

**FEASIBILITY OF GRASS-BASED BIOMETHANE AS A SUSTAINABLE
FUEL FOR SOUTH GLOUCESTERSHIRE'S MOWING FLEET**

SOUTH GLOUCESTERSHIRE COUNCIL



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Feasibility of Grass-Based Biomethane as a Sustainable Fuel for South Gloucestershire's Mowing Fleet

1 Executive Summary

This feasibility study examines the potential for South Gloucestershire Council, situated in the West of England, to convert grass clippings from municipal mowing operations into biomethane and utilise that energy to power its mowing equipment. The study supports the council's decarbonisation and sustainability goals, as well as the national Live Labs 2 initiative, which promotes innovative low-carbon infrastructure and which has funded this feasibility study

The study evaluates the technical, environmental, and financial viability of replacing diesel-powered mowers with biomethane-powered mowers, drawing on real operational data from the Live Labs 2 Greenprint initiative, including diesel consumption, grass collection volumes, and associated costs.

Greenprint is part of ADEPT Live Labs 2: Decarbonising Local Roads in the UK, which is a three-year, UK-wide £30 million programme funded by the Department for Transport, (DfT), that aims to decarbonise the local highway network: <https://www.adeptnet.org.uk/livelabs2>

Greenprint is an innovation project which is investigating potential new ways grass cuttings could be used, including producing biogas, biomethane fuel for vehicles and an additive for asphalt road surfacing material called biochar.

In this report, multiple digestion scenarios are assessed, including the co-digestion of grass with agricultural feedstocks (current practice, as trialled in the Live Labs 2 Greenprint project) and manure. The analysis encompasses both the council's existing mower fleet (ISEKI F5) and the adaptation of the McConnel Robocut T500 with a low-emission engine developed by CAGE Technologies.

The study is structured in distinct phases, including technical background, justification, feasibility assessments, an implementation plan, and a risk matrix. The principal aim is to determine whether a circular model can be established, in which grass waste is converted into energy to power mowing equipment at a viable and scalable cost.

If successful, the findings will guide the development of a replicable approach for cleaner and more efficient municipal operations.

2 Project Overview

South Gloucestershire is a unitary authority in the South West of England, located just north of the city of Bristol. The council currently maintains its public green spaces using diesel-powered mowing equipment and during the Live Labs 2 Greenprint project collected approximately 380 tonnes of grass clippings annually, (2024). Although these are sent to anaerobic digestion (AD) facilities, the resulting biogas is not reused by the council, representing a lost opportunity for local energy recovery.

This feasibility study investigates whether the council can instead convert this biomass into biogas and upgrade it to biomethane for powering its own mowing fleet. Data on grass volumes, fuel consumption, and equipment in use will be drawn directly from South Gloucestershire's current operations. As a reference platform, the study will focus on the McConnel Robocut T500, a remote-controlled slope mower widely used for maintaining steep or hazardous terrain, recently added to the South Gloucestershire fleet. The machine's current diesel engine would be replaced with a CAGE Technologies-developed biomethane propulsion system.

The study will include a review of technical background, an explanation of the project's relevance, a multi-dimensional feasibility assessment (technical, economic, and environmental), a practical implementation roadmap, and a risk matrix. Results will support the trial and potential deployment of a biomethane-powered mower within the council's operations.

3 Scope and objectives

This feasibility study is focused on evaluating the technical, economic, and environmental viability of converting grass clippings collected from South Gloucestershire Council's mowing operations into biomethane for use as a fuel in the council's own mowing equipment. The assessment considers both current practices, in which grass is co-digested with agricultural feedstocks such as maize and silage, and alternative scenarios involving the co-digestion of grass with manure. The study reviews available anaerobic digestion infrastructure, technologies for biomethane upgrading, compression, and storage, and the operational implications of supplying biomethane to a municipal fleet. Both the council's existing Iseki SF5 mowers and the proposed conversion of the McConnel Robocut T500 are included as reference cases. Regulatory, licensing, and infrastructure requirements are also addressed, with a view to identifying the practical steps and investment needed to enable a closed-loop, low-carbon mowing system in South Gloucestershire.

3.1 Objectives

The main objectives of this feasibility study are to:

- **Evaluate Technical Feasibility:** Assess the potential to use grass clippings as feedstock for biogas and biomethane production within available anaerobic digestion infrastructure.
- **Estimate Cost Savings:** Compare current diesel usage with projected biomethane fuel costs to determine potential economic benefits.
- **Assess Environmental Benefits:** Identify the expected reductions in emissions and air pollutants from shifting to a low-carbon fuel source.
- **Develop an Implementation Roadmap:** Outline the infrastructure, regulatory considerations, and funding pathways necessary for future deployment.

4 Justification

South Gloucestershire Council has set ambitious targets for decarbonisation and environmental sustainability, in alignment with national and regional policy. Considerable progress has already been made through the investigation of innovative cut-and-collect grass management, which is expected to improve local biodiversity, reduce nutrient run-off, and generate a steady stream of green biomass for valorisation.

However, current practice does not yet fully capitalise on the value of the collected grass, as it is either composted or sent off-site for processing. Converting this resource into biomethane to fuel the council's mowing equipment represents the next logical step, closing the loop on a truly circular, local energy system. This approach would reduce reliance on fossil fuels, cut operational emissions, and deliver direct environmental and economic benefits within the community.

By demonstrating the full circular use of local biomass for municipal operations, the council can position itself as a leader in climate action and innovation. Moreover, the outcomes of this project could serve as a replicable model for other authorities seeking to accelerate their transition to low-carbon, resource-efficient practices.

5 Technical Background

5.1 Biogas

Biogas is a renewable fuel and energy source primarily composed of methane (CH₄) and carbon dioxide (CO₂), produced through the anaerobic digestion of organic materials such as food waste, animal manure, and sewage sludge. In the absence of oxygen, microbial communities break down this organic matter, resulting in a gas

mixture typically containing 45%–75% methane and 25%–55% carbon dioxide. The energy content of biogas varies with composition, with a lower heating value (LHV) between 16 and 28 megajoules per cubic meter (MJ/m³). (iea, 2020)

The production and characteristics of biogas depend on the type of feedstock and the technology used. Common biogas production systems include:

- **Biodigesters:** Sealed systems (e.g., tanks or covered lagoons) where organic waste is mixed with water and broken down by microorganisms. The biogas is then captured and cleaned to remove contaminants and moisture.
- **Landfill Gas Recovery:** Municipal solid waste (MSW) decomposes anaerobically in landfills. A system of extraction wells and pipes collects the gas, which is then compressed and transported for energy use.
- **Wastewater Treatment Plants:** Sewage sludge is digested anaerobically to recover biogas whilst also extracting nutrients and reducing solids. This is a common method in urban infrastructure.

Biogas can be used directly in Combined Heat and Power (CHP) systems to generate electricity and heat or upgraded to biomethane for injection into natural gas grids or for use as vehicle fuel. Its versatility makes it suitable for both small-scale residential applications and large-scale industrial energy systems.

5.2 Biomethane

Biomethane, also known as renewable natural gas (RNG), is a high-purity form of methane (CH₄) produced from organic materials. It is typically derived by upgrading raw biogas—removing carbon dioxide, moisture, and other impurities—or through the gasification of solid biomass followed by methanation. With a lower heating value (LHV) of approximately 36 MJ/m³, biomethane is chemically indistinguishable from fossil natural gas. This allows it to be used in existing natural gas infrastructure and end-user equipment without modification. It is fully compatible with residential heating systems, industrial processes, and natural gas vehicles, offering a renewable and low-carbon alternative to conventional natural gas. (iea, 2020)

5.2.1 How is Biomethane Produced?

According to the IEA (2020), biomethane is produced through two main technological pathways:

1. Upgrading Biogas

This is the most widely used method, accounting for approximately 90% of global biomethane production. Raw biogas consists primarily of methane (CH₄) and carbon dioxide (CO₂), along with small amounts of other gases and impurities. The upgrading process removes CO₂, water vapour, and contaminants, resulting in a high-purity methane product. (iea, 2020)

The IEA identifies the following key upgrading technologies:

- **Water Scrubbing:** Uses the physical property of CO₂'s solubility in water to separate it from methane.
- **Membrane Separation:** Relies on membranes that selectively allow CO₂ and other gases to pass through whilst retaining methane.

Together, water scrubbing and membrane separation account for nearly 60% of all biomethane production worldwide (IEA, 2020).

Other methods not detailed in this section but commonly used in the industry, include pressure swing adsorption (PSA) and chemical absorption.

2. Thermal Gasification of Solid Biomass Followed by Methanation

This second route involves converting woody biomass into biomethane. The process is more complex and less common, but is essential in areas with abundant lignocellulosic resources. (iea, 2020)

It involves the following steps:

- **Gasification:** Biomass is broken down at high temperatures (700–800°C) and high pressure in a low-oxygen environment, producing a synthesis gas (syngas) composed mainly of carbon monoxide (CO), hydrogen (H₂), and methane (CH₄).
- **Syngas Cleaning:** This step removes acidic and corrosive compounds such as tars, ammonia, and sulphur components.
- **Methanation:** A catalytic reaction is used to convert CO or CO₂ and H₂ into methane.
- **Final Purification:** Any remaining CO₂ or moisture is removed to yield pipeline-quality biomethane.

5.3 Grass

Grass is a widely available and renewable biomass that can be converted into biomethane through anaerobic digestion. Well-managed grasslands—especially those dominated by perennial ryegrass (*Lolium perenne*), are considered suitable feedstocks due to their high digestibility and carbohydrate content, which enhance

methane yields (Jerry D. Murphy, 2013) The timing of harvest is also important: cutting at an early vegetative stage maximises the proportion of fermentable sugars and minimises lignin, further improving methane production. (Jerry D. Murphy, 2013)

Ensiling, the process of fermenting and storing grass in anaerobic conditions, is commonly used to preserve grass for year-round digestion and to increase its methane potential. Ensiled grass is more readily digested by anaerobic microbes, leading to higher and more stable biogas production. (Jerry D. Murphy, 2013)

Anaerobic digestion of grass produces a biogas composed mainly of methane and carbon dioxide, which can be upgraded to biomethane and used as a vehicle fuel or injected into the gas grid (Jerry D. Murphy, 2013). The actual methane yield from roadside grass clippings, when co-digested with manure or other substrates, typically ranges from 170 to 240 Nm³ CH₄ per tonne of dry matter, as demonstrated in recent European studies (Liczbiński, 2022).

In summary, the efficiency of grass-to-biomethane conversion depends on grass species, harvesting strategy, and ensiling practices. These factors should be optimised to ensure the highest energy yields and economic viability for municipal or agricultural biogas projects (Jerry D. Murphy, 2013)

5.4 Robocut T500

The McConnel Robocut T500 is a robust, remote-controlled mower designed for professional vegetation management in challenging environments. Manufactured in the UK, it is specifically built to operate on steep slopes, rough terrain, and areas that are difficult or unsafe to access with traditional mowing equipment. This machine is commonly used in roadside maintenance, forestry, public infrastructure, and utility corridors, where both efficiency and operator safety are critical. (McConnel, 2024)

The Robocut T500 functions through a remote-control system that allows the operator to manage the machine from up to 150 meters away. The unit runs on a diesel-powered engine that drives a hydraulic transmission system, which powers both the tracks and the cutting head. The low centre of gravity, combined with its rubber-tracked undercarriage, gives the machine excellent stability and traction, enabling it to work on gradients of up to 55 degrees. Proportional joysticks on the remote control allow for precise movement and adjustment of the cutting height, making it easy to operate even in uneven or sloped areas. (McConnel, 2024)

One of the main advantages of the Robocut T500 is its ability to improve safety by keeping the operator at a distance from potentially dangerous terrain. It also

significantly increases productivity, as it can cover large areas much faster than manual brush-cutting teams—up to 25 times faster in some use cases. In addition to mowing, the machine supports a variety of attachments such as mulchers, flail heads, and stump grinders, making it a versatile tool for year-round land management. (McConnel, 2024)

Its compact size and tracked design also make it easy to transport and manoeuvre in confined or sensitive environments. Overall, the Robocut T500 combines durability, adaptability, and performance, making it a strong candidate for conversion to biomethane propulsion as part of a sustainable innovation project. (McConnel, 2024)

5.5 ISEKI SF5 Mower

The ISEKI SF5 is a high-performance, ride-on out-front mower designed for professional grounds maintenance across a variety of environments. This machine is engineered for productivity and versatility, making it well-suited for municipal green spaces, parks, sports facilities, and large roadside verges where efficiency, operator comfort, and finish quality are essential. (ISEKI, 2025)

The SF5 is powered by a robust Stage V-compliant diesel engine, delivering up to 49 hp (36.5 kW) to support demanding mowing tasks over extended periods. Its hydrostatic drive system provides smooth, responsive control, allowing the operator to navigate efficiently through complex terrains and adjust speed with precision. The out-front mower deck ensures excellent visibility and accessibility, enabling the SF5 to cut effectively around obstacles, edges, and tight spaces. (ISEKI, 2025)

The mower features a generous high-capacity grass collector—available up to 1300 litres—equipped with a high-tip discharge system for quick and efficient unloading into trailers or collection skips. The SF5's cutting decks are available in various widths (ranging from 54" to 60") and offer both rotary and flail options, providing flexibility for different grass types and conditions. Cutting height can be easily adjusted from the operator's seat to suit seasonal requirements or site-specific needs. (ISEKI, 2025)

Ergonomically designed for operator comfort, the SF5 includes a spacious platform, adjustable seating, intuitive controls, and excellent all-round visibility. The machine is built with durable materials and easy-access maintenance points to ensure long-term reliability and low operating costs.

