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**Consultation: Business Models for Engineered Greenhouse Gas Removals (GGRs)**

Brief Summary

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## **Introduction**

To deliver the Paris Agreement’s goals on time, greenhouse gas reduction alone is not enough anymore. Multiple sectors are unable to decarbonize by 2050, hindering the achievement of net zero by 2050, and to counterbalance these emissions, investing in greenhouse gas removal technologies is prominent.

While nature-based GGR methods like afforestation and soil carbon sequestration are effective in CO2 removal, barriers like land constraints and timescales for sequestration can hinder the efficiency of these projects. In order to reach the targets on time, these nature-based methods need to be complemented by engineered GGR solutions such as Bioenergy with Carbon Capture and Storage (BECCS), and Direct Air Carbon Capture and Storage (DACCS).

While there are very few such projects operating on a global scale, the UK government aims to take lead in deploying them to remove CO2 at the speed and scale needed to meet the climate targets, while also supporting thousands of green jobs to enhance the UK economy.

## **Section 1: Rationale for developing business models for GGRs**

***Background to the consultation***

Through the Net-Zero Strategy, the government intends to develop markets and incentives for engineered GGR technologies. Although the government is already investing £100m in research and development towards GGR technologies, the absence of a mature market or predictable revenue streams for negative emissions acts as a major policy barrier against investments. This creates revenue uncertainty for technology developers and investors, increasing costs of finance and discouraging investment in high-cost first-of-a-kind projects. As a first step to address this prevailing barrier, BEIS is consulting on business models to attract private investments to enable GGR projects to deploy within this decade.

Such a scheme is especially advantageous to the AD industry, as providing a revenue support mechanism for negative emissions can encourage more plants to install carbon capture and storage (CCS). Seeking insights from the stakeholders, this consultation sets the premise for the government to introduce a contract-based business model for early GGR projects.

***Barriers to deploying GGRs***

There’s a wide range of market barriers consisting of technology-specific barriers as well as general barriers that constrain the investment and deployment of GGRs.

In summary, the main barriers to deploying engineered GGRs include:

* a lack of predictable, long-term demand and stable revenue streams for the production of negative emissions;
* high capital and operating costs, coupled with difficulty obtaining finance due to uncertain return on investment;
* immaturity of voluntary carbon removal markets and uncertainty around future scales and prices;
* the current absence of CO2 transport and storage infrastructure;
* technology and construction risks for ‘First of a Kind’ projects;
* absence of widely recognised and accepted monitoring, reporting and verification (MRV) frameworks to assure the quantity and permanence of carbon removals; and,
* uncertainty over the long-term policy and regulatory framework for greenhouse gas removals.

While some of these barriers are already being addressed, several policy interventions will be necessary to overcome the remaining barriers and enable GGR projects to deploy over the next decade and beyond.

***Delivering a portfolio of GGR technologies***

Policies that are currently in development that could support the deployment of specific GGR technologies through the CCUS cluster sequencing programme, without the need for additional policy interventions to stimulate investment in GGRs include:

* **Power BECCS Business Model:** This model reflects the advanced technological readiness of this specific technology and the significant co-benefits of both power and negative emissions
* **Industrial Carbon Capture (ICC) Business Model (including Waste):** This could deliver negative emissions by enabling the capture and permanent storage of biogenic CO2. The business model is being designed to incorporate payments for captured biogenic CO2 (as well as payments for fossil CO2) and will integrate potential future markets for negative emissions.
* **Hydrogen Business Model:** The model is designed to apply to a range of hydrogen production technologies and operating patterns. While the Hydrogen Business Model does not explicitly incentivise or reward negative emissions, it will support both the capture plant and hydrogen production plants for CCUS-enabled hydrogen producers. It may therefore provide sufficient policy support for Hydrogen BECCS routes such as biomass gasification with CCS, delivering negative emissions through the capture and permanent storage of biogenic CO2.

While these policies will support the early deployment of certain GGR technologies, delivering negative emissions alongside other services, they alone will not achieve the Government’s ambition to have a diverse portfolio of innovative GGR technologies. Although the exact scalability, costs, and commercial potential of each technology are not known in detail due to the limited scale of the technology on the global scale, it is evident that a range of broad suite of technologies will be needed to sequester the magnitude of CO2 that will be needed to reach the climate objectives.

To address this barrier, the government intends to develop a business model for GGRs that provides a technology-neutral framework for rewarding negative emissions across a range of technologies and focuses exclusively on the negative emissions component of a GGR project.

