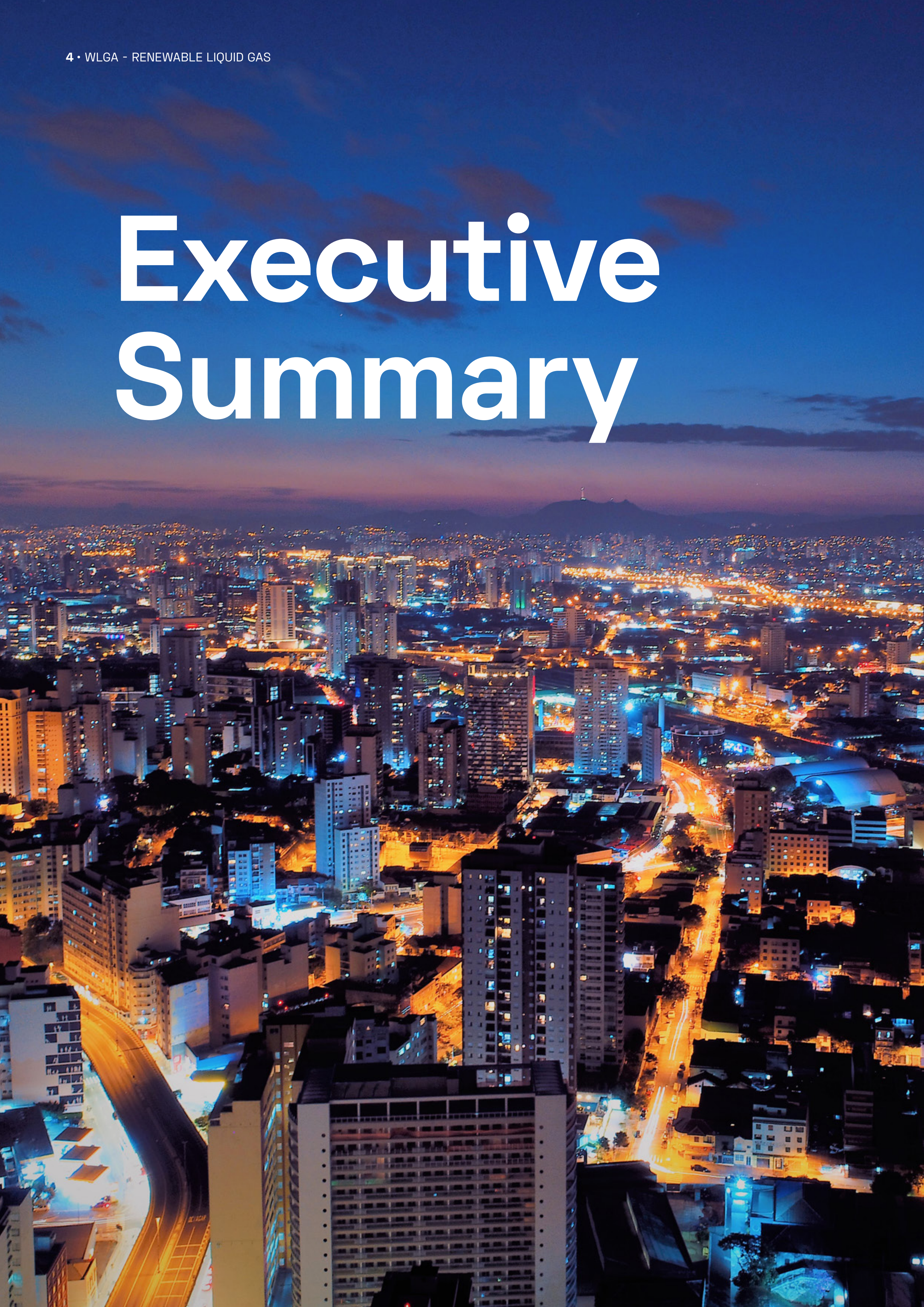
RENEWABLE LIQUID GAS

THE KEY TO A LOWER-CARBON FUTURE

WLGA
Energy Anywhere

Contents

Executive Summary



Decarbonisation efforts to meet ambitious climate goals have put a strain on industries and companies that are burdened to help meet these targets. The targets, such as the Paris Agreement's target of limiting global warming to 1.5°C by reducing CO_2 emissions by 45% by 2030 and achieving net zero by 2050, are important and it will take a coordinated effort among industries, innovators, and policymakers to achieve these goals.

The global LPG industry has long played a critical role in the global energy mix and has shown great commitment to helping achieve climate targets. The development and integration of renewable Liquid Gas (rLG) - including renewable propane, renewable butane, and renewable dimethyl ether (rDME) – can contribute significantly to meeting decarbonisation targets whilst maintaining energy security and accessibility across power generation, domestic, commercial, on-road, off-road, agriculture, and industrial sectors.