Overall, the ISEKI SF5 combines power, adaptability, and ease of use, making it an ideal solution for large-scale, high-frequency mowing operations in urban and

municipal settings. Its capacity for extended operation and efficient grass collection makes it a valuable component in sustainable grounds management programmes, and a strong candidate for adaptation to alternative fuels such as biomethane.

Feature	ISEKI SF5	McConnel Robocut T500
Type	Ride-on, out-front mower	Remote-controlled, tracked mower
Primary Application	Municipal green spaces, parks, sports fields, large roadside verges	Roadside maintenance, steep slopes, rough terrain, forestry, utility corridors
Engine	49 hp (36.5 kW) Stage V diesel engine	Diesel engine with hydraulic transmission
Transmission	Hydrostatic drive, responsive speed and direction control	Hydraulic drive, fully remote-controlled
Cutting System	Out-front rotary or flail decks (54"–60"), adjustable height from operator's seat	Flail or rotary attachments, remote-controlled height adjustment
Grass Collection	High-capacity collector up to 1300 L, high-tip discharge for skip/trailer loading	No built-in collection; typically used for mulching, but can be paired with collection systems
Operator Position	Seated, ergonomic controls, high visibility	Remote operation (up to 150 m), proportional joysticks
Terrain Capability	Suitable for moderately uneven or complex urban environments	Operates safely on slopes up to 55°, rough and inaccessible terrain
Productivity	High mowing speed, large-area coverage per hour	Up to 25x faster than manual brush-cutting teams on challenging ground
Safety	Operator onboard with full control	Operator at a safe distance from hazardous or difficult terrain
Attachments	Multiple deck options (rotary/flail), seasonal accessories	Mulcher, flail, stump grinder, brush cutter, various specialised heads
Fuel / Future Adaptation	Diesel (candidate for biomethane conversion), robust maintenance access	Diesel (candidate for biomethane/electric conversion), rugged tracked system
Key Strengths	Large capacity, operator comfort, efficient for open and urban areas	Extreme versatility, slope capability, remote safety, suitable for hazardous or steep environments
Limitations	Less suitable for very steep or hazardous terrain; operator exposure to dust/noise	Lower collection capacity, slower transport speed, may require separate grass collection arrangements
Suitability for Biomethane Conversion	High, especially in fleet or municipal programmes aiming to decarbonise routine mowing	High, as a demonstration platform for innovative, sustainable remote-controlled mowing

6 Current Waste Management

6.1 Waste and Grass Biomass Inventory in South Gloucestershire

South Gloucestershire Council manages a large and diverse flow of green and organic waste, collected from households, recycling centres, and council grounds operations. Understanding these baseline tonnages is critical for assessing the potential and scale of any circular economy or bioenergy initiative.

Table 1. Summary Table: Green and Food Waste Tonnages (2023/24)

Waste Stream	Tonnage (2023/24)
<i>Domestic kerbside-collected green waste</i>	14,692.96 tonnes
<i>HWRC (recycling centre) green waste</i>	4,575.77 tonnes
Total household green waste	19,268.73 tonnes
<i>Green waste collected by SGC Grounds team</i>	457.94 tonnes (23/24)
<i>Green waste collected by SGC Grounds team</i>	606.80 tonnes (24/25)
Food waste (disposed via AD)	
<i>2022/23</i>	9,544 tonnes
<i>2023/24</i>	8,318 tonnes
<i>Live Labs grass (cut & collect 2024, pilot)</i>	382.12 tonnes

South Gloucestershire Council maintains a total grassland area of 473 hectares across its urban and peri-urban territory. For the 2024 season, a subset of 36.5 hectares (spread across seven of the district’s approximately fifty parishes) was selected for implementation of the Greenprint “cut & collect” pilot. Over the course of four mowing cycles in these pilot areas, a total of 382.12 tonnes of grass clippings was collected, resulting in an average yield of 10.47 tonnes per hectare for the season. Of the total grass collected, only 127.34 tonnes were delivered to an anaerobic digestion (AD) facility, with the remainder sent to composting due to logistical constraints and technical challenges encountered during the initial stages of the trial.

Table 2. Total Grass areas

PARAMETER	VALUE
TOTAL GRASS AREA (HA)	473
TOTAL AREA COLLECTED (HA)	36.50
NO. CUTS 2024 SEASON	4
GRASS COLLECTED (TON) 2024	382.12

GRASS DISPOSED AD (TON) 2204	127.34
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Suppose this approach were to be expanded to the entire council-managed grassland. In that case, it is estimated that annual collections could reach nearly 5,000 tonnes of grass, highlighting the substantial resource potential for future circular initiatives. In addition to the grass areas directly managed by the council, South Gloucestershire also oversees a rural verge network extending approximately 937 kilometres, which is managed by external contractors and typically cut just once per year, primarily for safety and visibility rather than biomass recovery.

6.2 Electricity generation 2024

During the 2024 season, South Gloucestershire Council delivered 127.34 tonnes of grass clippings from the Greenprint “cut & collect” pilot to the Cannington anaerobic digestion (AD) facility. According to plant records, this input generated a total of 22,107 kWh (22.1 MWh) of renewable electricity, representing approximately 0.18% of the AD plant’s total annual electricity production of 12,500 MWh. Although the council collected 382.12 tonnes of grass in total during the season, only a third could be processed by the AD plant due to logistical and technical constraints. If it had been possible to process the entire amount, the extrapolated electricity yield would have reached 66,338 kWh (66.3 MWh), based on the actual conversion rate achieved with the delivered grass.

Table 3. Electricity Generation from Greenprint Grass at Cannington AD Facility (2024)

PARAMETER	VALUE
GRASS DELIVERED TO AD (T)	127.34
ELECTRICITY GENERATED (KWH)	22,107
TOTAL GRASS COLLECTED (T)	382.12
EXTRAPOLATED ELECTRICITY (KWH)	66,338
TOTAL ANNUAL PLANT PRODUCTION (MWH)	12,500
GRASS SHARE OF PLANT OUTPUT (%)	0.18

6.3 Machinery and Fleet

Based on the SGC Vehicles & Plant inventory, South Gloucestershire Council has established a dedicated fleet for “cut & collect” operations, designed to manage both the mowing and bulk transport of grass clippings. The system centres around three Iseki SF5 ride-on mowers equipped for grass collection, supported by a tractor for towing, a tandem axle hook lift trailer with 3 identical containers, and a small

number of handheld or supplementary electric tools for finishing and detail work. All core equipment in the current configuration is diesel-powered.

Table 4. Cut & leave Equipment and Costs (2024)- Taken from Live Labs Equipment Cost

EQUIPMENT	QTY	TOTAL COST	USEFUL LIFE	COST / YEAR
RANSOME HR300	4	£ 154,000.00	3	£ 51,333.33
KUBOTA F391	1	£ 30,925.00	3	£ 10,308.33
HUSQVARNA 520IRX BRUSHCUTTER STRIMMER	2	£ 678.00	2	£ 339.00
STIHL BG86C HANDHELD BLOWER	4	£ 3,840.00	2	£ 1,920.00
HUSQVARNA 525BX HANDHELD BLOWER	2	£ 968.00	2	£ 484.00
TOTAL		£ 190,411		£ 64,384

In contrast, the council’s traditional “cut & leave” operations require a simpler fleet, with each gang typically using four standard ride-on mowers (with no collection system) and basic handheld tools. This approach incurs an annualised equipment cost of approximately £64,400, whereas the more advanced cut & collect programme requires £95,100 per year in equipment costs—a difference of 48%. The higher cost reflects the greater complexity, durability, and logistical requirements associated with collecting and transporting biomass, but also provides the necessary platform for future circular initiatives such as on-site biomethane production and use.

Table 5. SGC Cut & Collect Equipment and Costs (2024)-Taken from Live Labs Equipment cost

EQUIPMENT	QTY	TOTAL COST	USEFUL LIFE	COST / YEAR
TRAILER TANDEM AXLE HOOKLIFT TRAILER WITH 3 CONTAINERS	1	£ 46,800.00	6	£ 7,800.00
ISEKI SF5 X 3	3	£ 152,460.00	3	£ 50,820.00
KUBOTAF4C-501MOWER - NB: This mower was hired not purchased	1	£ 60,000.00	3	£ 20,000.00
MUTHING FLAIL KIT FOR ISEKI SF551 MOWER	1	£ 11,040.00	3	£ 3,680.00
CASE MAXXUM 125 TRACTOR (WU71 TKA - ASSET NUMBER 43652	1	£ 74,800.00	6	£ 12,467.00
HUSQVARNA 520IRX BRUSHCUTTER STRIMMER	2	£ 678.00	2	£ 339.00
		£ 345,778.00		£ 95,106.00

6.4 Diesel Consumption

During the 2024 Greenprint “cut & collect” pilot, fuel consumption and costs were closely tracked throughout all mowing cycles. The total fuel used by mowers was 7,299.7 litres, at an average 2024 diesel price of £1.09 per litre, resulting in a mower fuel cost of £7,956.67. Additional fuel expenditure included £298.95 for plant transportation and £325.86 for moving grass between collection sites and storage facilities – not including onward transport for disposal via AD. This brought the total fuel-related operational cost for the programme to £8,282.53.

With 382.12 tonnes of grass collected, this equates to an average fuel use of 19.1 litres per tonne and an average total fuel cost of £21.68 per tonne of grass managed.

Table 6. Fuel Consumption

Metric	Value
<i>Mower fuel used (litres)</i>	7,299.7
<i>Average cost per litre 2024 (£)</i>	£1.09
<i>Mower fuel cost (£)</i>	£7,956.67
<i>Diesel for plant transportation (£)</i>	£298.95
<i>Fuel cost between site & disposal (£)</i>	£325.86
<i>Total fuel-related operational cost (£)</i>	£8,282.53
<i>Grass collected (tonnes)</i>	382.12
<i>Average fuel use (L/tonne grass)</i>	19.1
<i>Average total fuel cost (per tonne)</i>	£21.68

According to the Year 2 Greenprint report, cut & collect operations in South Gloucestershire were significantly more costly than the traditional cut & leave approach. The total annual cost of implementing cut & collect, (less disposal costs in the form of the costs of transporting the biomass to the AD plant), was £169,974, compared to £114,211 for the conventional method—making cut & collect nearly 48% more expensive overall. This cost difference reflects the added complexity of collection, transport, and processing, as well as higher labour and maintenance requirements. These findings highlight the financial challenge of scaling up cut & collect under current conditions and suggest that further optimisation and innovation will be essential to improve cost-effectiveness in future phases of the programme.

6.5 Co-digestion Scenarios

For this feasibility study, three operational co-digestion scenarios have been defined to assess the technical, environmental, and economic implications of producing biomethane from roadside grass collected through the Greenprint “cut & collect” programme in South Gloucestershire. Each scenario assumes the use of existing anaerobic digestion (AD) infrastructure, with grass acting as a complementary feedstock to different types of agricultural residues. The analysis focuses on how varying the co-substrate affects methane yield, process stability, and overall system feasibility.

6.5.1 Scenario 1 – Current Practice (Grass + Maize/Silage)

This scenario reflects the current feedstock strategy used by the AD facilities processing council-collected grass. Grass clippings are combined with maize silage and other ensiled crops, which are already part of the agricultural supply chain in the surrounding region. The higher digestibility and sugar content of maize provide a complementary substrate to grass, improving biogas yields and ensuring stable digester performance. Feedstock proportions, retention times, and operational parameters are assumed to match existing practice at the reference AD plant, with seasonal grass availability supplemented year-round by stored silage.

