BIOENERGY ASSOCIATION

Pathway to renewable LPG

Webinar - NZ Bioenergy Association

28 April 2021

LPG Association of New Zealand

Advisian
Worley Group

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Outline

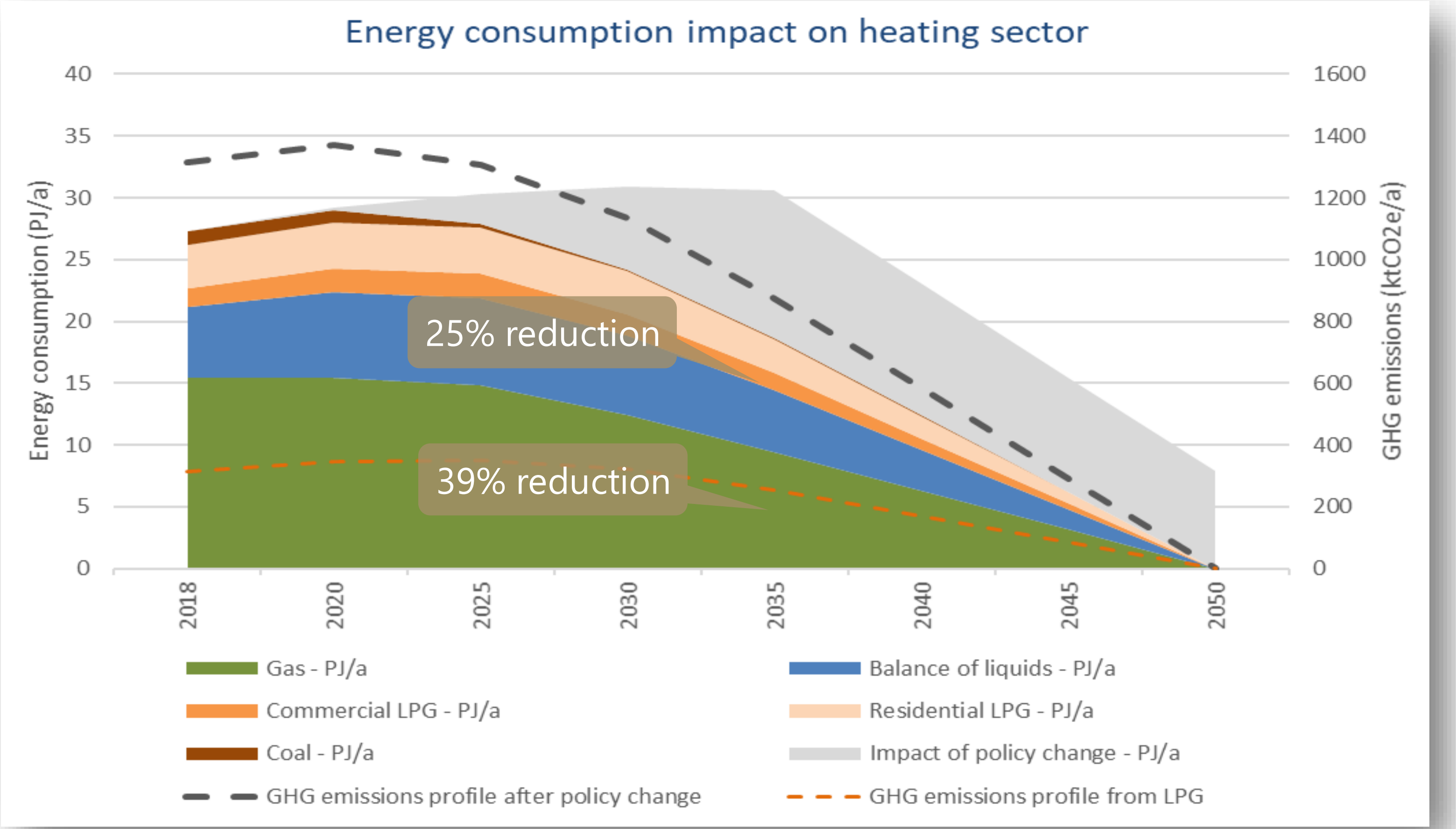
- Flintstone
  - Indirect substitution challenge
- Eureka & disclaimer
  - What is renewable LPG
- Possible production pathways
  - First generation “drop-in”rLPG
  - Second generation “drop-in”rLPG
  - Third generation “drop-in”rLPG
  - “Blend-in” component production
- Pathway assessment

Demonstrate why encouraging rLPG production through existing infrastructure is preferable to “no new connections” approach

Flintstone

"Setting a date by when no new natural gas connections are permitted, and where feasible, all new or replacement heating systems installed are [to be] electric or bioenergy [based]. This should be no later than 2025 and earlier if possible."