In 2024, the World Liquid Gas Association (WLGA) commissioned NNFCC and Frazer-Nash Consultancy to conduct a study on pathways to produce rLG across the world.

The study, available to WLGA members, aimed to address the question of "How much rLG can realistically be produced and supplied, given feedstock constraints and technological advancements?" by:

1

Providing a holistic assessment of renewable feedstock availability for rLG production, considering competition from alternative low-carbon energy solutions.

2

Assessing and modeling in detail the development and potential for technological pathways to supply rLG through to 2050.

3

Estimating the potential for rLG production beyond 2050, given constraints to global bio-based feedstock.

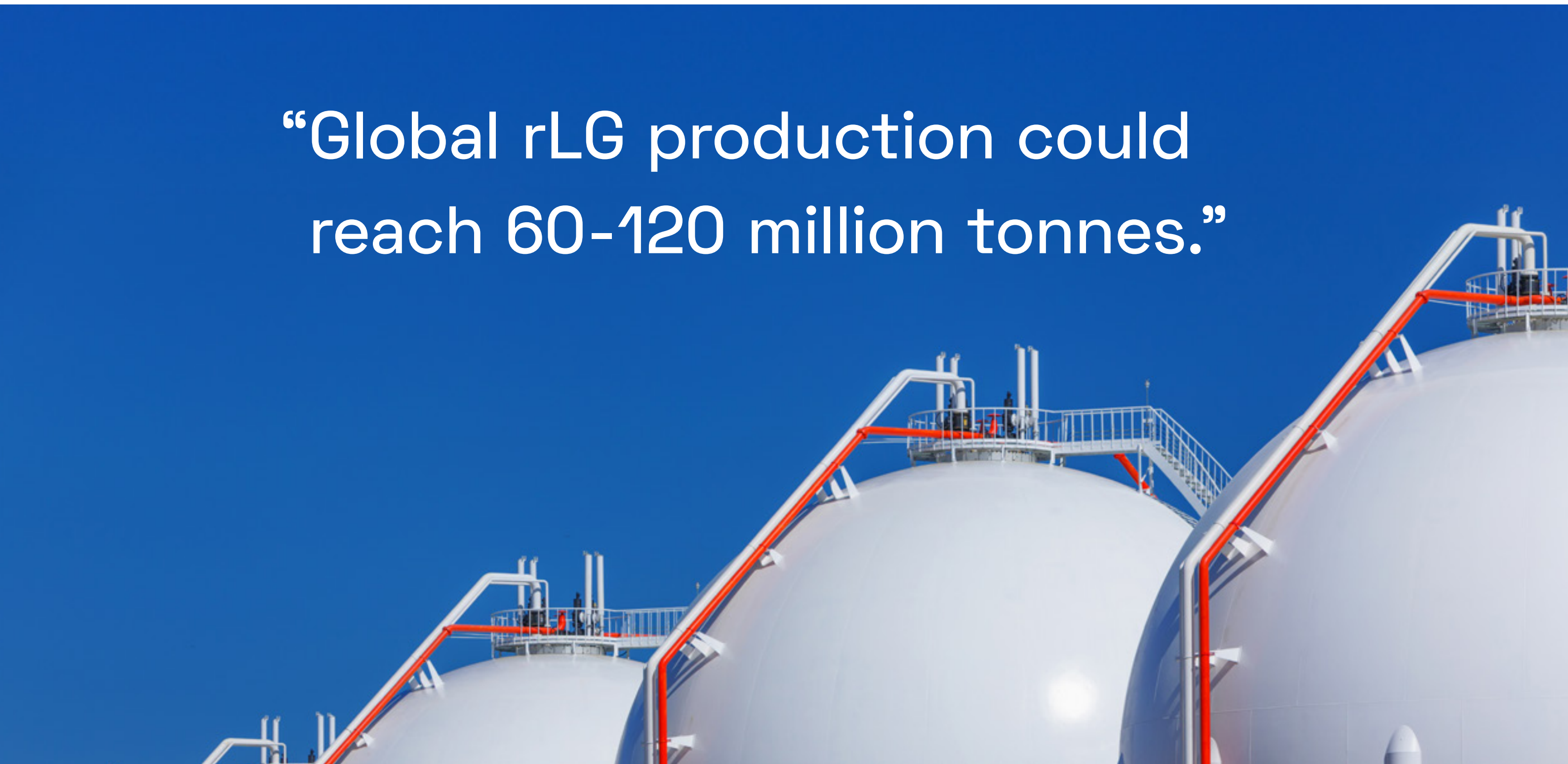
Ultimately, the study showed that global rLG production could reach 60-120 million tonnes (Mt), with a central estimate of 88 Mt, of liquefied petroleum gas (LPG)-equivalent by 2050, saving up to 238 Mt CO_2 annually. However, without adequate policy support, rLG production could fail to reach a quarter of this potential, risking leaving billions of consumers without access to secure, affordable, and sustainable energy. Supportive, technology-neutral policy action is needed to reach global decarbonisation targets, and leveraging LPG's existing infrastructure and clean energy credentials is a key component of the lower-carbon future of energy.