6.5.2 Scenario 2 - Grass + Cow Slurry

The second scenario replaces pig slurry with cow slurry, which generally has slightly higher dry matter and volatile solids content. Its methane potential is estimated at $\approx 15 \text{ m}^3 \text{ CH}_4/\text{t}$ fresh, consistent with reported biogas yields of 25–30 m^3/t (50–55% CH_4).

At the same assumed total slurry input of 71,872 tonnes/year, cow slurry would generate 1,078,089 $\text{m}^3 \text{ CH}_4$, equivalent to around 3.57 GWh of electricity per year. This represents a notable improvement over pig slurry but still remains significantly lower than that of silage or food waste-based digestion. Operationally, cow slurry provides stable digester performance and is easier to handle than pig slurry, but its low energy density continues to limit economic viability unless combined with higher-yielding substrates such as grass or crop residues.

6.5.3 Scenario 3 – Grass + Pig Slurry

This scenario considers the co-digestion of roadside grass with pig slurry, which represents a readily available agricultural residue in many rural areas. Pig slurry typically contains a high proportion of water and a relatively low volatile solids content, as most of its energy has already been extracted by the animal during digestion. Literature and UK Farm Advisory Service data suggest methane yields of

≈ 9 m³ CH₄ per tonne fresh slurry, corresponding to a biogas yield of roughly 20 m³/t with a methane fraction of 50–55%.

For the modelled case, a total input of 71,872 tonnes/year of pig slurry would produce 646,853 m³ CH₄, generating approximately 2.15 GWh of electricity per year. While the feedstock is abundant and compatible with existing AD plants, the very low energy yield per tonne makes the process less efficient compared to food waste or grass-silage co-digestion. Furthermore, pig slurry's high dilution limits digester loading rates, increasing handling and transport costs.

At the same assumed total slurry input of 71,872 tonnes/year, cow slurry would generate 1,078,089 m³ CH₄, equivalent to around 3.57 GWh of electricity per year. This represents a notable improvement over pig slurry but still remains significantly lower than that of silage or food waste-based digestion. Operationally, cow slurry provides stable digester performance and is easier to handle than pig slurry, but its low energy density continues to limit economic viability unless combined with higher-yielding substrates such as grass or crop residues.

6.5.4 Scenario 4 - Grass + pig VeDoWS

The final scenario examines pig manure collected and processed under the VeDoWS (Vera-Doepfer Wet-Dry Separation) system, which mechanically separates solids from slurry to create a higher-solids, nutrient-rich feedstock. Laboratory testing and industry data report a methane yield of ≈ 78 m³ CH₄/t fresh, which is significantly higher than raw slurry due to the removal of excess water and concentration of degradable organics.

At the same input mass of 71,872 tonnes/year, the VeDoWS feedstock produces ≈ 5.6 million m³ CH₄, generating up to 18.47 GWh of electricity annually. This scenario demonstrates a substantial increase in energy output and would theoretically maximise biomethane production from agricultural residues. However, its broad implementation is currently limited by the need for on-farm separation equipment, stricter hygiene and permitting requirements, and higher handling costs. Moreover, separated solid manure is not widely available at consistent scale, which constrains the feasibility of large-scale adoption.

Table 7. Co-digestion Scenarios comparison

<i>Feedstock (fresh)</i>	<i>Typical biogas yield (m³/t FM)</i>	<i>Typical CH₄ fraction (%)</i>	<i>Indicative methane (m³ CH₄/t FM)</i>	<i>Source</i>
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<i>Cattle slurry (farm-collected)</i>	20	50–55	≈10–11	Farm Advisory Service TN698 table of “Typical Biogas Yield”.
<i>Pig slurry</i>	20	50–55	≈10–11	Farm Advisory Service TN698.
<i>Livestock slurry (general)</i>	20–25	~50–55	≈10–14	IEA Bioenergy Task 37 notes slurry often yields 20–25 m ³ biogas/t (context vs. maize 180–220). (IEA Bioenergy)
<i>Food waste (generic, Scotland planning guide)</i>	43	50–55	≈23–24	Farm Advisory Service TN698 (Food waste row).
<i>Food waste (case study, Japan)</i>	≈111	(not stated; often ~60)	≈67 if 60% CH ₄	IEA Bioenergy Task 37 Food Waste Digestion: plant processed ~9 t/d and produced ~1,000 m ³ /d biogas ⇒ ~111 m ³ /t.

In summary, the VeDoWS pig manure scenario demonstrates the highest biomethane and energy output, nearly nine times greater than standard pig slurry. However, its widespread deployment faces logistical and economic constraints. Both pig and cow slurry are technically feasible but generate substantially lower methane yields, making them less competitive unless used as co-substrates alongside higher-yield materials such as grass, silage, or food waste. Therefore, this study will adopt the current co-digestion operational conditions (2024–2025), as they have demonstrated the highest process efficiency.

6.6 Year-on-Year Comparison: 2024 vs 2025

During the course of this study, the 2025 cut-and-collect data were received, which are analysed in the following section.

Operational data for 2025 show a reduction in the total volume and weight of grass collected compared with the 2024 season. The quantity of grass gathered decreased from 382 tonnes in 2024 to 209 tonnes in 2025, reflecting a reduction in grass growth and fewer loads transported. As a result, the total operational cost fell from £80,454 to £74,868 even though fuel prices remained broadly similar across both years (around £1.05 per litre).

However, when examining the performance indicators, the efficiency yields show a mixed picture. The mower fuel yield improved slightly, decreasing from 50.6 L/ha in 2024 to 33.1 L/ha in 2025, indicating that mowing operations became more fuel-efficient per hectare. In contrast, the transport fuel yield increased from 12.5 L/ha to 24.5 L/ha, and from 0.31 to 1.40 L/m³, suggesting that the smaller quantities of

grass collected in 2025 required proportionally more fuel for transportation, likely due to longer travel distances or partial load transfers.

Labour costs also decreased, from £65,062 to £50,296, with a corresponding improvement in labour yield from £445.6/ha to £344.5/ha, likely reflecting better resource allocation and shorter cutting cycles. Overall, the 2025 season achieved lower total expenditure but at the expense of reduced productivity, as less grass was processed while fuel use per tonne increased. These results highlight the sensitivity of “cut & collect” logistics to scale and collection density: smaller harvests tend to increase transport inefficiencies, even when mowing operations themselves become more economical.

Table 8. Greenprint Year-on-Year Comparison: 2024 vs 2025

	2024	2025
<i>Volume of grass (m³) (as cut)</i>	5,868.00	2,555.00
<i>Grass collected 2024 (Ton)</i>	382.12	208.60
<i>Diesel price (L)</i>	109.82	104.69
<i>Mower Fuel (diesel) (L)</i>	7,386.43	4,840.32
<i>Mower Fuel Cost (£)</i>	£ 8,051.21	£ 5,834.09
<i>Yield fuel mowers (L/hectare)</i>	50.59	33.15
<i>Transportation Fuel (Diesel) (L)</i>	1,824.58	3,578.00
<i>Transportation Fuel (£)</i>	£ 1,988.79	£ 2,791.10
<i>Yield fuel transport (L/hectare)</i>	12.50	24.51
<i>Yield fuel transport (L/volume)</i>	0.31	1.40
<i>Cost of Labour (£)</i>	£ 65,062.45	£ 50,296.58
<i>Yield labour(L/hectare)</i>	445.63	344.50
<i>Plant cost (£)</i>	£ 5,351.84	
<i>Total Cost (£)</i>	£ 80,454.29	£ 58,921.78

6.7 Operational Baseline for Feasibility Assessment

The operational baseline for this feasibility assessment was established using the Council’s own performance data from the 2024 and 2025 “cut and collect” campaigns. Both seasons covered a comparable working area of approximately 36.5 hectares, providing a sound empirical basis to derive realistic fuel and labour yields representative of the Council’s current mowing operations.

Instead of relying on external benchmarks, the dataset was reorganised to reflect the specific drivers of each activity. Fuel and labour requirements for mowing were normalised per hectare cut, as these costs scale directly with field area, while transport performance was expressed per cubic metre of grass collected, since haulage effort depends primarily on material volume and travel distance rather than land area.

Table 9. Operational Baseline for Feasibility Assessment

	Scenario	2024	2025
<i>Volume of grass (m³) (as cut)</i>	4023.98	5,868.00	2,555.00
<i>Grass collected 2024 (Ton)</i>	295.36	382.12	208.60
<i>Grass yield 2024 (ton/ha)</i>	8.09	10.47	5.72
Diesel price (L)	105	109.82	104.69
<i>Mower Fuel (diesel) (L)</i>	6,113.38	7,386.43	4,840.32
<i>Mower Fuel Cost (£)</i>	£ 6,419.04	£ 8,051.21	£ 5,834.09
<i>Yield fuel mowers (L/hectare)</i>	41.87	50.59	33.15
<i>Transportation Fuel (Diesel) (L)</i>	3,443.17	1,824.58	3,578.00
<i>Transportation Fuel (£)</i>	£ 3,615.33	£ 1,988.79	£ 2,791.10
<i>Yield fuel transport (L/hectare)</i>	18.50	12.50	24.51
<i>Yield fuel transport (L/volume)</i>	0.86	0.31	1.40
<i>Cost of Labour (£)</i>	£ 57,679.52	£ 65,062.45	£ 50,296.58
<i>Yield labour(L/hectare)</i>	395.07	445.63	344.50
<i>Plant cost (£)</i>		£ 5,351.84	
Total Cost (£)	£ 67,713.89	£ 80,454.29	£ 58,921.78

6.7.1 Grass yield and diesel price

In 2024, approximately 382 tonnes of grass were collected (yield: 10.47 t/ha), while in 2025 this fell to 209 tonnes (5.72 t/ha), indicating a year with lower biomass availability or less favourable growing conditions. For all calculations, a diesel unit cost of £1.05 per litre (ex-VAT) was applied, representing the Council’s effective fuel price after VAT recovery.

Mowing operations

Fuel logs for mowing equipment show a total consumption of 6,113 litres of diesel for the 2024 campaign. When normalised to the area serviced, this corresponds to an average of 41.9 L/ha, which is used as the baseline yield for mower fuel consumption. This value captures the typical operational efficiency of the “cut and

collect” process, including idling, turning, and partial overlaps. The associated fuel cost for mowing is approximately £6,419, providing a direct cost reference for energy use in cutting operations.

6.7.2 Transport operations

For grass transport, recorded fuel use totalled 3,443 litres of diesel, equivalent to £3,615 at the baseline fuel price. Because haulage demand is influenced by load volume and collection distance rather than by area, the fuel consumption was normalised to the volume of grass moved, giving an average yield of 0.86 L per cubic metre. This indicator allows the transport component to be scaled accurately with varying grass yields or changes in the number of trips per cut.

6.7.3 Labour and operational costs

Labour records indicate an expenditure of approximately £57,680 for mowing and collection over the 36.5 hectares in 2025, resulting in a labour yield of £395 per hectare. This measure reflects both direct fieldwork and associated collection support.

When combined with fuel for mowing and transport, the total operational cost of the 2025 campaign is calculated at £67,714, forming the baseline cost envelope for the feasibility model

6.7.4 Baseline relevance

This reconstructed baseline directly represents how the Council’s system currently performs under real conditions, encompassing true mowing productivity, transport efficiency, and workforce costs. The three key operational yields—41.9 L/ha for mowing, 0.86 L/m³ for transport, and £395/ha for labour—provide the parameters used to scale up to the 30% grass-area scenario examined later in the study.

By grounding the analysis in recorded data rather than generic assumptions, the model ensures that subsequent estimates of biomethane demand, diesel savings, and RTFC generation accurately reflect the Council’s operational reality and provide a robust foundation for evaluating the potential transition toward a circular, energy self-sufficient mowing system.

7 Technical feasibility

7.1 Biogas and Biomethane Production Calculations

To establish the energy potential of the grass collected in the base scenario, it was first necessary to estimate the volume of biomethane that could be generated

through anaerobic digestion and then convert this to the corresponding amount of electrical energy. These values are essential for assessing the technical feasibility of replacing diesel consumption with energy derived from locally produced biomethane.

The total methane volume was calculated from the operative Biochemical Methane Potential (BMP) applied to the total amount of grass collected within the 30% area expansion scenario. The operative BMP value of 55 m³ CH₄ per tonne of fresh grass was adopted based on empirical data from European verge grass digestion studies, representing realistic full-scale performance. Given a total grass input of 1,149.10 tonnes, the resulting methane yield was:

$$\text{CH}_4 \text{ (m}^3\text{)} = 1,149.10 \times 55 = 63,200.50 \text{ m}^3$$

This value represents the gross methane volume potentially recoverable under steady-state digestion conditions.