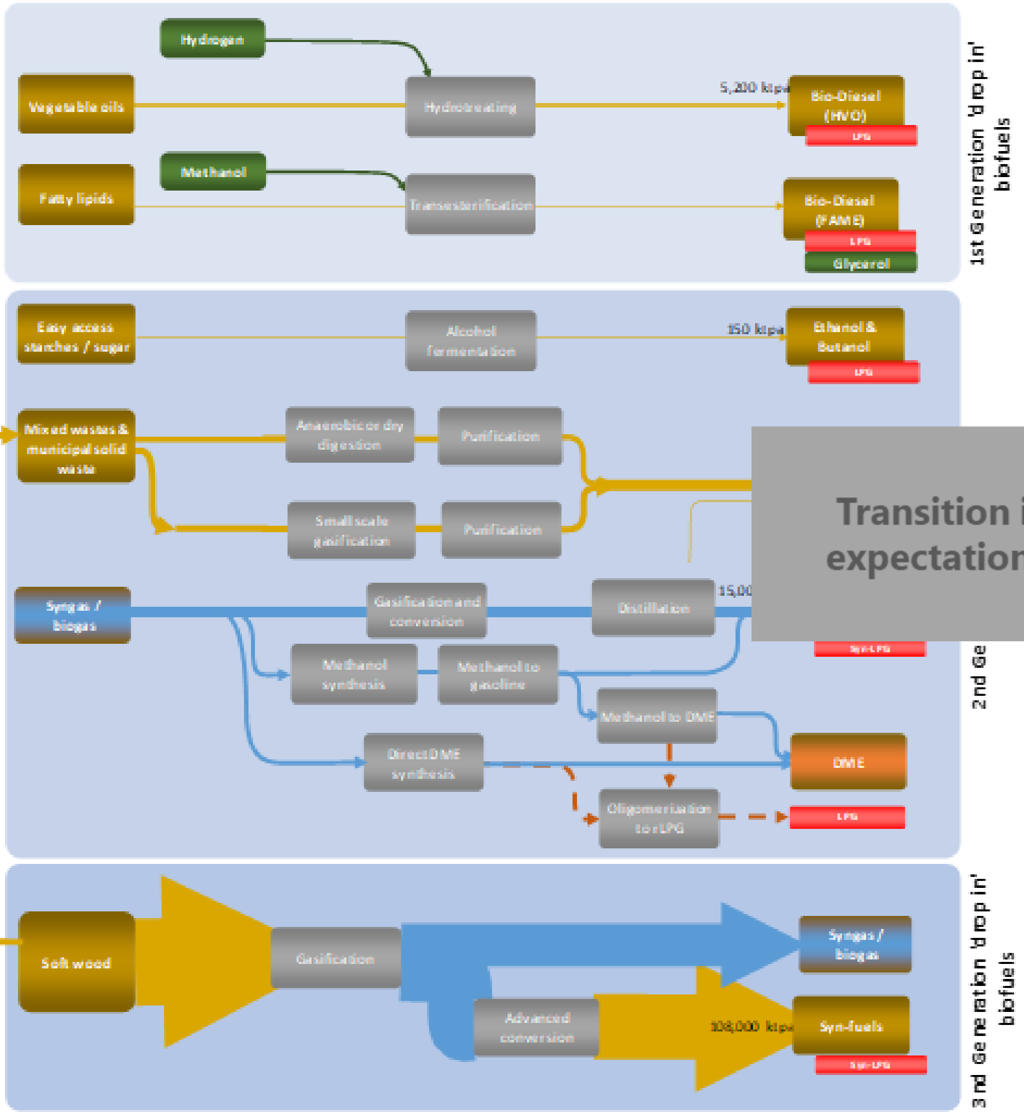
CCC - Necessary action 9c

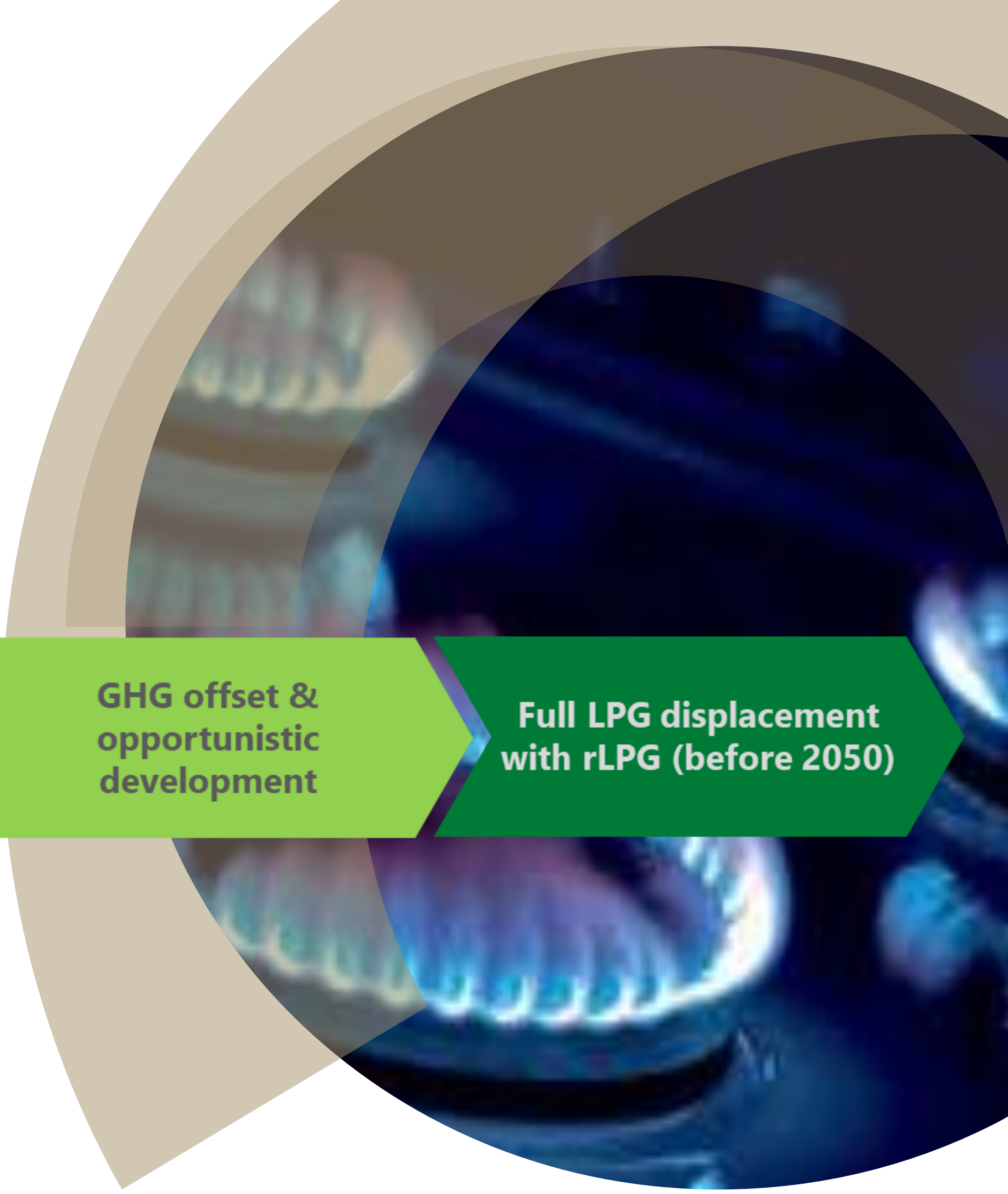


Indirect substitution challenge

Indirect substitution challenges

Alternative approach





Transition in GHG expectation (2025)