Technologies that could potentially benefit from a GGR business model include, but are not limited to:

* **Direct Air Carbon Capture and Storage (DACCS):** the capture and storage of CO2 from the ambient air using separating agents that can be regenerated using heat, water or both.
* **Bioenergy with Carbon Capture and Storage (BECCS):** the capture and storage of CO2 from biomass which is used to produce low-carbon energy – particularly in sectors such as biofuels, anaerobic digestion, biomethane, and energy-from-waste that are not supported by other mechanisms such as the ICC and Power BECCS business models.
* **Carbon-negative concrete:** the production of zero-carbon lime, which delivers negative emissions by naturally absorbing CO2 from the atmosphere after it has been used as a building material.
* **Seawater CO2 removals:** the capture and storage of CO2 from seawater via chemical or electrochemical means.

***The Government’s approach to GGR deployment***

In consultation with the relevant stakeholders, the Government has developed a set of overarching guiding parameters that will guide the BEIS’s approach to deploying GGRs in the UK.

* Enable GGR projects to deploy from the mid-to-late 2020s at the speed and scale required to support the delivery of the UK’s Carbon Budgets, particularly Carbon Budgets 5 and 6 (2028-37).
* Position the UK as a global pioneer in the development and deployment of GGR technologies – providing green jobs and export opportunities as part of our Green Industrial Revolution
* Incentivise negative emissions to balance emissions from hard-to-decarbonise sectors, ensuring that GGRs is not deployed as a substitute for emissions reduction and do not reduce the pressure to decarbonise.
* Provide sufficient certainty to investors and project developers to unlock private sector investment, ensuring that projects are financed primarily by the private sector with the government providing the minimum necessary support.
* Ensure that any direct government support is proportionate, provides value-for-money for the taxpayer, and is compatible with subsidy control rules.
* Facilitate a transition towards a market-based framework for negative emissions, providing a clear pathway to reducing government support over time and allowing the most cost-effective route to achieving net zero.
* Provide a route to market for a diverse portfolio of GGR solutions – allowing a suite of different technologies to commercialise in order to reduce reliance on any single technology.
* Guarantee that GGR projects deliver permanent removal of CO2 from the atmosphere based on a full lifecycle assessment and robust standards for monitoring, reporting and verification (MRV).
* Deploy GGRs in a responsible manner which avoids unintended consequences for the environment or other perverse incentives, ensuring that all GGR projects are subject to stringent environmental regulations and sustainability criteria.
* Incentivise continued innovation, reduced costs and supply chain emissions, and improvements in process efficiency

## **Section 2: A contract-based business model for negative emissions**

This section outlines the Government’s intention to introduce a contract-based business model for engineered GGRs. This would address one of the main investment barriers by providing revenue support for negative emissions.

Among the barriers that hinder investments in GGRs, the barrier most commonly cited by stakeholders is the fact that there is currently no stable price incentive for negative emissions. While the cost of GGR technologies is higher than the credit prices on voluntary carbon markets, current climate policies do not provide a direct incentive for polluting industries to invest in carbon removals to counterbalance their emissions. Therefore, the GGR developers are concerned that there will be no sufficient market demand for their product to justify the investment.

Two policy approaches are available to the government to address this barrier:

* **Demand-side interventions:** policies that stimulate demand for negative emissions from the private sector, providing a source of revenue for GGR projects.
* **Supply-side interventions:** policies that provide direct government support to individual GGR developers to enable commercial viability.

***Principles for policy design***

The Government has developed a set of key design principles which we have used to assess the strengths and weaknesses of supply-side policy options for GGRs.

|  |  |
| --- | --- |
| **Principle** | **Description** |
| Revenue Certainty | The policy should provide sufficient revenue certainty to enable investors and project developers to make investment decisions. |
| Value for Money | The policy should deliver its objectives in a way which minimises the cost to the government, adheres to subsidy control rules, and does not lead to excessive returns for developers. |
| Deliverability | The policy should be feasible to implement in the mid-2020s and avoid unnecessary complexity and undue administration costs. |
| Competition | The policy should promote innovation and encourage competition between suppliers. |
| Market Development | The policy should incentivise project developers to seek private buyers for credits and support the growth of a robust market for negative emissions. |
| Technology Neutral | The policy should be sufficiently flexible to support a range of different technologies to commercialise, recognising that the capital and operational expenditure (capex/opex) requirements of producing negative emissions will vary significantly between projects, and should not create an enduring advantage for technologies that are less expensive today. |
| Reduced Support | The policy should allow for government support to reduce over time (both within the contract life and across different rounds of contract awards) as costs fall and the market for negative emissions matures. |
| Compatibility | The policy should be compatible with other policy incentives and support mechanisms for co-products and services, provided that subsidy control rules are adhered to, and it can be demonstrated that there is no double-subsidisation of the same process costs. |
| Reaching GGR targets | The policy should offer reasonable certainty of delivering the quantity of removals the government is aiming for. |

***Options for supply-side policy support***

The Government has considered a range of supply-side policy interventions that could address the key policy and market risks that impede the delivery and scale-up of GGRs.