To express this in mass terms, the standard density of methane (0.716 kg/m³) was applied:

$$\text{CH}_4 \text{ (kg)} = 63,200.50 \times 0.716 = 45,251.56 \text{ kg}$$

This conversion enables direct comparison with energy values expressed on a mass basis and supports subsequent energy balance calculations.

The energy obtainable from this methane was then determined by applying the lower heating value (LHV) of methane together with the conversion efficiency of a gas engine. Using an LHV of 9.97 kWh/m³, the total chemical energy content of the methane is approximately:

$$E_{\text{tot}} = 63,200.50 \times 9.97 \approx 630,000 \text{ kWh}$$

Assuming a typical gas engine efficiency of 28%, the usable mechanical energy becomes:

$$E_{\text{mech}} = 630,000 \times 0.28 \approx 176,400 \text{ kWh}$$

This represents the amount of mechanical work that could realistically be produced from locally generated biomethane, and therefore the potential energy available to displace diesel use in mowing and transport operations under the 30% area scenario.

7.2 BMP Selection and Reference Justification

The determination of a representative Biochemical Methane Potential (BMP) for South Gloucestershire roadside grass was a critical step in establishing realistic energy projections for the feasibility study. Laboratory BMP testing provides an indication of the theoretical methane yield achievable under ideal digestion conditions. However, as demonstrated by extensive literature and operational data, laboratory results tend to overestimate actual performance in full-scale anaerobic digesters due to process inefficiencies, feedstock handling, and substrate degradability.

Three laboratory samples of verge grass collected from sites Y164, Y62, and Mangotsfield Road were analysed under batch conditions at 37 °C over 40 days. The results indicated fresh-basis methane potentials of 153, 107, and 92 L CH₄/kg fresh, with a simple arithmetic mean of 117.33 L CH₄/kg fresh. Using the density of methane (0.66 kg/Nm³), this corresponds to approximately 77.44 kg CH₄ per tonne of fresh grass. These values represent the upper biochemical potential of the material under controlled conditions.

Table 10. Input lab results - bmp average

INPUT LAB RESULTS -	Y164	Y62	Mangotsfield Road	Average
BMP AVERAGE				
Dry matter (DM%)	47.00%	38.15%	27.85%	37.67%
VS (% de MS)	89.20%	89.56%	90.11%	89.62%
BMP biomethane (l/kg fresh)	153	107	92	117.33
CH ₄ (% biogás)	60.00%	64.00%	62.00%	62.00%

While the laboratory findings confirm that the grass contains a reasonable proportion of biodegradable organic matter (average dry matter 37.7% and volatile solids 89.6% of DM), comparison with published European data indicates that actual digestion yields for similar substrates are substantially lower. Field and pilot-scale trials of roadside grass silage typically report 52–60 L CH₄/kg fresh, with methane concentrations between 54–58%, as evidenced in studies from Belgium (Grassification, Inagro 2020–2021) and IEA Bioenergy Task 37 datasets. These datasets consistently show a 40–50% reduction from laboratory BMP values once digester kinetics, fibre content, and mechanical losses are accounted for.

Table 11. BMP Reference Justification

Roadside grass type/season	TS (% FM)	BMP (L CH₄/kg FM)	Conditions / Notes	Source	Data type
<i>Roadside grass (ensiled, mixed cuts)</i>	~32%	56	107.9 m ³ biogas/t FM, 56.5% CH ₄	Grassification D1.4.1 (Belgium, 2021)	Lab BMP test
<i>Roadside grass (spring cut, ensiled)</i>	~25–30%	90–105	150–180 m ³ biogas/t FM, higher sugar content	Bermg(r)as project (Belgium)	Lab BMP test
<i>Roadside grass (autumn cut, ensiled)</i>	~25–30%	35–85	60–150 m ³ biogas/t FM, more lignified	Bermg(r)as project (Belgium)	Lab BMP test
<i>Roadside grass silage (20% in co-digestion with manure, pilot digester)</i>	~32%	≈55–60	Stable process, CH ₄ ~54–58%, biogas 7.5–9 m ³ /h	Grassification pilot (Inagro, Belgium, 2020–21)	Pilot / real digester
<i>Roadside grass silage (mono-digestion, pilot landfill-type digester)</i>	n.a.	≈52–56	96.4 ± 72.3 m ³ biogas/t FM; converted with 54–58% CH ₄	Rumbeke pilot (Belgium, 2019–20)	Pilot / real digester
<i>Roadside grass silage (co-digestion with manure, pilot CSTR ~150 m³)</i>	~32%	≈52–56	97.4 ± 34 m ³ biogas/t FM; allocated yield per tonne of RG	Beitem pilot (Belgium, 2020–21, Inagro)	Pilot / real digester

Accordingly, the feasibility model adopts 55 L CH₄/kg fresh (≈ 55 m³ CH₄/t fresh) as the operative BMP for all subsequent scenarios. This value reflects the expected methane yield under typical full-scale operating conditions and provides a conservative but technically credible basis for estimating biomethane potential and associated energy recovery from roadside grass.

7.3 Upgrading and Compression Using the Bennamann CapCH₄-AD System

To upgrade the raw biogas produced through anaerobic digestion into high-purity biomethane suitable for use as a vehicle fuel, this study evaluates the Bennamann CapCH₄-AD system. This modular, containerised solution integrates biogas purification, upgrading, and compression within a single mobile unit. It has been

identified as a viable option for this feasibility study because it requires minimal? civil infrastructure, can be rapidly deployed near existing anaerobic digestion (AD) plants, and aligns with the project's aim of creating a scalable, decentralised circular energy system.

The CapCH₄-AD unit operates with an average electrical consumption of 15 kW and a processing capacity of 20 kg of CH₄ per hour. Based on the methane output estimated for the base scenario (45,251.56 kg CH₄ per year), the system would need to operate for approximately 2,262.6 hours annually, representing 37% of its maximum design capacity of 6,000 operating hours per year.

Accordingly, the annual electrical energy demand for upgrading and compression was calculated as:

$$E_{process} = 15 \text{ kW} \times 2,262.6 \text{ h} = 33,938.67 \text{ kWh/year}$$

This represents the total parasitic energy load of the upgrading process, which must be considered in the overall system energy balance to determine the net biomethane available for use.

Two operational power supply options were assessed:

- **Option 1 – Grid Electricity**

In this configuration, the CapCH₄-AD unit draws electricity from the grid at an estimated cost of £0.15/kWh, resulting in an annual operating cost of approximately £5,090.80. This approach preserves the full methane yield for upgrading, making 45,251.56kg CH₄ per year available as usable biomethane for fuelling the mowing fleet.

- **Option 2 – Self-Generation (Powered by Biogas)**

Alternatively, the system could be powered using a portion of the methane produced on-site. Assuming an engine efficiency of 27%, approximately 9,027.1 kg CH₄ per year (around 20% of total production) would be consumed to meet the energy requirement, leaving 35,499.96 kg CH₄ available for fuelling purposes. While this option would improve energy independence, it would reduce the net fuel output and increase system complexity.

For this feasibility study, the grid electricity option has been adopted as the baseline scenario, as it reflects the current design and standard operating practice of the Bennamann CapCH₄-AD system. Nonetheless, Bennamann has indicated ongoing development of self-powered configurations, which could provide valuable future opportunities for fully off-grid or rural applications.

7.4 Renewable Transport Fuel Certificates (RTFCs) – Policy Context and Valuation Framework

The Renewable Transport Fuel Certificate (RTFC) is the core incentive mechanism within the UK’s Renewable Transport Fuel Obligation (RTFO), administered by the Department for Transport (DfT).

The RTFO was introduced in 2008 to encourage the supply and use of low-carbon, renewable fuels in transport, helping the UK meet its decarbonisation and energy security targets. (Department Of Transport, 2023)

Under this framework, any supplier who places more than 450,000 litres of fossil transport fuel on the UK market per year is legally obliged to demonstrate that a proportion of their fuel is renewable. This obligation is discharged by submitting RTFCs, certificates that prove renewable fuel has been supplied or, alternatively, by paying a “buy-out” fee to the DfT. (Department Of Transport, 2023)

Each RTFC represents a unit of renewable energy supplied to a “relevant transport mode” (road, rail, non-road mobile machinery, inland waterways, or recreational craft when used for transport purposes).

7.4.1 How the RTFC system works

Issuance of Certificates

For every verified quantity of renewable fuel supplied for transport use in the UK, the DfT issues RTFCs to the registered supplier through its online reporting system. The number of RTFCs awarded depends on:

- the energy content of the fuel (measured in megajoules or kWh),
- the feedstock type, and
- whether the fuel qualifies for double-counting under the waste-derived fuel provisions.

According to DfT guidance, one RTFC is awarded for each kWh of renewable fuel supplied, adjusted for the fuel’s specific energy density. (Department Of Transport, 2023)

In the case of biomethane produced from waste feedstocks (for example, grass clippings or food waste processed via anaerobic digestion), the fuel qualifies for double RTFCs, recognising its superior greenhouse-gas savings and sustainability credentials. (Department Of Transport, 2025)

Energy-based allocation

Because RTFCs are issued per unit of energy rather than per unit of volume or weight, the number of RTFCs generated per kilogram varies by fuel type. Biomethane contains approximately 50 MJ of energy per kilogram (13.9 kWh/ kg).

Applying the RTFO conversion methodology and the double-counting rule for waste-derived fuels, this equates to roughly 3.8 RTFCs per kilogram of biomethane supplied for transport.

This figure aligns with DfT’s published Renewable Fuel Statistics (ENV0101), which record around 3,700–3,900 RTFCs per tonne of waste-derived biomethane supplied in recent reporting years. (GOV UK, 2025)

7.4.2 Market value of RTFCs

Price formation

RTFCs are tradable instruments. Their price is determined by supply and demand between renewable-fuel suppliers (who generate RTFCs) and obligated fossil-fuel companies (who need them).

The DfT does not purchase or fix its value, but it establishes a buy-out price that caps the market:

- £0.50 per RTFC for standard fuels
- £0.80 per RTFC for development fuels. (Department Of Transport, 2023)

Consequently, the value of Renewable Transport Fuel Certificates (RTFCs) has been assumed at £0.25 per certificate. This reflects a mid-point within the trading range observed during Q1 2025, when ESL Fuels (as reported in Fuel Oil News) noted that RTFCs were exchanging between 23.90 pence and 26.30 pence per certificate. (Fuel oil news, 2025)

Value per kilogram of biomethane

Given that waste-derived biomethane yields approximately **3.8 RTFCs/kg**, the certificate revenue alone equates to:

Table 12. RTFC Market Price

RTFC Market Price	RTFCs per kg (waste)	Value from RTFCs (£/ kg)
£0.20	3.8	£0.76

£0.25	3.8	£0.95
£0.30	3.8	£1.14

Therefore, at typical market conditions (\approx £0.25 RTFC), a producer earns just under £1 per kg of biomethane from RTFCs alone.

- **Combined economic value of biomethane**

Beyond the certificates, the biomethane itself holds a commodity value as a vehicle fuel. The UK pump-price equivalent for white diesel (after duty) is currently around £1.10 kg⁻¹ eqv., based on energy content. (GOV.UK, 2025)

Hence, combining both elements gives an indicative total value of around £2.05 per kg of waste-derived biomethane supplied for transport:

$$\text{£1.10 (commodity fuel) + £0.95 (RTFC revenue) } \approx \text{£2.05 per kg}$$

Both components are **market-driven** and can fluctuate with global fuel prices and RTFC trading activity, which introduces some volatility into project revenues. However, market data from 2024–25 show relative stability within these bands.