GHG offset & opportunistic development

Full LPG displacement with rLPG (before 2050)

WLPGA

Liquid Gas UK

Prized fuel

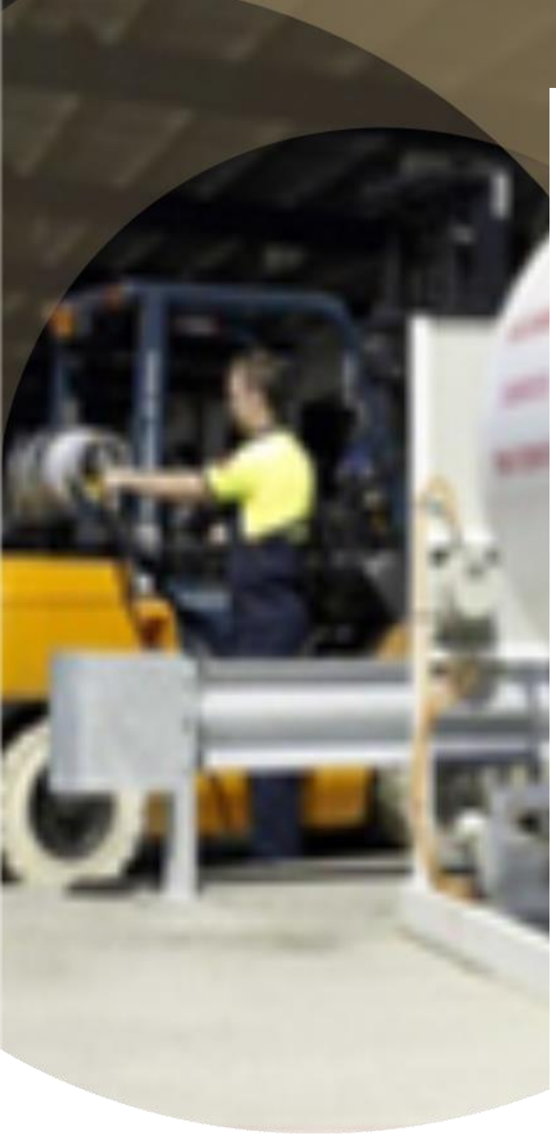
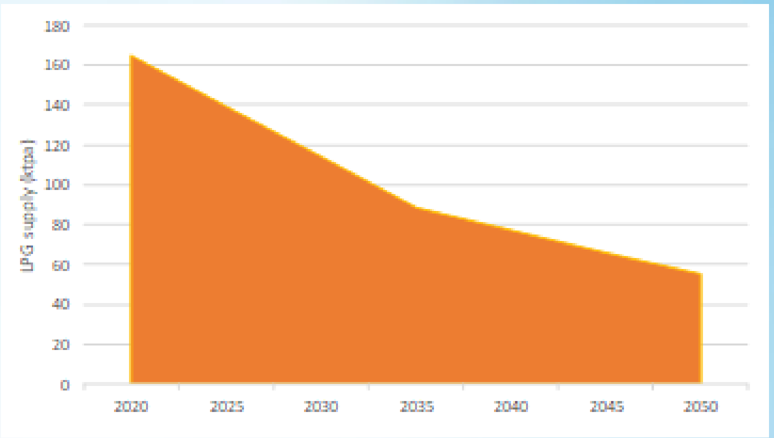


Table 3 – Current LPG market parameters (based on 2020)

Parameter	Demand	GHG emissions
Annual domestic production	165 ktpa	
Domestic demand	95 ktpa North Island; 90 ktpa South Island (35 ktpa is reticulated) 185 ktpa total (20 ktpa is imported) 9.4 PJ/a	560 $ktCO_2e/y$
Indicative number of customer installations	178,000 excluding BBQs, camping and mobile	
Indicative industrial volume	56 ktpa	170 $ktCO_2e/y$
Indicative commercial volume	38 ktpa;	115 $ktCO_2e/y$
Indicative residential volume	70 ktpa	210 $ktCO_2e/y$
Indicative portable volume	21 ktpa	65 $ktCO_2e/y$

Can a fossil fuel be decarbonized?



Eureka moment/s

"What previously seemed impossible seems practical"

Renewable LPG pathways

Propane (C_3H_8) Butane (C_4H_{10})

Product from a broad range of low carbon LPG production pathways e.g.:

- BioLPG
- SynLPG
- eLPG
- Dimethyl-ether (DME)

Dimethyl-ether (C_2H_6O)

Breakdown complex molecules

BioLPG / SynLPG pathways:

$$C_6H_{12}O_6 \rightarrow 3\ CH_4 + 3\ CO_2$$

$$C_6H_{12}O_6 \rightarrow C_3H_6 + 3\ H_2 + 3\ CO_2$$

eLPG pathway:

