeted marketing events for end-users, information/training events, sector exhibitions, etc. ROLE FOR ALL MARKET ACTORS – ASSOCIATIONS, LPG DISTRIBUTORS.
- Collection of market data of LPG agricultural emission data to demonstrate the contribution LPG engines are making to carbon saving targets etc., to be targeted at governments. ROLE FOR ASSOCIATIONS.
- Cultivate retailer, end-user, and government awareness of LPG as an exceptional energy source. The LPG industry must work vigorously to create and maintain a high level of awareness regarding LPG's unique benefits among propane retailers, consumers, and lawmakers. OEMs and system developers should view heavy engine markets as attractive sources of revenue that are strategically important because of growing figures. Farmers, truck drivers and municipalities should be educated to see LPG as an exceptional fuel that they can use cleanly and cost effectively in nearly every application. Lawmakers must understand LPG's advantages, particularly its superior environmental performance, to ensure proper consideration in environmental regulations. ROLE FOR LPG DISTRIBUTORS, ASSOCIATIONS, REGULATORS.

## 6.5. Establish and Know the Market

- There is often a low literacy level among rural farmers. This is certainly the case in India and Africa. Low literacy presents a range of constraints on introducing and sustaining the safe and efficient use by farmers of a new fuel such as LPG. ROLE FOR INDUSTRY ASSOCIATION.
- Without properly trained, deployed, motivated, managed and rewarded LPG distribution, sales, accounts and service personnel, any agricultural supply program will be in serious jeopardy. This applies with equal force to both direct and indirect employees, such as the staff of independent retailers, local agents, technical support operations, drivers and cylinder handlers. ROLE OF LPG DISTRIBUTORS – TRAINED AND COMPETENT MARKET SUPPORT STAFF

## 6.6. Ability to Pay

Success will clearly depend on the supplier's ability to match product offers to the levels of disposable income of different segments. Subsistence farmers often make use of surplus crops and livestock sales as their main income stream. With so much of the rural economy based on subsistence farming, income tends to be seasonal and, at times, variable due to droughts, floods, and other natural disasters. Inclusion of flexibility and possibly loan accounts, will help farmers to manage the seasonality of their income when it comes to purchasing LPG. ROLE OF LPG COMPANIES.

## 6.7. Ensure an Efficient Market Chain is Created to Handle the Product

Without a proper local network of sales outlets that provide customer with convenient access to the product, it will be impossible to build LPG market penetration in the household sector. LPG is often simply not available in close and regular proximity to agricultural areas. Without a local and trusted point of sale outlet that can be conveniently accessed by rural areas, the product will not be purchased and used. ROLE OF LPG COMPANIES.

## 6.8. Regulatory Challenges Must be Addressed to Enhance Market Opportunities

- **Lobbying** to ensure that LPG powered engines are included in the regulatory framework and incentive schemes. This should cover all types of uses, static and mobile. The primary role for the associations and LPG companies is to make policy-makers aware of the benefits of these systems using LPG, their safety and the potential of this technology. ROLE FOR ASSOCIATIONS.
- **Lobbing** to ensure worldwide standards and certification regulations for OEMs and retrofit technologies. Associations, LPG companies and manufacturers must ensure that policy-makers and regulators develop safe, reliable regulations that are in compliance with emissions requirements. ROLE FOR ASSOCIATIONS.
- **Standards** must be harmonised. ROLE FOR ASSOCIATIONS, POLICY MAKERS.

## 6.9. Technology Development: Slow Rate Will Limit or Stop Growth

- **Investment in R&D** to support and accelerate the development of LPG fuel technology in SHDEs and maximise its potential market applications. This is probably the most important enabler at present since development of other competitive fuels and technologies has largely overtaken those of LPG resulting in a serious lack of LPG engines. If this does not change rapidly, enormous opportunities will be lost and LPG may even disappear in some parts of the world as an agricultural engine and equipment fuel option. This could include investments to adapt existing natural gas fuelled engines to run on LPG. Besides investment, a long-term vision of what the market requires on such is needed. Primary role for manufacturers and developers but also largely for LPG companies. There could be a role also for policy makers by making R&D funding available to develop new product concepts suited to their markets. ROLE FOR MANUFACTURERS (to develop), LPG DISTRIBUTORS (to assist with funds), ASSOCIATIONS (to facilitate).
- **Market analysis** to identify which markets, market sectors and applications have the most potential, types of engines needed and what R&D developments should be made to ensure that the technology is well-suited to future needs and trends. ROLE FOR MANUFACTURERS AND ASSOCIATIONS.
- **Aftermarket conversion quality** needs to be improved to offer consistent and high-quality conversions well adapted to the specific engine applications. This includes developers, manufacturers and installers.
- Development of advanced and innovative applications needs to be developed. ROLE FOR LPG DISTRIBUTORS.