Four leading options have been identified:

* **Contract Schemes**

A contract scheme provides risk-sharing between the private and public sectors – mitigating the risk to project developers that market revenues will not be sufficient to cover costs and providing an appropriate return on investment.

This mechanism is likely to deliver the most appropriate intervention to provide ongoing revenue certainty for negative emissions for early GGR projects. This would attract private investment while ensuring that financial, technology and policy risks are appropriately shared between the government and the private sector.

* **Tax Credits**

Project developers may receive a financial incentive for negative emissions in the form of tax credits (i.e. a deduction from their total tax liability).

This, however, could be a complex mechanism for incentivising GGRs and may not benefit all businesses. This could mean they are difficult to deliver in the short term as well.

* **Competition Funding**

To support the initial demonstration of large-scale GGR projects, direct government funding could be awarded to technology developers through competitions. Applications could be assessed across a range of criteria including scalability, commercial potential, value-for-money, economic benefits, and co-products and services.

This approach is considered to be more appropriate as a means of incentivising pilot projects or technological innovation, rather than supporting a portfolio of large-scale commercial plants.

This would involve a high initial cost to the Exchequer due to the high upfront payments that would be needed to compensate for a lack of revenue certainty throughout the lifetime of the project

* **Regulated Asset Base Models**

A Regulated Asset Base (RAB) model is a tried-and-tested method to finance large-scale infrastructure assets such as water, gas and electricity networks in the UK. Under this model, an economic regulator awards companies a license to charge a regulated price to consumers in exchange for providing essential infrastructure.

This model is not considered to be suitable for financing a portfolio of GGR projects as RAB models are best-suited for projects that require high capex, large-scale construction and long-term contracts, for example, new nuclear plants.

***Negative emissions contract options***

This consultation examines 3 leading options for a contract-based business model and invites the stakeholders to weigh in on what approach is the most suitable.

The options are;

* **Negative Emissions Contract for Difference (CfD)**

Under a Negative Emissions CfD, project developers would receive a fixed ‘strike price’ for negative emissions, based on their costs and a return on investment.

In the first instance, developers seek to sell their negative emissions credits for the highest price on the open market. Where the market price is below the strike price, the government pays the difference to the developer, while where the reference price exceeds the strike price, the difference is paid by the provider. Through this mechanism, the project developer receives a guaranteed price for negative emissions for the duration of the contract, while the burden on the Government diminishes as the market price rises.

*Advantages:* Mechanism’s track record in UK decarbonisation policy with notable examples of CfDs working successfully in low-carbon sectors such as renewable electricity | Explicit inclusion of market revenues

*Challenges:* Policy design must recognise significant differences between the GGR and offshore wind sectors | Applicability of a CfD scheme to small-scale GGR projects

* **Negative Emissions Payment**

In this scheme, the Government recognises negative emissions as a public good and provides a fixed payment for project developers per unit of negative emissions produced (on a £/tCO2basis). The payment level could be agreed upon with each project via auctions or bilateral negotiations and should provide sufficient revenue certainty for developers to proceed with the investment (by covering developers’ costs and providing a return on investment). In practice, a Negative Emissions Payment combined with credit sales on the market will be similar in operation to a carbon Contract for Difference

*Advantages:* Provide project developers with a stable, guaranteed price for negative emissions | Inclusion of credit sales in a Negative Emissions Payment scheme will support the development of the negative emissions market

*Challenges:* Exposes the Government to the risk of low credit prices on the market, particularly in the near term when the market is at an early stage of maturity

* **Negative Emissions Guarantee**

A Negative Emissions Guarantee scheme would enable project developers to bid for the option to sell their negative emissions credits to the Government at a guaranteed price at regular intervals (for instance, every 3 years). Having secured this option, developers would then look to sell their negative emissions credits for the highest price on the market. If there is a lack of demand on the market, developers may exercise the option to sell their unsold credits to the Government at the guaranteed price (up to an agreed maximum quantity).

*Advantages:* Role of the market as the primary source of revenue for negative emissions, with the Government providing a backstop while markets remain in their infancy

*Challenges:* Risk that a Guarantee could, perversely, hinder the development of the negative emissions market.

***Contract Allocation Process***

Currently, two main approaches to awarding contracts are being explored:

1. reverse auctions, in which developers compete for government support through a sealed bid in a competitive process, and
2. bilateral negotiations between the Government and developers following an expression of interest.

From these 2, reverse auctions have been highly successful in accelerating the deployment of offshore wind while achieving significant cost reductions. There is an opportunity to replicate this success in the GGRs sector.