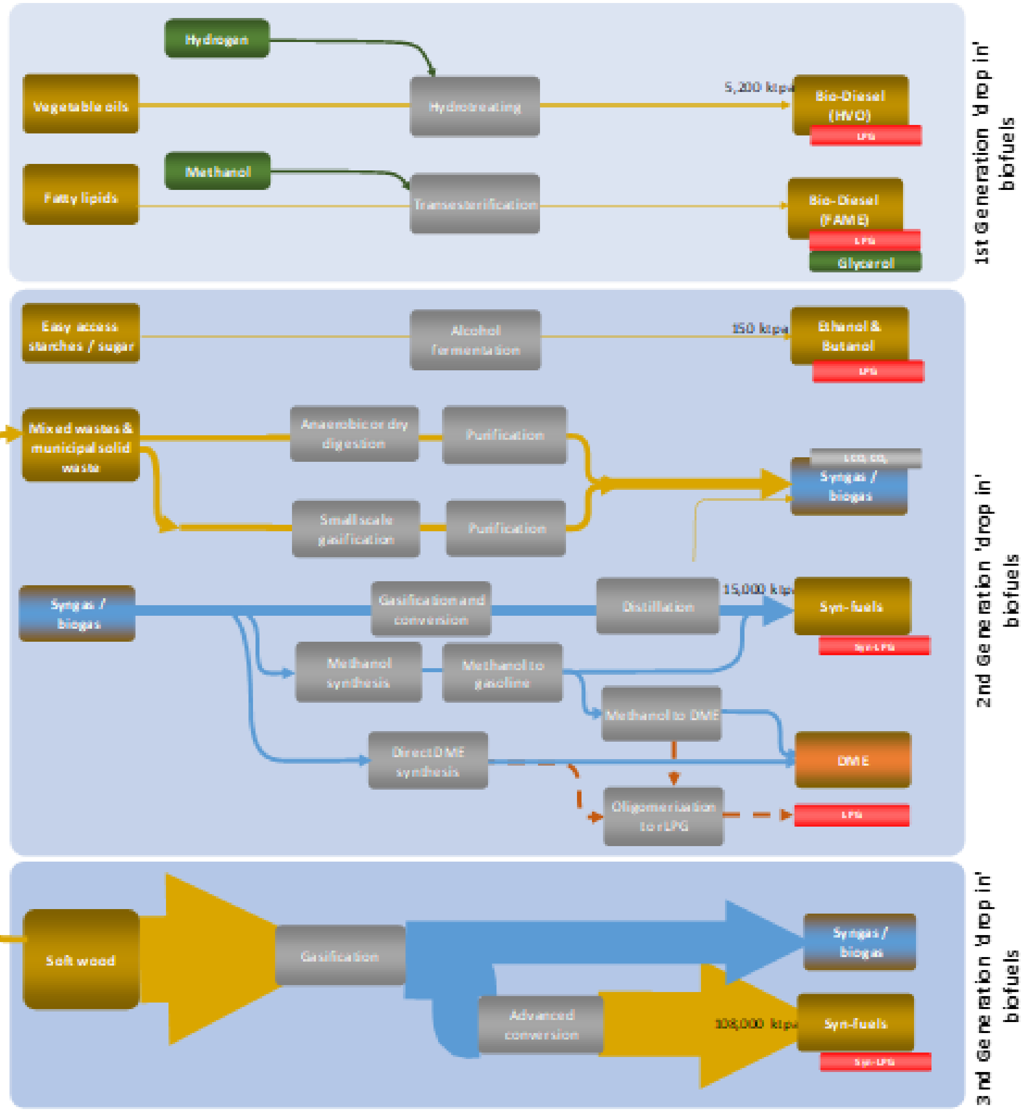
$$3\ CO_2 + 24\ H_2 \rightarrow 3\ CH_4 + 6\ H_2O$$

$$3\ CO_2 + 18\ H_2 \rightarrow C_3H_6 + 6\ H_2O$$

Build-up molecules

Possible production pathways

Target mix is quite different from International literature



3.2 ktpa rLPG yield

9 ktpa rLPG from wastewater / manure sources

30 ktpa rLPG equivalent (as rDME).

40 ktpa rLPG from biogas conversion.

20 ktpa rLPG yield

First generation "drop-in" rLPG

- Minimum commercial scale is 50 tpd (~18 ktpa)
- rLPG is typically 5 -10% of the product slate
- Target contribution is 3.2 ktpa rLPG yield from 2 @ 36 ktpa plants

ZBIOD plant

Z Energy built a fatty lipid to bio-diesel plant in Wiri, Auckland in 2016 for a nominal $26 million investment. The facility has a bio-diesel capacity of 20 million L/y (16 ktpa or 0.76 PJ/y) using tallow as feedstock. This is 0.5% of New Zealand's current diesel demand.

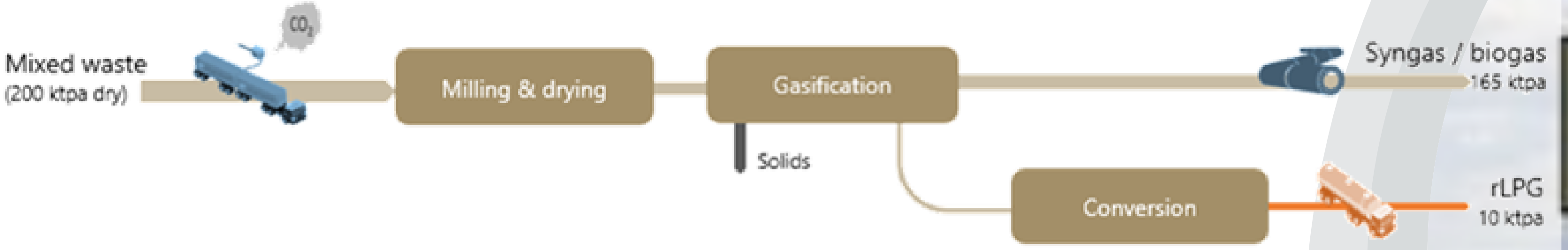
The plant feed rate is ~50 ton/day.

Based on an expected 5% side yield, the potential renewable LPG yield is 0.8 ktpa.