## 6.10. Commercialisation and Getting Products to Market: Trained Installers, Distribution/Servicing/Maintenance Networks are required

- **Support with developing partnerships in new regions** for distribution and sales of LPG SHDEs, equipment and vehicles. The role of the associations is to put their members in touch with local partners to develop sales channels and distribution networks. ROLE FOR REGIONAL ASSOCIATIONS.
- **Expanding offerings** to include LPG SHDEs, equipment and vehicles via existing sales channels, to develop these new relationships. ROLE FOR MANUFACTURERS AND ASSOCIATIONS.
- **Market research** to identify which customer segments to target and what drives and motivates those customers in their decision-making process about acquiring a new engine or equipment. To educate distributors and other customer front actors. ROLE FOR ASSOCIATIONS and MANUFACTURERS.
- **Expand refuelling network.** ROLE OF LPG COMPANIES to develop extensive refuelling infrastructure and dedicated refuelling systems.

## 6.11. Standardisation, Harmonisation and Other Barriers are Key for Succeeding in the Market

- **Developing international standards** for LPG Engines to be shared across the industry. ROLE FOR ASSOCIATIONS/ GOVERNMENT.

- **Fuel quality** to be harmonised to serve as the basis for engine and technology development and reliable and consistent engine performance. Technology should help provide a higher quality product and adequate controls to maintain it. ROLE FOR LPG COMPANIES/GOVERNMENT.
- **Ensuring good quality fuels.** The LPG companies should always and everywhere ensure good quality fuel and customer satisfaction with continuous and reliable service. It is important to provide the OEMs with a constant quality chemical composition. ROLE FOR LPG COMPANIES.
- **Improved controls** in the distribution chain so that LPG can maintain its prime qualities and keep it free of impurities and contaminants. ROLE FOR LPG COMPANIES/GOVERNMENT.
- **Lobbying to support the emissions requirements/technologies and to ensure legal compliance.** ROLE FOR ASSOCIATIONS.

# Abbreviations

| | |
|---|---|
| CARB | California Air Resources Board |
| CAGR | Compound Annual Growth Rate |
| CI | Compression ignition |
| CHP | Combined Heat and Power (CHP) |
| DEF | Diesel exhaust fluid |
| DGE | Diesel gallon equivalent |
| DPF | Diesel particulate filter |
| DI | Direct injection |
| DI-PI | Direct injection gasoline and port injection LPG |
| ECAs | Emission controlled areas |
| ESC | European Stationary Cycle |
| ETC | European Transient Cycle |
| GDI | Gasoline direct injection |
| GGE | Gas Gallon Equivalent |
| GHG | Greenhouse gases |
| GLGE | Gasoline-powered lawn and garden equipment |
| GSE | Ground Support Equipment |
| HC | Hydrocarbons |
| HDE | Heavy duty engine |
| HDDF | Heavy duty dual engine |
| HDV | Heavy duty vehicle |
| LDI | Liquid direct injection |
| LEZ | Low emission zones (LEZ) |
| LGI | Liquid gas injection |
| LPI | Liquid port injection |
| LNG | Liquefied natural gas |
| LPG | Liquefied petroleum gas |
| LSHFO | Low Sulphur Heavy Fuel Oil |
| MMBtu | Million of BTUs |
| NAAQS | National Ambient Air Quality Standards |
| NGV | Natural gas vehicle |
| NMHC | Non-methane hydrocarbons |
| NOx NO and NO2 | Nitric oxide and nitrogen dioxide |
| NRMM | Non- Road Mobile Machinery |
| NRV | Non- Road Vehicles |
| OEM | Original equipment manufacturer |
| PI | Port injection |
| PM | Particle matter |
| PN | Particle number |
| PPM | Parts per million |
| SI | Spark ignition |
| SHDE | Small Heavy-Duty Engine |
| SMM | Small Mobile Machinery |
| THC | Total hydrocarbons |
| VOC | Volatile organic compounds |
| VPI | Vapour port injection |
| ULEZ | Ultra Low Emission Zone |
| UNECE | United Nations Economic Commission for Europe |
| CNG | Compressed natural gas |
| $CO_2$ | Carbon dioxide |
| EV | Electric vehicle |
| HDV | Heavy-duty vehicle |
| LDV | Light-duty vehicle |
| SCC | Social cost of carbon |

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