Introduction

LPG is a cornerstone of the global energy mix, accounting for roughly 2% of global energy demand. Per the WLGA 2024 Statistical Review of Global LPG, in 2023, worldwide LPG production reached 359.5 Mt with total consumption of 357.0 Mt. Consumption of LPG for energy purposes was 209.3 MT whilst the remaining production went into refinery and chemical uses. Approximately 3 billion consumers rely on LPG for energy, particularly in remote areas where LPG is a critical energy solution.

As a cleaner-burning fuel than coal or oil, LPG reduces air pollutants like particulate matter (PM2.5) by up to 99% and sulfur oxides by 95%, offering immediate health benefits. As an example of the impact of LPG in reducing emissions, the World Health Organization estimates that replacing solid fuels with LPG for cooking could prevent 500,000 premature deaths annually from household air pollution, particularly in developing regions. Renewable Liquid Gas builds on this foundation, slashing carbon emissions by over 80% more whilst leveraging the vast existing LPG infrastructure.

In 2024, the WLGA commissioned NNFCC and Frazer-Nash to explore rLG's global potential, assessing feedstock availability, technological pathways, and production forecasts to 2050 and beyond. This report synthesises multiple studies to project rLG supply under three scenarios - baseline (limited support), moderate (balanced growth), and high (optimal conditions) - whilst accounting for competition from sectors like petrochemicals and hydrogen. Renewable Liquid Gas offers a scalable, drop-in solution to decarbonise energy across multiple sectors, including hard-to-decarbonize applications and locations, while increasing the availability of clean energy to meet growing energy demands, provided policy frameworks are implemented to support the continued development, commercialisation, and adoption of rLG.



Pathways, Feedstocks, and Global Production

Nine key pathways (Table 1) were selected from 23 options via multicriteria analysis, focusing on feedstock availability, technology readiness level, and commercial interest. The selected pathways include co-production (e.g., hydrotreated vegetable oil (HVO) and hydrotreated esters and fatty acids (HEFA), Alcohol-to-Fuel) and dedicated routes (e.g., Biogas-to-rLG, Gasification-to-DME). Feedstocks - solid wastes (e.g., municipal solid waste (MSW), wood residues), lipids (e.g., used cooking oil, tallow), ethanol crops, and biogas - were assessed regionally, with competition factors (90% baseline, 20% high) used to model availability constraints. Each of these pathways is either in production or testing.

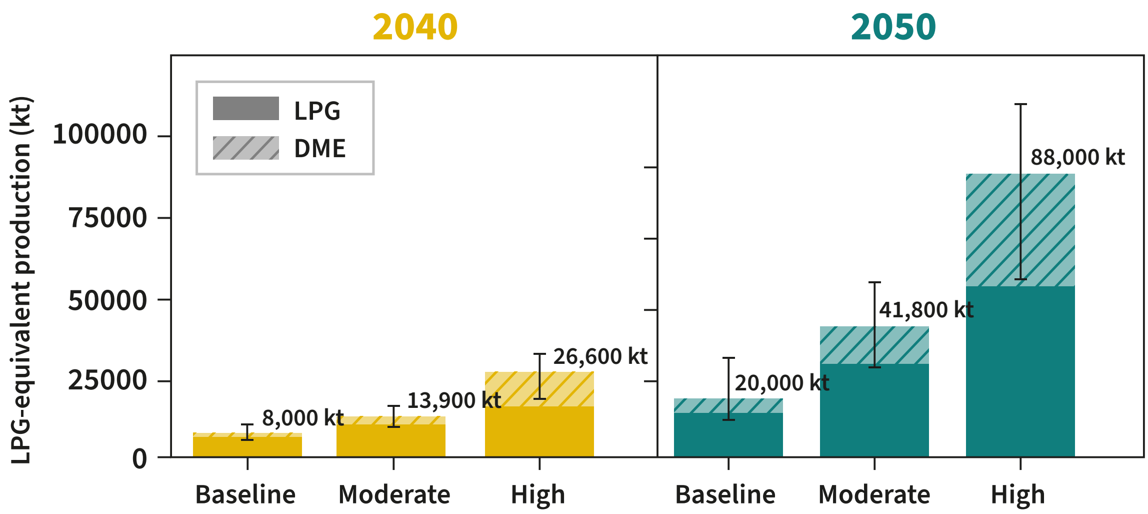
Table 1
The key pathways for rLG production selected for modelling in the study