7.4.3 RTFC Implications for feasibility studies

Based on the calculated methane production of 45,251.56 kg CH₄, the total number of certificates that could be claimed under the RTFO scheme can be estimated as:

$$RTFC_{total} = 45,251.56 \text{ kg CH}_4 \times 3.8 \text{ RTFC Kg} = 171,956 \text{ RTF}$$

Assuming an average market value of £0.25 per certificate, consistent with Q1 2025 trading data reported by ESL Fuels (*Fuel Oil News*, 2025) showing RTFCs exchanging between 23.9 p and 26.3 p, the potential certificate revenue would be:

$$\text{£}_{RTFC} = 171,956 \text{ RTFCs} \times \text{£0.25} = \text{£42,989}$$

In addition to this incentive, if the produced biomethane were marketed as a transport fuel, its commodity value would approximate £1.10 kg⁻¹, aligned with the current price of white diesel on an energy-equivalent basis. The sale of the total 45,251.56 kg of biomethane would therefore generate:

$$\text{£}_{fuel} = 45,251.56 \text{ kg} \times \text{£1.10} = \text{£49,777}$$

Combining both revenue streams yields a total potential annual income of approximately £92,766, assuming the entire gas output is upgraded, certified and sold for transport use. Alternatively, if the biomethane were retained for the Council's own fleet, the RTFCs could still be claimed, with the monetary benefit realised as a reduction in fuel expenditure rather than direct sales revenue.

7.5 Conversion of Mowing Operations to Biomethane

To evaluate the feasibility of replacing diesel with locally produced biomethane, a specific scenario was modelled in which the Council's mowing fleet is assumed to operate entirely on upgraded biogas. Two representative mower types were analysed:

1. The ISEKI SF5 (SF551), corresponding to the diesel ride-on mowers currently used by the Council, and
2. The ROBOCUT T600, a remote-controlled slope mower proposed as an alternative technology.

The objective of this stage was to estimate how much biomethane would be required to deliver the same mowing performance currently achieved with diesel. This provides the basis for comparing the potential biomethane demand against the production capacity of the anaerobic digestion (AD) plant and for quantifying the associated fuel savings and RTFC revenue.

7.5.1 Methodology and Assumptions

The analysis was based on the measured diesel consumption rates of each mower (litres per hour) and their working widths and forward speeds. These operational parameters were used to determine the effective area cut per hour, and hence the diesel consumed per unit of area.

The diesel energy consumption was then converted to an equivalent chemical energy requirement in methane, using the lower heating values (LHV) of each fuel and accounting for the different engine efficiencies between compression-ignition (diesel) and spark-ignition (gas) engines.

The following standard assumptions were adopted:

- Forward speed (v): 4 km/h (4,000 m/h)
- Diesel lower heating value (LHV Diesel): 9.94 kWh L⁻¹

- Methane lower heating value (LHV CH₄): 9.97 kWh m⁻³
- Engine efficiency correction (diesel → gas): +11% (factor = 1.11)

This reflects the typically lower thermal efficiency of spark-ignition gas engines compared with diesel engines of similar size.

Step 1 – Area cut per hour

The productive area covered per hour is obtained from the cutting width multiplied by the forward speed:

$$A = \text{width} \times v$$

Mower	Width (m)	Speed (m/h)	Area cut per hour (m²/h)
Robocut T600	1.50	4,000	6,000
ISEKI SF5	1.65	4,000	6,600

Step 2 – Diesel consumption per 1,000 m²

Hourly diesel use (L/h) divided by the area per hour gives the fuel consumed per 1,000 m²:

$$\text{Diesel}_{1000} = \frac{\text{Fuel rate (L/h)} \times 1000}{\text{Area (h) (m}^2\text{/h)}}$$

MOWER	DIESEL RATE (L/H)	AREA (M²/H)	DIESEL PER 1,000 M² (L)
ROBOCUT T600	4.75	6,000	0.7917
ISEKI SF5	4.80	6,600	0.7273

These values represent the amount of diesel required to cut one “block” of 1,000 m² under ideal steady-state conditions.

Step 3 – Energy input from diesel

The energy used per 1,000 m² is the fuel volume multiplied by its LHV:

$$E_{\text{diesel},1000} = \text{Diesel}_{1000} \times \text{LHV}_{\text{diesel}}$$

Mower	Diesel (L/1,000 m²)	LHV (kWh/L)	Energy (kWh/1,000 m²)
Robocut T600	0.7917	9.94	7.87
ISEKI SF5	0.7273	9.94	7.23

Step 4 – Adjustment for gas engine efficiency

To perform the same mechanical work using a spark-ignition gas engine, approximately 11% more chemical energy is required.

$$E_{CH_4,1000} = E_{diesel,1000} \times 1.11$$

Mower	Diesel energy (kWh/1,000 m²)	Correction factor	Required CH₄ energy (kWh/1,000 m²)
Robocut T600	7.87	1.11	8.74
ISEKI SF5	7.23	1.11	8.03

Step 5 – Conversion from energy to biomethane volume

Finally, dividing by the methane LHV gives the equivalent biomethane volume:

$$CH_4 \text{ (m}^3\text{/1,000 m}^2\text{)} = \frac{E_{CH_4,1000}}{LHV_{CH_4}}$$

Mower	CH₄ energy (kWh/1,000 m²)	LHV CH₄ (kWh/m³)	Biomethane (m³/1,000 m²)
Robocut T600	8.74	9.97	0.876 m ³ CH ₄ /1,000 m ²
ISEKI SF5	8.03	9.97	0.807 m ³ CH ₄ /1,000 m ²

These are the base theoretical rates under continuous mowing conditions and are shown in the analysis as 0.87 m³/1,000 m² (Robocut) and 0.80 m³/1,000 m² (ISEKI).

Step 6 – Calibration with observed operational data

In practice, municipal cut-and-collect operations involve overlapping passes, turning, unloading and idling, which significantly reduce effective field efficiency. To obtain realistic values, the model was calibrated using the Council's actual fuel consumption records: 6,113.38 L of diesel used to mow 146 ha.

$$\frac{6,113.38}{146} = 41.87 \text{ L diesel/ha}$$

Converting this to energy:

$$41.87 \times 9.94 = 416.21 \text{ kWh per ha (diesel energy)}$$

Applying the 1.11 efficiency factor:

$$416.21 \times 1.11 = 462.00 \text{ kWh per ha as CH}_4$$

and converting to gas volume:

$$\frac{462.00}{9.97} = 46.34 \text{ m}^3 \text{ CH}_4 \text{ per hectare}$$

This observed figure corresponds to an effective field efficiency (FE) of about 0.17 ($\approx 17\%$) when compared with the base model, confirming that real mowing conditions reduce theoretical performance by roughly a factor of six.

Step 7 – Calibrated biomethane requirements

Applying the calibrated efficiency yields the **actual fuel demand** per area:

Mower	Base (m ³ CH ₄ /1,000 m ²)	FE	Adjusted (m ³ CH ₄ /1,000 m ²)	per ha (m ³ CH ₄)
ISEKI SF5	0.807	0.174	4.64	46.4 m ³ /ha
Robocut T600	0.876	0.174	5.03	50.3 m ³ /ha

Under current operating conditions, the ISEKI SF5 mower, representing the existing fleet, would require approximately 46.4 m³ of biomethane per hectare, while the Robocut T600 would require around 50.3 m³ per hectare when operating under equivalent field efficiency.

If a single representative value is needed for overall energy-balance modelling, the Council-calibrated mean of 46.3 m³ CH₄ per hectare provides a robust and evidence-based estimate of biomethane demand for grass-cutting operations.

At present, there are no commercially available cut-and-collect mowers offered as off-the-shelf biomethane-powered products; any deployment would therefore require engine conversion or prototype adaptation of existing diesel platform

7.5.2 Scenario: 30% area utilisation and four annual cuts

In this scenario, it is assumed that the Council's cut-and-collect mowing operations are powered by biomethane instead of diesel. The analysis corresponds to the 30%

use area, covering approximately 473 hectares, mown four times per year, equivalent to an annual operational area of about 568 hectares.

Two mower types were analysed (the ISEKI SF5 and the ROBOCUT T600) to represent the current and potential future fleet. Their individual fuel-use profiles were averaged to obtain a representative figure for the Council's overall mowing operations.

Biomethane requirement and fuel displacement

From the calibrated field analysis described previously, the effective fuel requirement for mowing under real operational conditions is approximately 46.34 m³ of biomethane per hectare. Applying this rate across the 30% area scenario gives a total annual demand of about 27,300 m³ of CH₄, equivalent to 19,546 kg of biomethane when converted using a methane density of 0.716 kg /m³.

This fuel substitution would offset an estimated 23,784 litres of diesel per year, based on the observed diesel use of 41.87 L/ha in the baseline data.

At the current VAT-exempt diesel rate of approximately £1.05 per litre, the corresponding annual fuel cost saving would be around £25,000, based on the displacement of roughly 23,800 litres of diesel per year.

RTFC generation and revenue

Following the previous analysis, each kilogram of biomethane supplied for eligible transport use earns roughly 3.8 Renewable Transport Fuel Certificates (RTFCs).

Using the fleet-average gas demand (19,546 kg*CH₄/yr), this equates to approximately:

$$19,546 \text{ kg CH}_4 \times 3.8 = 74,275 \text{ RTFCs /yr}$$

At an assumed market value of £0.25 per, the potential RTFC revenue would be around £18,600 per year.

Combined financial benefit

Combining the RTFC income with the avoided diesel expenditure gives a total indicative annual benefit of approximately £43,000–£45,000 per year, based on current fuel costs and average operational performance.

This represents the combined financial value of replacing fossil diesel with locally produced renewable biomethane while capturing government-backed incentives for verified low-carbon fuel use.

Implementation considerations

Currently, there are no commercially available cut-and-collect mowers designed to operate directly on biomethane. Implementation would therefore require engine conversion or prototype adaptation, including gas storage, ignition modification, and certification. These conversion and compliance costs should be incorporated as a capital investment in the project's financial model.

Furthermore, while road-registered vehicles clearly qualify for RTFCs, non-road mobile machinery (NRMM), such as large ride-on mowers, may require confirmation from the Department for Transport before the certificates can be claimed. A practical approach would be to allocate part of the biomethane production to the Council's road fleet, ensuring RTFC eligibility, while still using the same renewable fuel for on-site mowing to achieve full emissions reductions.

Summary

Under the 30% area scenario (≈ 568 ha /yr), the Council's mowing operations would require approximately 27,000 m³ of biomethane per year, displacing about 24,000 L of diesel.

This would yield around £25,000 per year in avoided fuel expenditure and an additional \sim £18,600 per year from RTFC revenue, resulting in a combined annual benefit of approximately £43,000–£45,000.

These results demonstrate that integrating waste-derived biomethane into the Council's mowing operations could deliver tangible economic savings while supporting the authority's broader decarbonisation and circular-energy objectives. These results demonstrate that integrating waste-derived biomethane into the Council's mowing operations could deliver tangible economic savings while supporting the authority's broader decarbonisation and circular-energy objectives.

7.6 Trucks & Vans

In addition to mowing machinery, the Council's cut-and-collect operations rely on a small fleet of trucks and vans used for transporting staff, clippings and equipment between depots and work sites. During the baseline mowing programme, which covered approximately 146 hectares cut four times per year, fuel records show a diesel consumption of 3,443 litres for these support vehicles, costing around £3,615 at the Council's net price of £1.05 per litre.

To align this information with the 30% area scenario used elsewhere in the study (equivalent to 142 hectares per cut, or approximately 568 hectares per year), the vehicle fuel demand was scaled proportionally to mowing activity. On this basis, the trucks and vans together would consume about 13,400 litres of diesel per year under the expanded 30% operating area. This quantity forms the reference point for

estimating both the equivalent biomethane requirement and the potential financial benefits of fuel substitution.

The energy content of this diesel corresponds to approximately 133,000 kilowatt-hours, calculated using the lower heating value of diesel (9.94 kWh per litre). Since spark-ignition gas engines are typically less efficient than compression-ignition diesel engines, an adjustment factor of 0.9 was applied to reflect the additional energy required when operating on biomethane. After this correction, the total annual gas energy demand increases to roughly 148,000 kilowatt-hours.

Converting this energy requirement into a volume of biomethane using the lower heating value of methane (9.97 kWh per cubic metre) gives an estimated 14,900 cubic metres of CH₄ per year. Based on the standard methane density of 0.716 kg/m³, this corresponds to about 10.6 tonnes of biomethane needed to replace the current diesel use of the Council's truck and van fleet in the 30% scenario.

At a net diesel cost of £1.05 per litre, displacing approximately 13,400 litres of fuel would result in around £14,000 per year in avoided fuel expenditure. In addition to this direct saving, the use of biomethane in these road-registered vehicles would qualify for Renewable Transport Fuel Certificates (RTFCs) under the UK's Renewable Transport Fuel Obligation (RTFO) scheme. As the biomethane would be produced from grass waste, it would be classed as a waste-derived renewable fuel and therefore eligible for double counting. Each kilogram of methane supplied for transport use earns roughly 3.8 RTFCs, which means the 10.6 tonnes of gas required would generate close to 40,000 certificates per year. Using the assumed average market value of £0.25 per certificate, this equates to an additional £10,000 per year in certificate income.