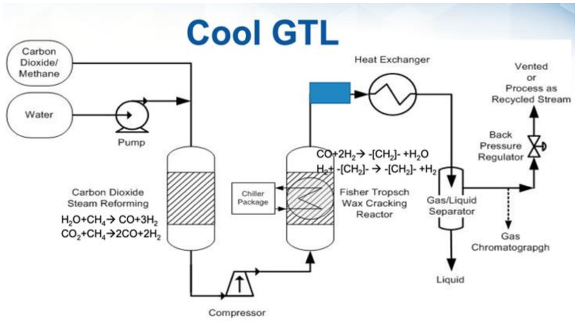
Z state that double production is easily achievable for the plant given feedstock availability.

Second generation "drop-in" rLPG

Small scale gasification and conversion



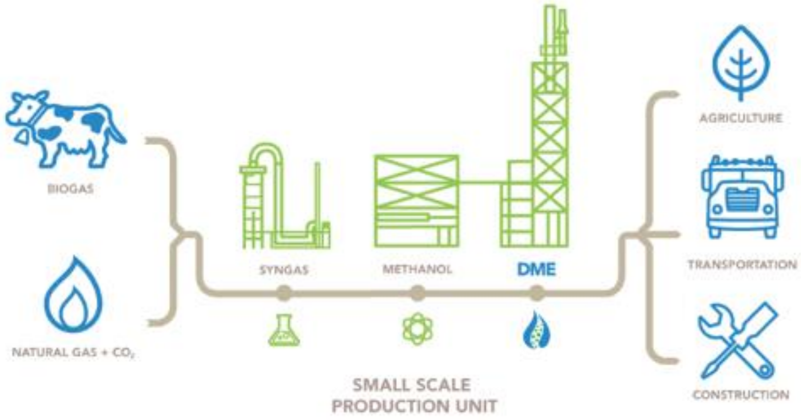
- Numerous "emerging" plays.
- Commercial scale for gasification is ~200 ktpa; Conversion system scale is approaching 10 ktpa.
- Target contribution is 9 ktpa rLPG from 3 targeted plants.



GHG footprint is dependent on current management of sourced waste

Second generation "drop-in" rLPG

Biogas (with CO_2) conversion



- Potential to manage methane emissions and derive value
- Standard plants -15,000 to 25,000 cows, produce 2.7 – 9 ktpa of DME, which is 1.7 - 5.6 ktpa rLPG equivalent
- Target contribution is 30 ktpa rLPG equivalent (as rDME).

GHG footprint is dependent on current management of sourced waste

"Blend-in" component production

- Conversion of biogas to either rLPG or rDME provide low cost "liquid fuel" production
  - Can monetise stranded assets … likely to target rDME
  - Low cost "soft wood" use pathway
  - Industrial scale to distribution and network balancing

- 20 and 30% v/v rDME: LPG blends are possible
  - Marginally heavier bottles;
  - Much lower GHG footprint.

Table 5 - DME / LPG blend properties

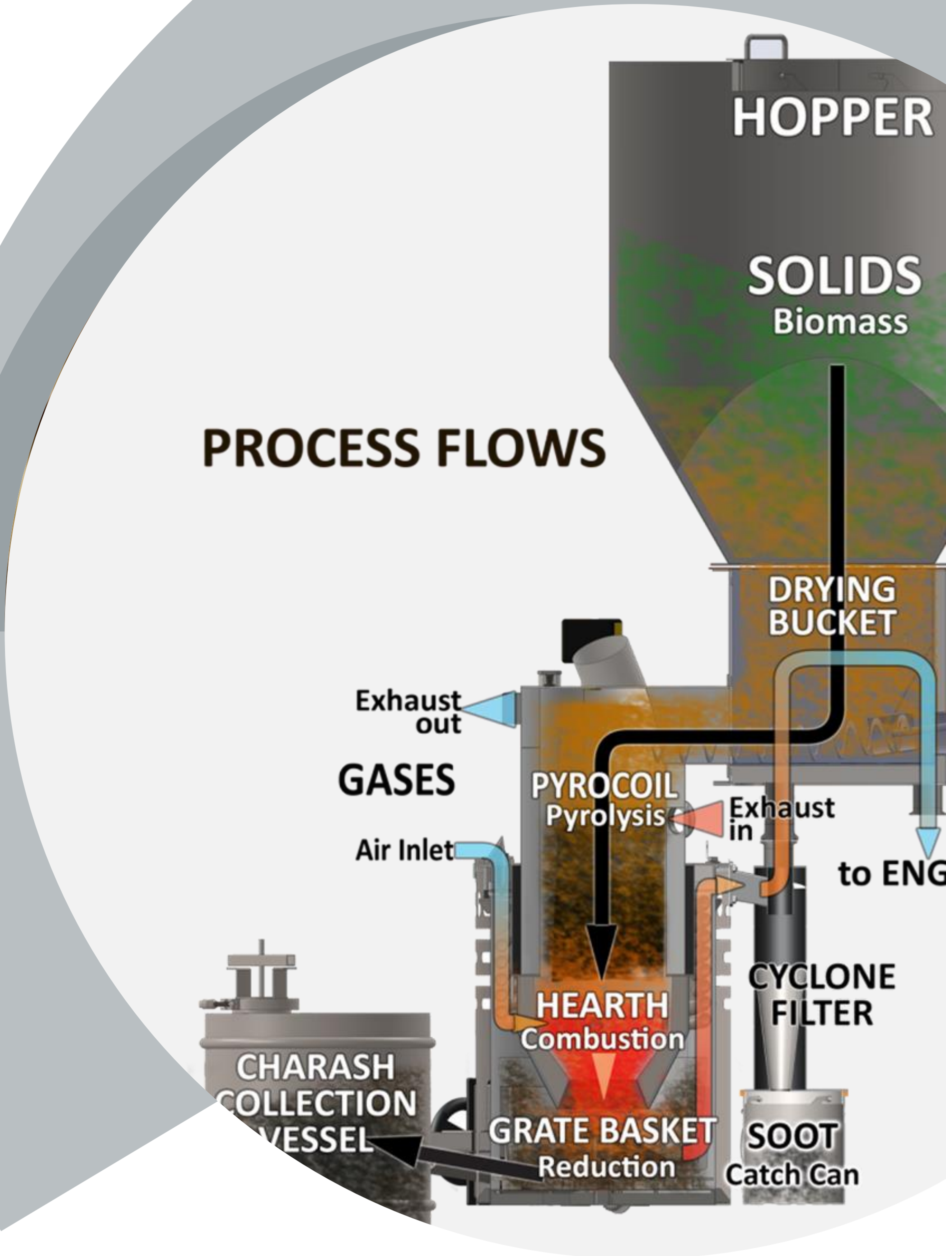
Parameter	Unit	DME	LPG	20 vol% DME / 80 vol% LPG
Mass density	kg/m^3	667	540	565.4
Heating value (LHV)	MJ/kg	28.8	46	42.6
Mass per bottle unit vol.	kg/m^3	567	432	459
Energy per bottle unit vol.	GJ/m^3	16.3	19.9	19.2