Pathway	Product or co-product	Feedstocks
Alcohol to fuel (LPG)	Renewable LPG	Ethanol
Biogas (LPG)	Renewable LPG	Biogas
Biogas (DME)	Renewable DME	Biogas
CO_2 & H_2 to fuel (DME)	Renewable DME	CO_2 Hydrogen
CO_2 & H_2 to fuel (LPG)	Renewable LPG	CO_2 Hydrogen
Gasification with FT (LPG)	Renewable LPG	MSW Waste wood & residues
Gasification (DME)	Renewable DME	MSW Waste wood & residues
HVO & HEFA (LPG)	Renewable LPG	Tallow UCO Virgin Oils
Pyrolysis (LPG)	Renewable LPG	MSW Waste wood & residues Waste tyres

The study modeled three scenarios (baseline, moderate, high) globally (Figure 1) and across six regions (Figures 3-8). Globally, in the high scenario - marked by strong policy support, rapid plant deployment, and low feedstock competition - the global production models peak at 88 Mt (central estimate of a range from 60 MT to 120 Mt) but achieving this growth hinges on critical support mechanisms. Without robust regulatory and political backing, production could fall below 22% of its potential, with market supply potentially dropping to less than 10% due to product competition. Success requires strong policies as outlined in this document.

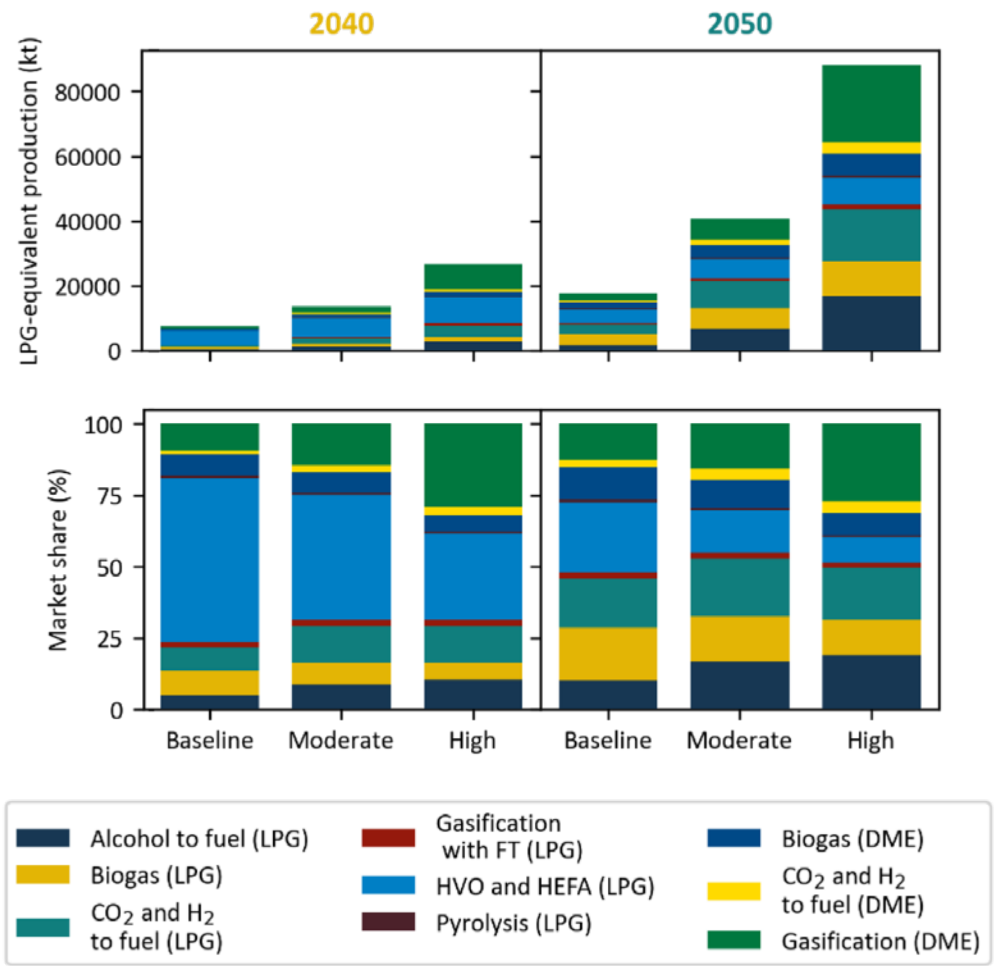
A current map of global rLG projects is available on the WLGA website at https://www.worldliquidgas.org/key-focus-areas/renewable-liquid-gas.

Figure 1
The central model estimates for the future production of rLG worldwide (LPG-equivalent)



It is important to view production potential through the lens of feedstock availability and production pathway potential (Figure 2). Through 2030, HVO/HEFA production leveraging lipid feedstocks dominates global rLG supplies. After 2040, constraints on lipid feedstocks shift reliance to alcohol-to-fuel and CO_2/H_2 pathways, with biogas and gasification scaling production.