When combined, the avoided diesel cost and the RTFC revenue represent a total potential annual benefit of approximately £24,000 for the Council's truck and van fleet within the 30% area mowing programme. This demonstrates that converting even the support vehicles to biomethane could provide a meaningful contribution to both operating-cost reduction and the wider decarbonisation objectives of the project.

At present, several manufacturers, including IVECO and Scania, offer compressed natural gas (CNG) trucks and vans that can operate entirely on renewable biomethane. Independent reviews by the Zemo Partnership (2023) and Refuels/Longspur Research (2024) report that these vehicles typically carry a purchase premium of around 15–30% compared with diesel models, but the difference can be recovered within two to three years of operation through lower

running costs and the additional RTFC income. It is therefore recommended that, when the Council next renews its fleet, biomethane-fuelled vehicles are included in the procurement assessment alongside conventional diesel options, so that total cost of ownership, emissions and local fuel-loop benefits can be fully compared.

7.7 Summary of 30% Area Scenario – Biomethane Balance and Financial Outcomes

The 30% area scenario represents the full implementation of the Council’s closed-loop grass-to-gas system, where grass collected from approximately 473 hectares (mown four times per year, equivalent to 568 hectares of annual cutting) is processed through anaerobic digestion to produce biomethane.

Under the technical assessment presented earlier, this area would yield approximately 21,947 m³ of biomethane per year. The table below summarises the expected gas utilisation, associated RTFC generation, and financial outcomes if both the mowing fleet and the logistics vehicles (trucks and vans) were converted to biomethane.

Table 13. Summary of 30% Area Scenario

COMPONENT	BIOMETHANE DEMAND (M ³ /YR)	BIOMETHANE (KG/YR)	RTFCS GENERATED (3.8 PER KG)	RTFC VALUE (£0.25 EACH)	DIESEL DISPLACED (L/YR)	FUEL COST SAVING (£1.05/L)	TOTAL BENEFIT (£/YR)
MOWERS (CUT & COLLECT)	27,300	19,546	74,275	£18,569	23,784	£24,973	£43,542
TRUCKS & VANS	14,865	10,643	40,444	£10,111	13,395	£14,065	£24,176
TOTAL INTERNAL USE	42,165	30,189	114,719	£28,680	37,179	£39,038	£67,718
AD PRODUCTION (GRASS 30% AREA)	≈63,200	45,252	—	—	—	—	—
SURPLUS AVAILABLE FOR SALE/EXPORT	≈21,000	≈15,000	57,000	14,250	16,500	30,750	30,750

*Assuming sale of surplus biomethane at £2.05/kg, comprising energy value (£1.10/kg, white diesel equivalent) plus RTFC revenue (£0.95/kg, based on 3.8 RTFCs @ £0.25 each)

7.7.1 Interpretation

After meeting internal energy needs, the Council would still have a surplus of about 21,000 m³ of biomethane, equivalent to 15 tonnes of methane, which could be sold to external buyers or injected into the local gas grid. At current market rates, this surplus biomethane has a combined value of approximately £2.05 per kg, comprising:

Energy value (white diesel equivalent): £1.10/kg = £16,500/year

RTFC revenue (3.8 RTFCs @ £0.25 each): £0.95/kg = £14,250/year

This remaining gas could therefore generate an additional £30,750 per year, bringing the total potential annual value of the 30% grass-to-gas system to around £98,500 per year.

7.7.2 Conclusion

Under the 30% deployment scenario, the Council's grass-derived biomethane resource would be sufficient not only to fully power its mowing and transport operations, but also to generate a saleable surplus, providing both environmental and economic returns.

The integration of waste-to-fuel conversion with local service delivery demonstrates a clear opportunity for the Council to establish a self-sustaining circular energy model, reduce operational carbon emissions, and access ongoing financial benefits through the RTFO incentive framework.

7.8 Carbon Savings and Environmental Impact

In addition to the financial benefits identified under the 30% area scenario, the transition from diesel to biomethane would deliver a substantial reduction in greenhouse gas (GHG) emissions across the Council's mowing and support fleet operations.

To quantify the emissions avoided, the baseline diesel consumption for the 30% area scenario, approximately 37,200 litres per year combining mowers and trucks/vans, was multiplied by the standard UK government emission factor for diesel combustion:

Diesel (road and non-road average): 2.68 kg CO₂e per litre (*BEIS/DEFRA, 2024*).

Biomethane derived from waste sources is considered a near-carbon-neutral fuel, as its CO₂ emissions originate from short-term biogenic carbon rather than fossil carbon. For conservatism, a residual lifecycle emission factor of 0.05 kg CO₂e per kWh was applied to account for compression and handling energy, equivalent to roughly 0.5 kg CO₂e per m³ CH₄.

Based on these factors:

- **Diesel emissions baseline:**

$$37,200 \text{ L} \times 2.68 \text{ kg CO}_2\text{e/L} = 99.7 \text{ tonnes CO}_2\text{e per year}$$

- **Biomethane residual emissions:**

$$42,000 \text{ m}^3 \times 0.5 \text{ kg CO}_2\text{e/m}^3 = 21 \text{ tonnes CO}_2\text{e per year}$$

Net GHG saving: \approx 79 tonnes CO₂e per year

Replacing all diesel currently used for mowing and logistics under the 30% programme with locally produced biomethane would therefore cut operational carbon emissions by around 80 tonnes of CO₂e each year, representing a reduction of roughly 80–85% compared with the diesel baseline.

This carbon saving would contribute directly to the Council's Net Zero and Climate Emergency Action Plan, while also reducing local air pollutants such as nitrogen oxides (NO_x) and particulate matter from diesel combustion. When combined with the projected financial benefits, these environmental gains further strengthen the case for implementing a circular grass-to-gas energy system that supports both fiscal sustainability and measurable carbon reduction across municipal operations.

7.9 Avoided Fugitive Methane Emissions

In addition to the fuel-displacement savings, the anaerobic digestion of grass prevents the release of methane that would otherwise be emitted during the natural decomposition of organic material. Methane is a highly potent greenhouse gas, with a Global Warming Potential (GWP) of 28 over 100 years and 82 over 20 years.

Under the 30% area scenario, the digestion of collected grass produces approximately 45.25 tonnes of methane per year. When upgraded and used as fuel, this methane is combusted into short-cycle biogenic CO₂ rather than escaping to the atmosphere. The avoided emissions are therefore:

GWP100 (28): $45.25 \text{ t CH}_4 \times 28 = 1,267 \text{ t CO}_2\text{e/year}$

GWP20 (82): $45.25 \text{ t CH}_4 \times 82 = 3,711 \text{ t CO}_2\text{e/year}$

Replacing all diesel currently used for mowing and logistics under the 30% programme with locally produced biomethane would therefore cut operational carbon emissions by around 80 tonnes of CO₂e each year, representing a reduction of roughly 80–85% compared with the diesel baseline.

This carbon saving would contribute directly to the Council’s Net Zero and Climate Emergency Action Plan, while also reducing local air pollutants such as nitrogen oxides (NO_x) and particulate matter from diesel combustion. When combined with the technical evidence presented above, these environmental gains strengthen the case for further exploration of a circular grass-to-gas energy system. A full financial appraisal would still be required to determine the economic viability of implementation.

8 Economic and Financial Feasibility

This section evaluates whether a 30% deployment of the Council’s grass-to-biomethane system, including conversion of the cut-and-collect mowing fleet and associated trucks and vans to biomethane, is economically viable under realistic operating conditions.

The analysis builds directly on:

- the operational baseline for mowing, transport and labour costs derived from the 2024–25 Greenprint “cut & collect” campaigns
- the biomethane demand and financial benefits calculated for the 30% area scenario in Sections 7.5 and 7.6
- the existing plant inventory and capital costs for cut-and-collect equipment from Live Labs data
- the Bennamann CapCH₄-AD upgrading system characteristics and electricity consumption
- published evidence on the capital cost premium for CNG/biomethane road vehicles (15–30% relative to diesel)

Cost estimation for biomethane-capable fleet equipment is based directly on South Gloucestershire Council’s actual procurement values for the existing diesel

machinery. A +20% capital cost premium is applied consistently to reflect recognised market price differentials for CNG/biomethane powertrains, which incorporate high-pressure storage systems and safety engineering not required for diesel.

This method ensures the financial model remains grounded in the Council's real operational costs while accurately representing the additional capital required for the transition to gaseous fuel systems.

8.1 Scope of the Economic Assessment

This assessment evaluates the financial implications of expanding the biomethane-enabled cut-and-collect programme to 30 per cent of South Gloucestershire Council's managed grassland. This equates to approximately 568 hectares per year (around 142 ha per cut across four seasonal cuts). Grass collected from this area is transported to anaerobic digestion to contribute to biomethane production, which is then used as transport fuel within the Council's fleet, as described in Sections 7.3–7.5.

To ensure transparency and decision-making confidence, the economic model includes the full spectrum of cost and revenue components associated with the transition to biomethane.

Capital expenditure reflects new and expanded assets required to operate a mechanised cut-and-collect system at this scale:

- Biomethane-fuelled ride-on mowers: primary grass harvesting and collection capability
- Biomethane trucks and vans: transportation of operatives, equipment and collected biomass
- Hooklift trailer and tractor capacity: bulk handling of increased grass tonnages to AD facilities
- Bennamann CapCH₄-AD upgrading and refuelling infrastructure: on-site purification, compression, storage and dispensing of biomethane for fleet operations

Operating expenditure is derived from directly observed labour and performance data collected during the 2024 Greenprint pilot season and scaled to reflect the expanded operational area. Recurring cost drivers include:

- Labour for mowing, biomass collection and transport; the dominant operational cost component
- Electricity for upgrading and compressing biogas into vehicle-grade biomethane

In parallel, the model incorporates the financial benefits enabled by waste-derived biomethane use:

- Avoided purchase of diesel fuel for both mower and logistics fleets
- Renewable Transport Fuel Certificate (RTFC) revenue, generated through certified renewable fuel displacement
- Surplus biomethane sales where production exceeds internal fleet consumption

To provide a robust and balanced evaluation, the financial performance is reviewed through two complementary analytical perspectives:

- Whole-system financial assessment, including all capital and operational costs associated with the cut-and-collect approach
- Energy-system financial assessment, which isolates only the fuel-related economics and the value created by biomethane production

Together, these perspectives enable the Council to understand both the overall affordability of altering how grassland is maintained and the self-sufficiency of the renewable fuel system when considered independently.

Overall, both financial perspectives lead to the same result: the biomethane-enabled cut-and-collect system does not deliver a positive financial return within the expected working life of the assets, under current labour costs, technology investment requirements and available incentives. Significant capital funding support or substantial operational efficiencies would be required for the transition to become economically viable.

8.2 Dimensioning of Fleet and Infrastructure

8.2.1 Mowers

Based on the operational performance recorded during the Greenprint pilot, three Iseki SF5 ride-on mowers delivered cut-and-collect operations across 36.5 hectares over four seasonal cuts. For this feasibility assessment, it is assumed that this fleet is operating at close to full capacity for the pilot area. Therefore, any increase in managed area requires a proportional increase in mowing capacity to maintain service levels and labour efficiency. Applying the same area-based scaling factor to approximately 142 hectares per cut (30% of the Council’s maintained grassland) yields:

$$\text{Mowers required} = 3 \times \frac{142}{36.5} \approx 11.7 \rightarrow \text{up to 10 units}$$

With three suitable units currently within the fleet, the economic model therefore assumes up to seven additional biomethane-fuelled ride-on mowers are required to support the 30% scenario. This planning assumption enables a conservative yet realistic representation of operational resource needs and reflects the principle that labour availability is a key cost driver and therefore machinery capacity cannot be assumed to be under-utilised.

Indicative cost considerations (non-modelled)

While the technical feasibility of operating mowing equipment on biomethane has been demonstrated, the associated costs remain subject to uncertainty at this stage. As biomethane-powered mowers would initially represent a specialist niche product, a cost premium relative to conventional diesel machines is likely in the early stages of deployment.

Indicative industry feedback suggests that the development of a compliant biomethane mower platform would require an initial engine and mower development programme, potentially involving costs in the order of £300,000–£500,000. Such development activity may be eligible for partial support through UK Government research and development programmes, such as those administered by the Advanced Propulsion Centre (APC).

Following development and certification, the additional cost per mower associated with biomethane operation, primarily related to engine conversion and fuel system installation, is expected to be relatively modest, potentially in the range of £5,000–£10,000 per unit. These figures are indicative only and would require confirmation through further engagement with manufacturers and certification bodies prior to procurement.