Third generation "drop-in" rLPG

Soft wood to biofuels

- Comparative advantage (cf. rest of world)
- Conventional synthesis requires ~500 ktpa (dry basis) scale
  - Methanol route is or direct DME routes possible
  - Likely rDME for automotive market + co-production
- Advanced synthesis trending towards ~200 ktpa scale
  - Broader opportunity and much lower feedstock transport logistics / GHG footprint
- Pyrolysis to bio-crudes is not an established pathway
- Target contribution is from 20 ktpa rLPG yield (7.5% of total) from 1 @ 1,250 ktpa dry feed, or several smaller plants

GHG footprint relates to biomass collection and green H_2 sourcing. ~20 ktCO_2eq/PJ



Pathway assessment

70% rLPG substitution scenario

Figure 20 – Target rLPG build-up – 70% rLPG substitution scenario

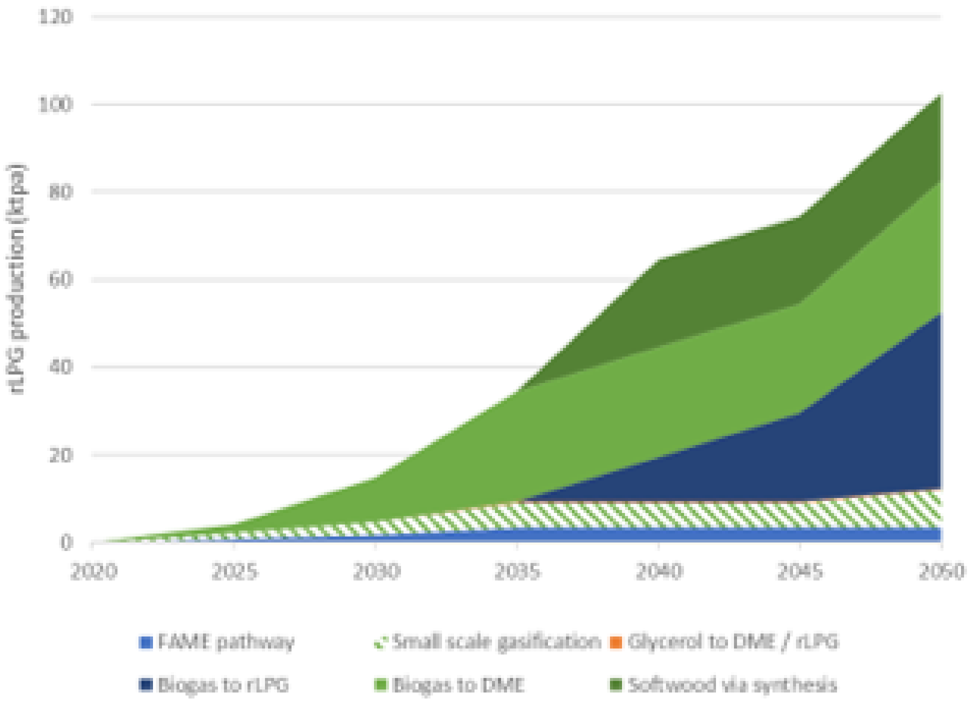
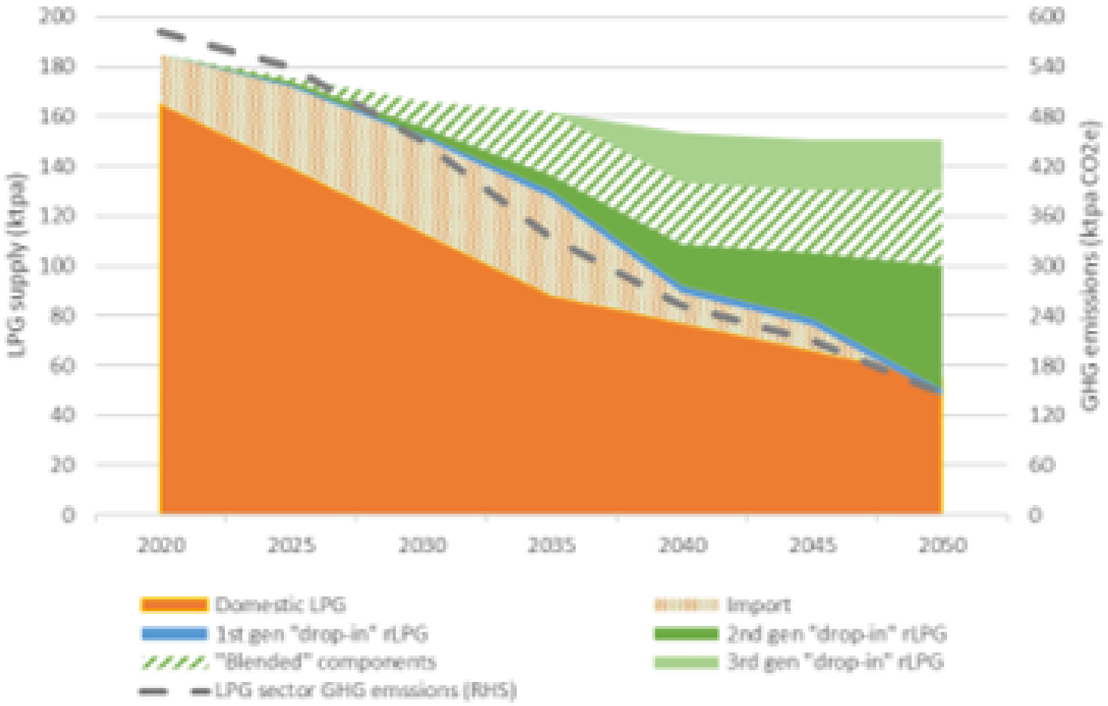