Figure 2
The production of rLG by each technological pathway worldwide in the baseline, moderate, and high outlook scenarios towards 2050. The top plot presents the raw volumes (LPG-equivalent) for each pathway, while the bottom plot presents the total share of the production market as a percentage.



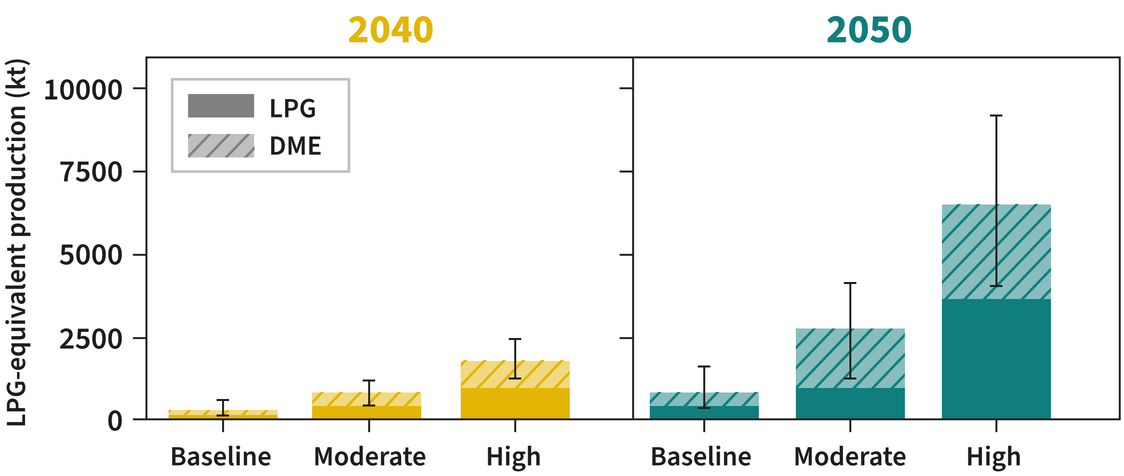
> "LPG is a cornerstone of the global energy mix, accounting for roughly 2% of global energy demand."

Regional Insights

AFRICA

Africa has an abundance of feedstocks that could be used to produce renewable fuels, though technology costs have hindered deployment. Africa shows significant growth potential beyond 2050.

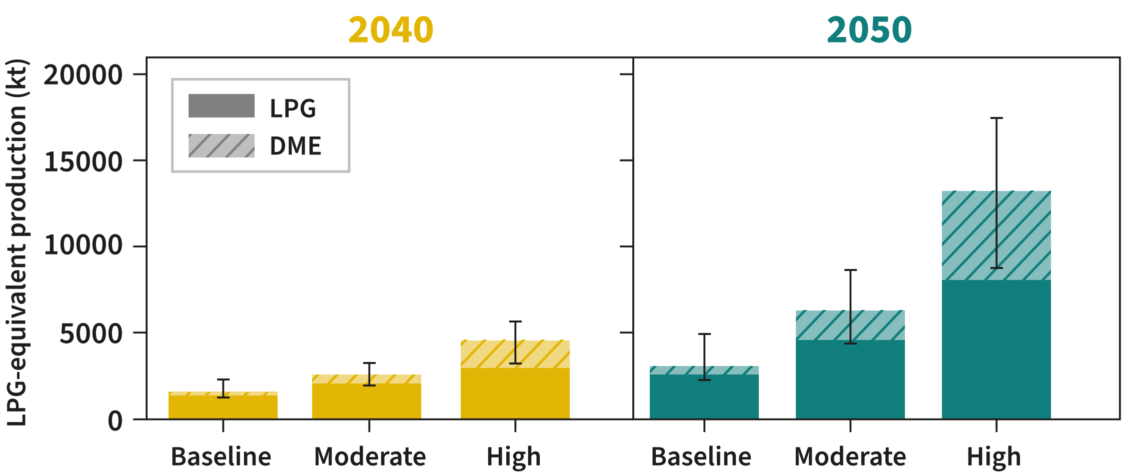
The central model estimates for the future production of rLG in Africa
(LPG-equivalent)



ASIA

Asia has great potential to produce rLG with high population density leading to abundant feedstocks and demand, although competition for feedstock could limit growth.