8.2.2 Trucks and vans

Fuel records show that diesel use in the logistics fleet increases from 3,443 litres per year under the current 146-hectare mowing programme to approximately 13,400 litres per year

under the 30% scenario (568 ha). This four-fold increase suggests that the existing transport vehicles are already operating near their practical utilisation limit.

To maintain operational efficiency and labour productivity, the logistics fleet is therefore scaled proportionally to the mowing area:

$$\text{Logistics vehicles required} = 3 \times \frac{568}{146} \approx \text{up to 12 units}$$

With three suitable vehicles currently in service, the model assumes **up to nine** additional biomethane-fuelled light-duty logistics vehicles may be required. This reflects a conservative planning assumption aligned to the increase in biomass movements and ensures consistency between the refuelled mower fleet and supporting transport operations.

8.2.3 Hooklift trailer and tractor

Bulk transport of collected grass to anaerobic digestion is a new operational requirement introduced by cut-and-collect. Based on pilot observations, the current hooklift trailer and tractor pairing are assumed to be operating at high utilisation for the existing captured material volume.

To scale to the 30% scenario, with more than four times the biomass volume moved off-site, the requirement for bulk handling capacity is calculated proportionally:

$$\text{Bulk transport units required} = 1 \times \frac{568}{146} \approx \text{up to 4 units}$$

With one hooklift trailer and tractor already in the fleet, up to three additional units may be required to support year-round operations. This approach ensures grass collection does not become a bottleneck, limiting mower productivity or requiring excessive additional labour hours.

8.2.4 Bennamann CapCH₄-AD

The Bennamann CapCH₄-AD modular upgrading and compression unit is treated as the core element of the biomethane infrastructure required to support the 30% cut-and-collect scenario. The system upgrades raw biogas from anaerobic digestion to vehicle-grade biomethane and enables on-site refuelling of the Council's fleet.

For this feasibility assessment, the system is specified in line with Bennamann's published performance envelope for the CapCH₄-AD platform:

- Upgrading and compression capacity: 20 kg CH₄ per hour
- Average electrical demand: 15 kW

- Annual methane requirement (30% scenario): 45,252 kg CH₄ per year

The required annual operating hours are therefore calculated as:

$$\text{Operating hours} = \frac{45,252}{20} = 2,262.6 \text{ hours per year}$$

This corresponds to approximately 37% utilisation of the system's nominal 6,000 operating hours per year, indicating that the unit is appropriately sized for the scenario without operating at full capacity. Annual electricity consumption is calculated as:

$$15 \text{ kW} \times 2,262.6 \text{ h} = 33,939 \text{ kWh per year}$$

At an assumed grid electricity tariff of £0.15 per kWh, the resulting operating cost for upgrading and compression is approximately £5,090 per year.

The capital cost of the Bennamann CapCH₄-AD system, including upgrading, compression and integrated control systems, is taken as £400,000, based on current supplier pricing. This cost represents the principal capital investment in the biomethane infrastructure and reflects the inclusion of containerised upgrading equipment, high-pressure compression, safety systems and certification suitable for vehicle refuelling applications.

The CapCH₄-AD unit is complemented by additional site infrastructure, such as high-pressure gas storage, dispensing equipment and associated civil and electrical works, which are considered separately within the overall gas infrastructure capital allowance.

8.2.5 Alternative biomethane supply via commercial AD plant operators

In addition to on-site or modular upgrading solutions, an alternative pathway for biomethane supply could involve sourcing fuel-grade biomethane from commercial anaerobic digestion (AD) plants already receiving food waste and grass from the Council. In principle, this could allow biomethane to be supplied without the need for on-site upgrading infrastructure.

However, commercial AD plants typically produce raw biogas, which must be upgraded to biomethane and compressed to meet vehicle fuel specifications. While upgrading and compression technologies are well established at industrial scale, their availability, configuration and commercial terms vary significantly between facilities.

The potential for commercial AD operators to supply biomethane directly, particularly in bottled or compressed form suitable for vehicle refuelling, depends on site-specific factors such as existing upgrading capacity, gas handling infrastructure, regulatory approvals, and contractual arrangements. While bottled biomethane supply is technically feasible and based on mature compressed natural gas (CNG) technologies, it is not yet a standard offering across the UK AD sector.

As a result, assessing the practical viability of this supply route would require further technical and commercial investigation, including engagement with individual AD operators, review of upgrading and compression capabilities, and consideration of regulatory and logistics constraints. Such an assessment is beyond the scope of the present feasibility study but is identified as a potential option for future evaluation.

8.3 Total Capital Expenditure (CAPEX)

The total capital expenditure for the 30% biomethane-enabled cut-and-collect scenario consolidates the fleet and infrastructure requirements derived from the preceding technical and operational analysis. The CAPEX reflects all assets required to deliver grass collection at scale, transport biomass to anaerobic digestion, and enable on-site upgrading and refuelling of biomethane for use within the Council’s fleet.

Fleet-related capital investment includes additional ride-on mowing units to maintain service levels under the cut-and-collect model, an expanded logistics fleet to support staff and material movements, and increased hooklift and tractor capacity to manage higher biomass volumes without constraining mower productivity or disproportionately increasing labour hours. Energy infrastructure investment is centred on the Bennamann CapCH₄-AD upgrading and compression unit, supported by associated gas storage, dispensing equipment and enabling civil and electrical works required for compliant vehicle refuelling.

Table 14. Total Capital Expenditure (CAPEX)

CAPEX COMPONENT	QUANTITY (PLANNING BASIS)	UNIT COST (£)	TOTAL COST (£)
Biomethane ride-on mowers	Up to 7 units	65,250	456,750
Biomethane trucks and vans	Up to 9 units	38,500	346,500
Hooklift trailer and tractor capacity	Up to 3 units	95,000	285,000
Bennamann capch ₄ -ad upgrading and compression unit	1 unit	400,000	400,000

Gas storage, dispensing, civils and commissioning (balance of plant)	Allowance	150,000	150,000
TOTAL CAPEX			1,638,250

8.4 Operating Expenditure (OPEX)

Operating expenditure reflects the ongoing costs required to deliver the 30% biomethane-enabled cut-and-collect scenario once the necessary fleet and infrastructure are in place. OPEX has been developed using observed operational data from the 2024 Greenprint pilot, scaled proportionally to reflect the expanded area, and supplemented with energy and maintenance assumptions consistent with the proposed biomethane system.

The principal operating cost drivers relate to labour requirements for mowing, biomass collection and transport, together with electricity demand associated with upgrading and compressing biogas to vehicle-grade biomethane. These costs are assessed alongside changes in fuel expenditure and revenues arising from the displacement of diesel and the generation of renewable transport fuel credits.

8.4.1 Labour

Labour constitutes the largest operating cost within the 30% biomethane-enabled cut-and-collect scenario. In contrast to cut-and-leave operations, cut-and-collect requires additional time for grass collection, unloading, handling and transport coordination, resulting in a higher labour input per hectare.

For this feasibility assessment, labour costs are derived directly from the Council's recorded performance during the 2024–2025 Greenprint cut-and-collect programme. These data reflect observed crew composition, working practices and operational conditions rather than theoretical benchmarks. Analysis of the pilot shows that labour expenditure of approximately £57,680 was required to service 36.5 hectares under cut-and-collect, corresponding to an average labour cost of approximately £395 per hectare.

Consistent with the scaling assumptions applied elsewhere in the economic model, it is assumed that the pilot workforce and associated equipment were operating at close to full practical utilisation. On this basis, labour demand is assumed to scale proportionally with managed area in order to maintain equivalent service levels. Applying the observed labour cost per hectare to the 30% scenario, equivalent to approximately 568 hectares per year, results in an estimated annual labour cost of approximately £224,000.

This labour cost represents an incremental operating requirement relative to the baseline cut-and-leave approach and reflects the additional activities inherent to collecting, handling and transporting grass biomass rather than leaving material in situ.

8.4.2 Electricity demand

Electricity consumption arises primarily from the operation of the biomethane upgrading and compression system required to convert raw biogas into vehicle-grade fuel. Electricity demand is therefore treated as an operating cost associated with running the energy infrastructure, rather than as a capital expenditure.

For the 30% scenario, the Bennamann CapCH₄-AD system operates at an average electrical load of approximately 15 kW. Based on the annual biomethane output required to meet fleet fuel demand, the system is expected to operate for approximately 2,262.6 hours per year, corresponding to around 37% utilisation of its nominal design capacity.

Annual electricity consumption is therefore calculated as:

$$15 \text{ kW} \times 2,262.6 \text{ hours} \approx 33,939 \text{ kWh per year}$$

Assuming a grid electricity tariff of £0.15 per kWh, the resulting annual electricity cost associated with biomethane upgrading and compression is approximately £5,090 per year.

This electricity demand scales with biomethane throughput and is independent of labour requirements for mowing and biomass handling

8.4.3 Maintenance

Maintenance costs are included within operating expenditure to reflect routine servicing, inspections and consumables associated with operating an expanded cut-and-collect fleet. While maintenance demand increases relative to the baseline due to higher utilisation of mowing and logistics equipment, the proposed fleet is assumed to be newly procured and operated under manufacturer warranty and planned municipal maintenance regimes.

For this feasibility assessment, maintenance expenditure is therefore estimated using a conservative allowance equivalent to 2% of the capital value of mobile

equipment, reflecting preventative maintenance during the initial warranty period rather than major component replacement.

Applied to the capital investment in biomethane ride-on mowers, trucks and vans, and hooklift and tractor capacity (approximately £1.09 million), this results in an estimated annual maintenance cost of approximately £21,800 per year.

Maintenance associated with the biomethane upgrading and compression system is assumed to be covered through supplier service and support arrangements and is therefore excluded from this allowance.

8.4.4 Total Operating Expenditure - OPEX

Operating expenditure for the 30% biomethane-enabled cut-and-collect scenario is dominated by labour costs associated with mowing, biomass collection and transport. Electricity consumption related to biomethane upgrading and compression, together with routine maintenance of the expanded fleet, represents smaller but material ongoing costs. All operating costs have been derived from observed pilot data or conservative, feasibility-level assumptions consistent with the operation of newly procured equipment under warranty.

Table 15. Total Operating Expenditure - OPEX

OPEX Component	Basis of estimation	Annual Cost (£/year)
<i>Labour</i>	Pilot-derived cost of £395 per hectare applied to 568 ha	224,000
<i>Electricity (biomethane upgrading & compression)</i>	33,939 kWh/year at £0.15/kWh	5,090
<i>Maintenance (fleet)</i>	2% of mobile asset CAPEX (£1.09 million)	21,800
Total Operating Expenditure (OPEX)		250,900

8.5 Financial Benefits

The biomethane-enabled cut-and-collect system generates financial benefits through the displacement of diesel fuel and the generation of Renewable Transport Fuel Certificates (RTFCs) associated with the use of waste-derived biomethane in transport applications. These benefits are assessed based on the internally

consumed biomethane required to operate the Council’s mower and logistics fleets under the 30% scenario.

Under this scenario, total internal biomethane demand is estimated at approximately 42,165 m³ per year, equivalent to 30,189 kg of methane. This demand is split between mower operations and trucks and vans supporting biomass transport and site logistics.

The displacement of diesel associated with this internal biomethane use is estimated at approximately 37,179 litres per year. Using the fuel price assumptions applied elsewhere in the assessment (£1.05 per litre), this corresponds to an annual fuel cost saving of approximately £39,038.

In addition to fuel cost savings, the use of waste-derived biomethane as a transport fuel qualifies for Renewable Transport Fuel Certificates. Based on an RTFC generation factor of 3.8 certificates per kilogram of methane, internal biomethane use generates approximately 114,719 RTFCs per year. Applying an assumed average market value of £0.25 per certificate, consistent with recent trading data, this results in RTFC revenue of approximately £28,680 per year.

Combined, the total annual financial benefit associated with internal biomethane use under the 30% scenario is therefore approximately £67,718.

The technical assessment also indicates that total biomethane production exceeds internal fleet demand, leaving a surplus of approximately 21,000 m³ per year (around 15 tonnes of methane). While this surplus may represent a potential additional revenue opportunity, its realisation depends on the availability of export routes or offtake arrangements and is therefore considered separately from the internal-use financial balance.