Figure 21 - NZ LPG market plan – 70% rLPG substitution scenario

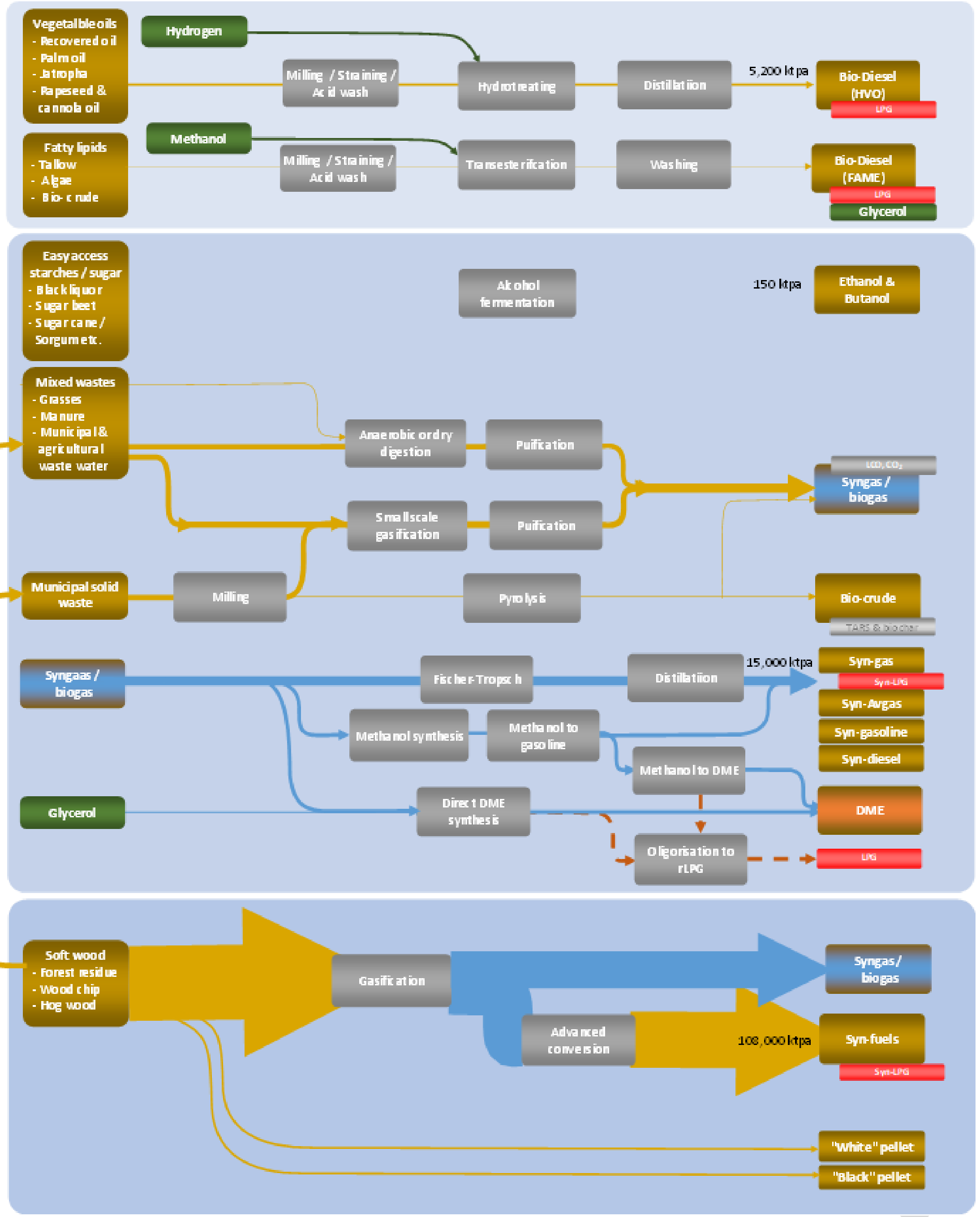


Matches cLPG decline | Realistic & achievable | Achieve target GHG reduction

70% rLPG substitution scenario

Table 7 - 70% rLPG scenario plant scale

Plant by 2035	Plant by 2050
2 @ 100 tpd FAME biodiesel plants ≈ 3.2 ktpa rLPG	
2 @ Mixed waste gasification to rLPG plants ≈ 6 ktpa rLPG	3 @ Mixed waste gasification to rLPG ≈ 9 ktpa rLPG
2 @ Wastewater / manure to rDME facility ≈ 25 ktpa rLPG equivalent (40 ktpa rDME)[68]	3 @ Wastewater / manure to rDME facility ≈ 30 ktpa rLPG equivalent (48 ktpa rDME)
	Biogas to rLPG capability ≈ 40 ktpa rLPG
	1 @ Softwood to biofuels plant ≈ 20 ktpa rLPG