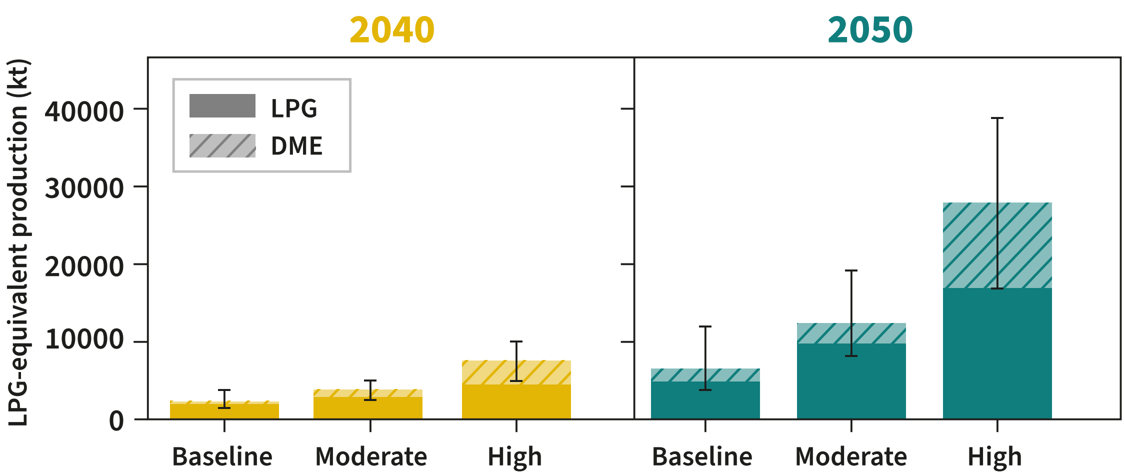
The central model estimates for the future production of rLG in Asia
(LPG-equivalent)



EUROPE

Ambitious net-zero targets create significant demand in Europe. Longer-term growth will depend on developing advanced pathways using renewable electricity, captured carbon, and other synthetic processes, which require sustained R&D investment and supportive policy frameworks to become commercially viable.

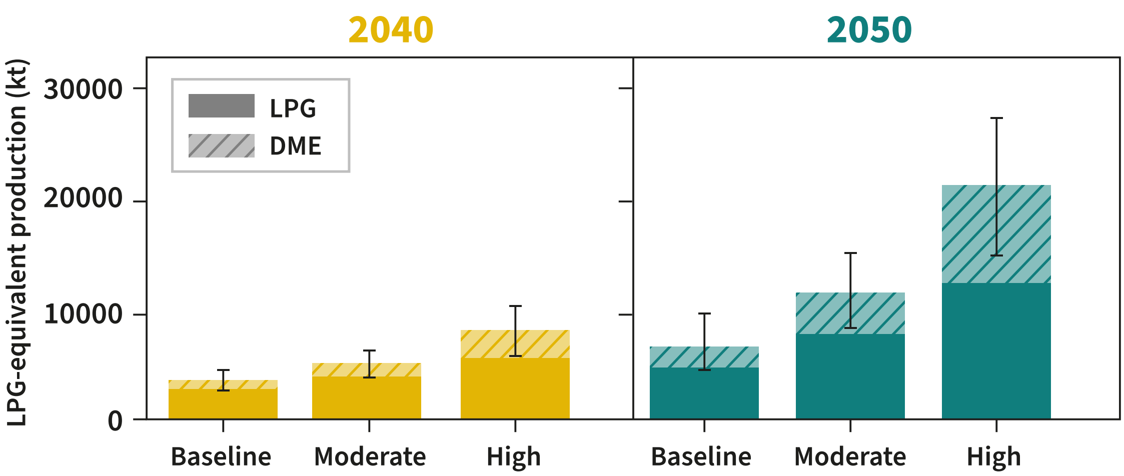
The central model estimates for the future production of rLG in Europe
(LPG-equivalent)



NORTH-AMERICA

Abundant feedstocks in significant quantities, paired with sustainable aviation fuel (SAF) mandates, accelerate co-production pathways near-term, while growth is dependent on new production pathways.

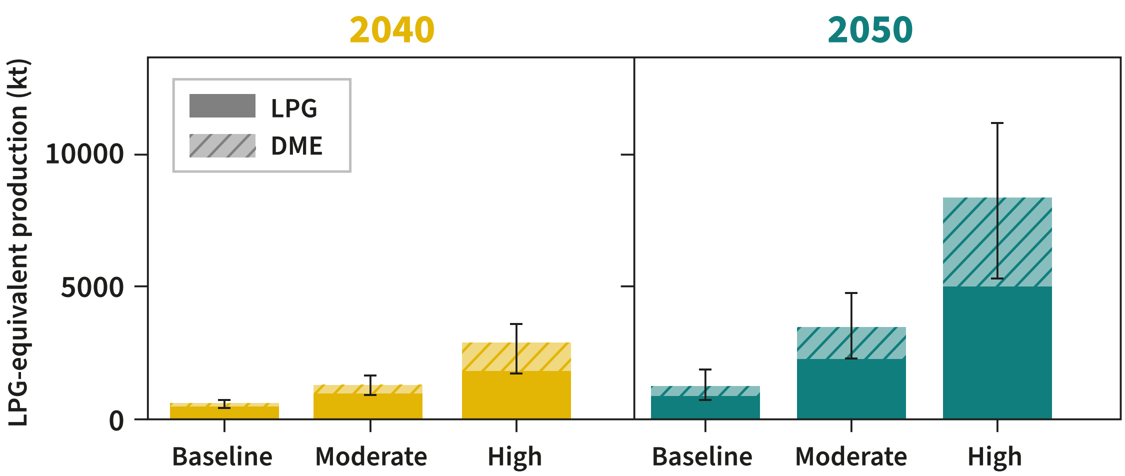
The central model estimates for the future production of rLG in North-America
(LPG-equivalent)