Table 16. Total Financial Benefits

COMPONENT	ANNUAL VALUE (£/YEAR)
FUEL COST SAVING (DIESEL DISPLACEMENT)	39,038
RTFC REVENUE	28,680
TOTAL FINANCIAL BENEFIT (INTERNAL USE)	67,718

The technical assessment indicates that total biomethane production exceeds the internal fuel demand of the Council's mower and logistics fleets, resulting in a surplus of approximately 21,000 m³ per year (around 15 tonnes of methane). At current market rates (£2.05/kg comprising energy value and RTFC income), this

surplus represents a potential additional revenue stream of approximately £30,750 per year. However, for conservatism and to avoid overstating economic viability, this surplus value has not been included in the base-case financial balance presented below.

8.6 Net operating balance

Bringing together the operating expenditure and the financial benefits associated with internal biomethane use provides a clear view of the annual operating balance of the proposed system.

Total annual operating expenditure for the biomethane-enabled cut-and-collect system is estimated at approximately £250,900 per year. This is dominated by labour costs, with smaller but material contributions from electricity consumption associated with biomethane upgrading and routine fleet maintenance.

Annual financial benefits arising from internal biomethane use, including avoided diesel expenditure and RTFC revenue, are estimated at approximately £67,718 per year. These benefits reflect only revenues and cost savings that can be realised with a high degree of confidence under current operating conditions and do not include any potential upside associated with surplus biomethane export.

The resulting net operating balance is therefore negative, with operating costs exceeding financial benefits by approximately £183,000 per year. This deficit persists before consideration of capital recovery, financing costs or asset replacement and therefore represents a structural imbalance between the cost of delivering cut-and-collect operations and the value of the energy recovered.

Table 17. Net Operating Balance

<i>Item</i>	<i>Annual value (£/year)</i>
<i>Total operating expenditure (OPEX)</i>	250,900
<i>Total financial benefits (internal use)</i>	67,718
<i>Net operating balance</i>	-183,182

If surplus biomethane sales were included, at an estimated value of £30,750 per year (comprising £16,500 energy value and £14,250 RTFC revenue), the net operating balance would improve to approximately -£152,432 per year. However, the base case presented excludes this income to provide a conservative assessment of operational viability.

8.7 Overall Economic Conclusion

The economic assessment demonstrates that, under current labour costs, technology pricing and incentive structures, the biomethane-enabled cut-and-collect system does not achieve a positive operating balance. Even when accounting for avoided diesel consumption and RTFC revenue, the additional labour and infrastructure costs required to deliver cut-and-collect at scale outweigh the financial benefits generated by biomethane production.

While technical performance indicates that biomethane generation is feasible and that surplus production may be available, the economic case remains constrained by the high operational intensity of grass collection and handling. Without significant reductions in labour requirements, substantial capital grant support, or material improvements in fuel incentive values, the proposed system cannot be considered economically viable within the expected working life of the assets.

The inclusion of surplus biomethane sales (approximately £30,750 per year at current market rates) would improve the financial position but would not eliminate the operational deficit in the base case scenario

9 Results and Conclusions

9.1 Overview

This feasibility study has assessed the technical, environmental, and economic viability of converting grass clippings from South Gloucestershire Council's cut-and-collect operations into biomethane for use in the Council's mowing fleet. The analysis is based on real operational data from the 2024 and 2025 mowing seasons and evaluates a 30% area deployment scenario covering approximately 473 hectares with four cuts per year.

9.2 Key Findings

9.2.1 Technical Performance: Confirmed Viability

The study confirms that a closed-loop grass-to-biomethane system is technically feasible and can operate as a self-sufficient energy platform for municipal mowing operations.

Under the 30% scenario, the Council would collect approximately 1,149 tonnes of grass per year, which through anaerobic digestion would yield 63,200 m³ of biomethane (45,252 kg). This production volume is more than sufficient to meet the combined fuel requirements of the mowing fleet and logistics vehicles, which

together demand approximately 42,165 m³ per year (30,189 kg). The system would displace 37,179 litres of diesel annually, equivalent to the entire fuel consumption of the expanded cut-and-collect programme, while still generating a surplus of 21,000 m³ (15,000 kg) available for sale or export.

The biomethane demand figures are derived from calibrated field data rather than theoretical calculations. Observed operational efficiency in cut-and-collect mowing is approximately 17% of ideal steady-state performance, reflecting the real-world impact of turning, overlapping passes, unloading cycles, and site-to-site transit. This conservative approach ensures that fuel requirements are accurately represented and that the system will perform reliably under actual municipal working conditions.

The use of an operative Biochemical Methane Potential (BMP) of 55 m³ CH₄ per tonne of fresh grass, substantially lower than laboratory-derived values of 117 m³/t, further demonstrates the study's commitment to realistic rather than optimistic projections. This BMP is based on full-scale European pilot data and accounts for substrate variability, digester kinetics, and mechanical losses typical of commercial AD operations.

9.2.2 Environmental Impact: Significant Carbon Reduction

The transition from diesel to biomethane delivers a substantial and measurable reduction in greenhouse gas emissions. The baseline diesel consumption of 37,179 litres per year is associated with approximately 99.7 tonnes of CO₂e emissions. Biomethane, as a near-carbon-neutral fuel derived from short-cycle biogenic sources, would reduce this to approximately 21 tonnes CO₂e per year. This accounts for residual emissions from compression and handling and delivers a net saving of approximately 79 tonnes CO₂e annually. This represents a 79% reduction in operational carbon intensity and aligns directly with the Council's Net Zero commitments.

Beyond carbon, the displacement of diesel combustion would reduce local air pollutant emissions, including nitrogen oxides (NO_x), particulate matter, and volatile organic compounds, contributing to improved air quality in the roadside and urban green space environments where mowing operations take place.

9.2.3 Economic Performance: Operational Deficit Persists

The economic assessment reveals that, under current cost structures and incentive frameworks, the biomethane-enabled system does not achieve a positive operating balance. The business case is constrained by the high labour intensity of cut-and-collect operations, which dominate total operating expenditure.

Total capital investment for full deployment is estimated at approximately £1.64 million, covering biomethane-compatible mowers, trucks and vans, hooklift trailers, the Bennamann CapCH₄-AD upgrading unit, and associated gas storage and dispensing infrastructure. Annual operating costs are estimated at approximately £250,900, of which £224,000 (89%) is attributable to labour for grass cutting, collection, and transport. Electricity for biomethane upgrading and fleet maintenance represent smaller but material ongoing costs.

Against these expenditures, the system generates financial benefits through two primary mechanisms: avoided diesel expenditure and revenue from Renewable Transport Fuel Certificates (RTFCs). Internal biomethane use displaces approximately £39,000 in annual diesel costs, while the waste-derived nature of the feedstock qualifies the fuel for double-counting under the UK's RTFO scheme, generating approximately 114,719 RTFCs per year worth approximately £28,680 at current market rates (£0.25 per certificate). Combined, these internal benefits total approximately £67,718 per year.

The resulting net operating balance is negative, with costs exceeding benefits by approximately £183,000 per year. This deficit persists before consideration of capital amortisation or financing costs and represents a structural imbalance between the cost of delivering cut-and-collect operations and the value of the energy recovered.

The 21,000 m³ surplus biomethane has a potential market value of approximately £30,750 per year, comprising energy sales at £1.10 per kg (£16,500) and RTFC revenue of £0.95 per kg (£14,250). If this revenue could be realised through confirmed offtake arrangements, the operating deficit would improve to approximately £152,000 per year. However, surplus sales are not included in the base-case financial assessment, as they depend on the availability of export infrastructure, contractual offtake, and sustained market pricing; these are factors that cannot be guaranteed at this feasibility stage.

It is important to note that RTFC prices are market-driven and have historically fluctuated between £0.15 and £0.60 over the past two years. While current prices have stabilised around £0.25, sustained increases above £0.30 per certificate would materially improve the financial position, adding £17,000–£20,000 in annual revenue. Similarly, any reduction in labour costs, through equipment efficiency gains, optimised logistics, or adjusted service levels, would directly improve the operating balance, as labour represents nearly 90% of total expenditure.

9.3 Strategic Implications and Recommendations

9.3.1 *Technical Feasibility Without Economic Viability*

The study's principal conclusion is that while the grass-to-biomethane system is technically sound and environmentally beneficial, it cannot be considered economically viable under current conditions without substantial external support or operational cost reductions. This finding does not diminish the technical achievement of demonstrating a fully circular, locally sourced renewable energy system for municipal operations; it simply reflects the current economic reality of biomass-to-fuel conversion at this scale.

The question for South Gloucestershire Council is therefore not whether the system can work, but whether the environmental and strategic benefits justify proceeding despite the economic shortfall.

9.3.2 *The Labour Cost Challenge*

The economic viability of this system is fundamentally constrained by a single factor: labour costs account for 89% (£224,000) of total annual operating expenditure. This operational intensity is the primary barrier preventing the project from achieving financial sustainability.

The £224,000 labour cost is derived from the Council's actual pilot data at £395 per hectare, applied to the 568 hectares of annual cutting activity in the 30% scenario. This cost reflects the current operational model for cut-and-collect, which requires significant manual effort for grass cutting, collection, loading, transport, and unloading.

In contrast, the financial benefits from diesel displacement and RTFC revenue total only £67,718 per year. Even if surplus biomethane sales are included (adding £30,750), the combined revenue of £98,468 still falls far short of covering the £224,000 labour expenditure alone, before considering electricity, maintenance, or capital recovery.

Critical threshold analysis: For the system to approach break-even on operating costs alone (before capital consideration), labour expenditure would need to fall to approximately £120,000–£140,000 per year. This represents a required reduction of 38–46% from current levels. Without this reduction, no amount of RTFC price improvement or surplus sales can close the structural deficit.

The study therefore identifies labour cost reduction as the single most critical factor determining project viability. Any pathway forward must address this constraint through one or more of the following mechanisms:

- **Equipment efficiency gains:** Larger-capacity collection systems that reduce labour hours per tonne collected
- **Process optimisation:** Improved routing, logistics coordination, or scheduling to reduce total labour input
- **Service level adjustments:** Reduced cutting frequency or selective application of cut-and-collect to highest-value areas
- **Alternative operational models:** Contracted services or mechanisation approaches that deliver lower per-hectare labour costs

Without addressing the labour cost structure, the project cannot achieve economic viability regardless of capital grant support or revenue enhancements. Capital grants would improve the investment case but would not resolve the annual operating deficit driven by labour intensity.

9.3.3 Conditions for Proceeding

The study does not recommend proceeding with deployment unless one of the following conditions can be satisfied:

- **Labour Cost Breakthrough:** Operational changes that reduce labour expenditure to £140,000 per year or below (a 38% reduction from baseline), bringing the system close to operational break-even.
- **Strategic Decision on Environmental Grounds:** The Council accepts the project as an environmental and innovation investment, recognising that it will require an ongoing annual subsidy of approximately £150,000–£180,000 to deliver the 79-tonne CO₂e reduction and demonstrate circular economy leadership. This would position the subsidy as a cost-per-tonne-of-carbon investment aligned with Net Zero commitments.
- **Combined Approach:** Capital grant support (covering 50–75% of the £1.64 million investment) combined with moderate labour efficiency improvements (20–30% reduction) that together make the total cost of ownership acceptable within the Council's decarbonisation budget.

The decision framework is therefore clear: either find a way to dramatically reduce labour costs, or accept the project as a strategic environmental investment that will operate at a deliberate deficit in service of broader sustainability goals.

10 Conclusion

The South Gloucestershire grass-to-biomethane feasibility study successfully demonstrates that a closed-loop renewable energy system for municipal mowing operations is technically achievable, environmentally beneficial, and operationally sound. The system can produce sufficient biomethane to fully power the Council's fleet while generating exportable surplus and achieving a 79% reduction in carbon emissions.

However, the economic case reveals a fundamental constraint: labour costs for grass collection and processing represent 89% of operating expenditure and create a structural deficit that cannot be overcome through fuel savings, RTFC revenue, or surplus sales under current operational models. Labour expenditure of £224,000 per year far exceeds the £98,468 in combined financial benefits (including surplus sales), resulting in a net operating loss of approximately £152,000 annually.

The critical finding is that labour cost reduction of 38–46% is required to approach operational break-even. Without this reduction, the project cannot achieve financial sustainability regardless of capital grant support or revenue enhancements. Capital grants would improve the investment case but would not resolve the annual operating deficit.

The Council must therefore decide whether to: (1) investigate operational changes that could deliver the required labour cost reduction and make the project viable; (2) proceed as a strategic environmental investment accepting the operating subsidy as part of its Net Zero commitment; or (3) defer deployment until economic fundamentals change.

The study provides the technical validation and economic clarity needed for the Council to make an informed strategic decision on this pathway to decarbonisation.