100% rLPG substitution scenario

Figure 22 – Target rLPG build-up – 100% rLPG substitution scenario

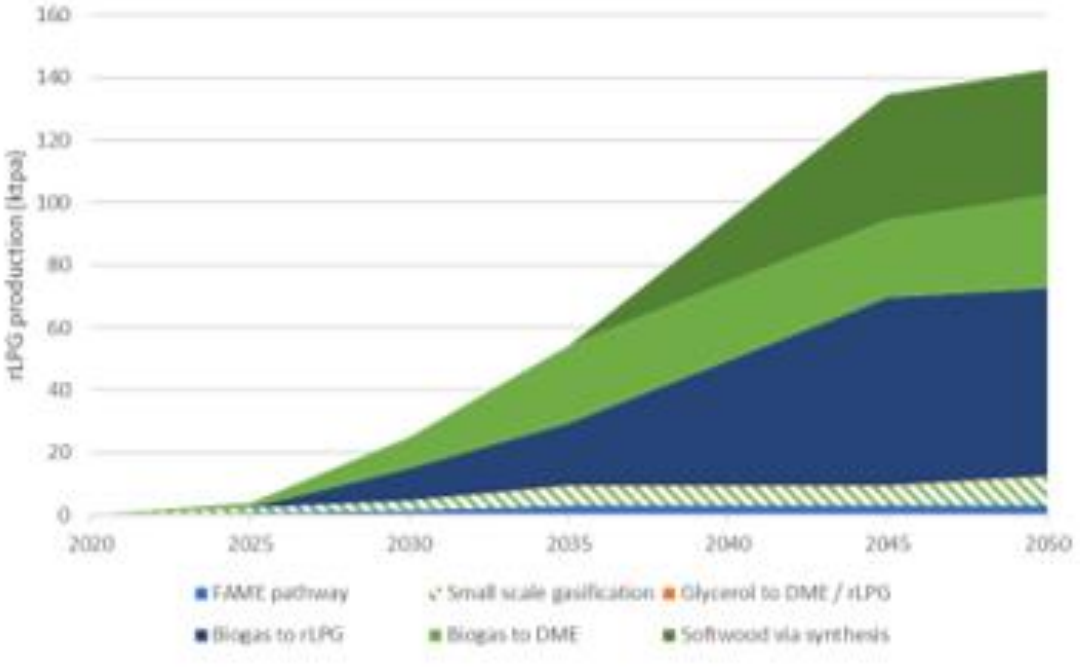
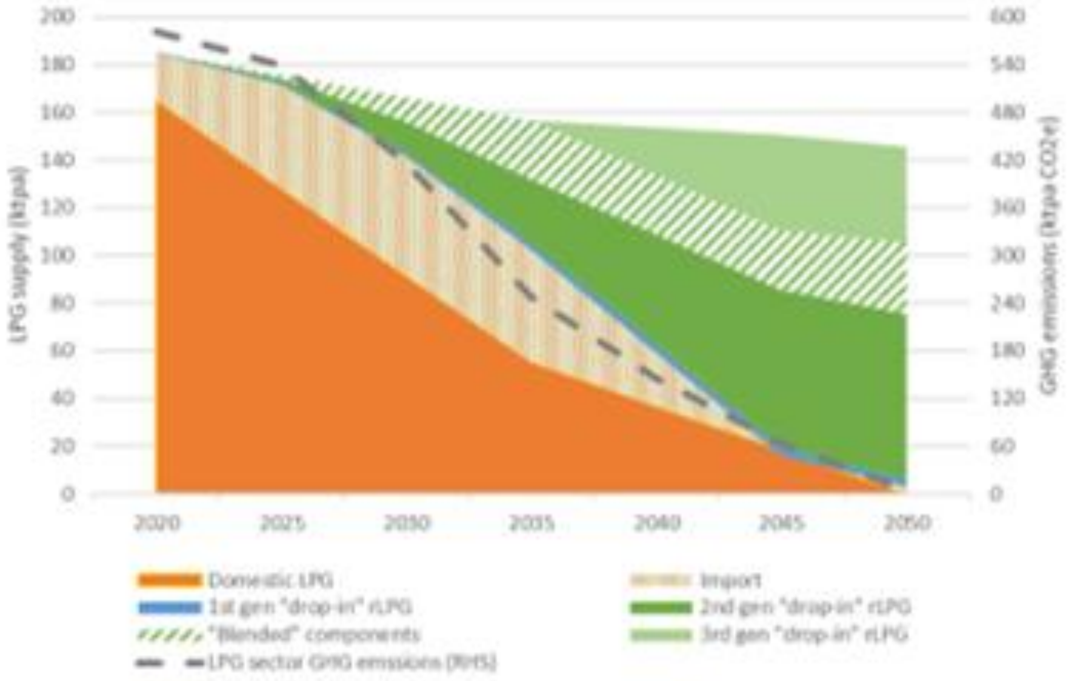


Figure 23 - NZ LPG market plan – 100% rLPG substitution scenario



cLPG decline / biogas inconsistency | rLPG production cost pressure

Logic blocks

LPG is an existing market suitable for progressive substitution

Indirect substitution can be challenging

Biogas is a "biomass" building block

The biomass pathway has huge advantage over the hydrogen based (eLPG) pathway

BioLPG / SynLPG pathways:

$$C_6H_{12}O_6 \rightarrow C_3H_6 + 3\ H_2 + 3\ CO_2$$

eLPG pathway:

$$3\ CO_2 + 18\ H_2 \rightarrow C_3H_6 + 6\ H_2O$$

There will be "competition" for biomass resources

Market volume may be limited and price points challenged

Choose to upgrade to LPG or higher order fuels?

Next steps

Transition in GHG expectation (2025) → GHG offset & opportunistic development → Full LPG displacement with rLPG (before 2050)

Going forward

Validate cLPG projection

1st gen biofuels techno-economic assessment & expectation setting

Capability of DME as an LPG blend stock

Dairy manure / wastewater recovery capacity

Explore prospects for biogas → DME → rLPG

Assess NG → DME → rLPG techno-economic assessment

Mapping of prospective opportunities

Softwood gasification status

2nd generation technology techno-economic & TRL/CRL assessment

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