SOUTH-AMERICA

South America has abundant feedstocks and, today, nearly 30% of ethanol production is there and it could be an rLG hub despite feedstock competition, contingent on policy support. South America shows significant growth potential beyond 2050, as well.

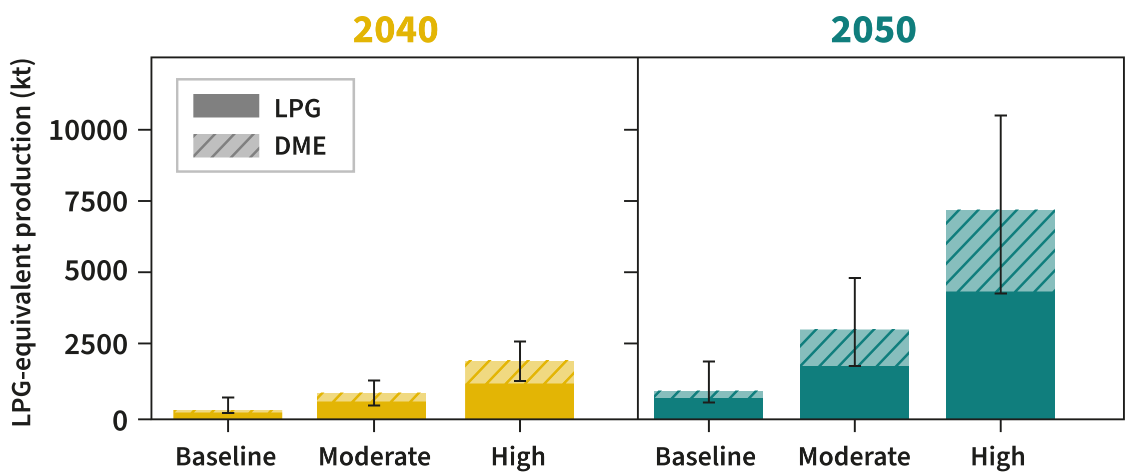
The central model estimates for the future production of rLG in South-America
(LPG-equivalent)



OCEANIA

Tallow from livestock farming underpins HVO/HEFA, with other pathways adding volume longer-term. Competition for feedstocks, particularly ethanol, could limit growth.

The central model estimates for the future production of rLG in Oceania
(LPG-equivalent)



Reduced Carbon Emissions

In the High scenario, the adoption of rLG could save over 238 Mt CO_2 annually by 2050

The production of rLG from these pathways achieves 65-70% carbon reductions against fossil comparators (94 gCO_2eq/MJ transport, 80 gCO_2eq/MJ heating) and the savings could be even greater with more efficient technologies and the commercialisation of carbon capture and storage technologies. But achieving these significant carbon emission reductions requires policy support.

Region	Estimated Carbon Savings (Mt CO_2eq)
Africa	17
Asia	36
Europe	74
North America	57
South America	22
Oceania	19
Global	**238**

Policy Recommendations

Each region will have their own specific policy recommendations, but at a global level it is important to pursue consistency across markets. Policy priorities include:

1. **Technology-Neutral Support:** Policy support that promotes all clean energy solutions, including the adoption of rLG across power generation, domestic, commercial, on-road, off-road, agricultural, and industrial markets.

2. **Regulatory Harmonisation:** Standardise lifecycle emissions globally, avoiding tailpipe-only metrics, to ensure that accurate carbon savings are recognised. Also, simplified regulations around chain-of-custody rules, certification schemes, and carbon accounting support market entry and growth.

3. **Financial Incentives:** Use tax credits, subsidies, grants, and low-interest loans to bridge cost gaps and fund infrastructure for both mature (e.g., HVO/HEFA) and emerging (e.g., CO_2/H_2) pathways are important. Incentives can also be used to boost feedstock supplies, which is a limiting factor in many regions.

4. **Research & Development and De-Risking Investments:** Provide funding support for pilot projects and public-private partnerships to commercialise innovative pathways. This support can mitigate investment risks, which derail many projects.

5. **Feedstock Security:** Harmonise sustainability standards and simplify waste regulations to increase feedstock access, which is critical for scaling production.

6. **Market Stability:** Implement consistent, realistic, long-term policies to attract capital, paired with policies that value co-products (e.g., rLG from SAF and renewable diesel production), thus boosting supply confidence.

7. **Consumer Adoption:** Provide incentives to drive demand for consumer products that support decarbonisation, including rLG-compatible appliances and equipment.

8. **Avoid Inhibition:** Provide equitable policy support across decarbonisation solutions without banning pragmatic options that meet consumer needs.

Conclusion

The production of rLG can reach 88 Mt of production by 2050, saving 238 Mt CO_2 annually, and production can exceed 200 Mt beyond 2050. Diverse production pathways spread risk and leverage global feedstocks. Yet, without critical policy action, production could stagnate at 10-25% of its potential. The industry, innovators, and policymakers must act now to realise rLG's key role in a low-carbon future.
The industry is actively working on this front and engaging with technology innovators to develop the pathways. Policy support is needed to close the loop.

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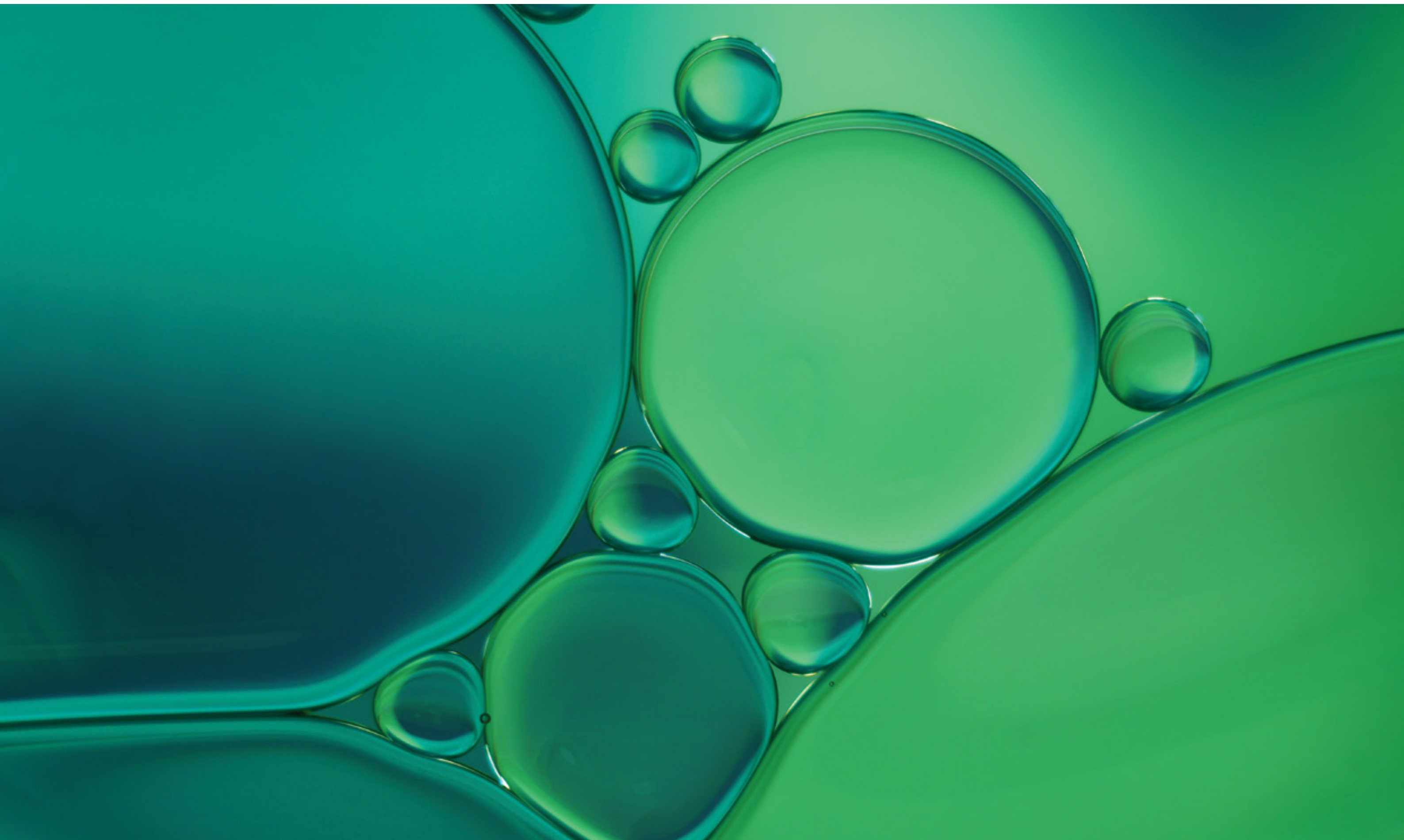

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