However, there are challenges associated with using a reverse auction process in the early stages of GGR deployment:

* **Insufficient competition:** The number of GGRs ready for deployment in the near term may not be sufficient to drive meaningful price competition between projects.
* **Wider deployment priorities:** As the objective of this stage is to support the deployment of a portfolio of GGR technologies over the coming decade, it cannot be accurately predicted which technologies will offer the greatest scalability, cost reduction, and other strategic benefits in the longer-term, so innovative technologies that are more expensive today mustn't be 'priced out’ of early deployment.
* **Challenges of pot design:** Although this would help projects compete on a more like-for-like basis, it will be challenging to define the number and scope of pots for early auctions given the widely varying characteristics and limited evidence on costs of GGR technologies. Having too many pots will create complexity and diminish competition while having too few pots could create competition between non-comparable technologies.

***Setting the contracted price***

Each contract mechanism considered in Section 2.4 involves the agreement of a guaranteed minimum price for negative emissions (on a £/tCO2 basis) in order to give revenue certainty to suppliers.

Finding the appropriate contracted price will be integral to the success of a GGR contract scheme. Too high a contract price would lead to overly generous payments from the government, excessive profits for project developers, and poor value for taxpayer money, while a too low price would not provide an investable proposition and projects may not be commercially viable for deployment. It will be necessary to set the contracted price at a sufficient level to cover the capex and opex costs of producing negative emissions, as well as provide a return on investment.

***Reference price***

In the longer term, average negative emissions credit prices could provide a stable reference price for a Negative Emissions CfD, based on a single negative emissions market or a compositional approach.

In the near term, this may not be appropriate due to the absence of an established market, price volatility, and the considerable price differentials between different GGR technologies. For early Negative Emissions CfDs, it could therefore be appropriate to define the reference price as the monthly average achieved sales price for each project.

A key design challenge of a Negative Emissions CfD is the weak incentive for project developers to seek the highest possible sales price for negative emissions credits on the market. Potential options to incentivise developers to achieve the maximum sales price include:

* **Gain-sharing:** developers may be permitted to retain a percentage of credit sales, which would be applied as an addition to the strike price; this would directly reward developers for achieving higher market prices but would require higher top-up payments by the government.
* **A price floor:** this would establish a minimum sales price that must be achieved, but would not provide an incentive to sell above that price.
* **Benchmarking:** the Government could mandate that credits should not be sold below an agreed benchmark, such as average international market prices; however, international market prices will also face volatility and may not provide an appropriate benchmark in the early stages of deployment.

***Contract length and review mechanisms***

A successful GGR business model will rely on an appropriate contract length. If a contract is too short, it may not provide sufficient long-term security for project developers and investors, and if a contract is too long, there is a risk that the Government supports a project longer than is necessary or becomes locked into a contract that does not provide value-for-money.

Evidence suggests that shorter contract lengths would increase total costs to the government for capex-dominated technologies such as offshore wind. Most GGR projects will be opex-dominated and shorter contracts could therefore reduce the burden on the government significantly.

However, BEIS also recognises that longer-term contracts may be more attractive to investors and developers, given the uncertainty around future market conditions and the commercial viability of projects once contracts expire.

***CO2 capture and utilization***

The Government’s business model for GGRs will incentivise the production of negative emissions, which is defined as the capture and permanent storage of CO2 from the atmosphere. In addition to producing negative emissions, it is recognised that GGR projects may potentially generate revenue from carbon capture and utilisation (CCU) activities, such as the sale and utilisation of CO2 in aviation synthetic fuels, beverages, or greenhouses. While CCU provides important benefits for the economy and decarbonisation efforts, it does not provide permanent removal of CO2 from the atmosphere. As such, these activities will not be supported by a GGR business model.

Payments through a GGR business model will be paid based on £/tCO2 stored so that the Government is not covering the costs of CO2 utilised. Any capex or opex that is required for both CCU and CCS operations could potentially be pro-rated to the amount of CO2 that is stored.

***Co-products and services***

The GGR business model will be designed to incentivise the production of negative emissions by creating a stable value for this service. However, we recognise that many GGR projects will deliver low-carbon co-products and services beyond negative emissions, and BEIS intends to design the GGR business model in a way that enables these projects to be deployed.

## **Section 3: Building a market for negative emissions**

This Section outlines the reasons why a well-functioning negative emissions market will be essential to leverage private capital and support the Government’s objectives for Greenhouse Gas Removal (GGR) deployment.

***Options for negative emissions markets***

There are two main approaches available to the government for building a market for negative emissions to support GGR projects over the next decade:

* **Compliance markets**, in which demand for negative emissions is created by the need to comply with a regulatory target or emissions cap.
* **Voluntary markets**, in which actors choose to purchase negative emissions credits on a non-mandatory basis as part of their efforts to meet corporate net zero targets or other sustainability goals.

***Compliance market options***

Two possible compliance markets for negative emissions are explored in this section:

* **Inclusion of negative emissions in the UK ETS**

The Net Zero Strategy identified the UK Emissions Trading Scheme as a possible long-term market for negative emissions. Depending on the scheme design, the inclusion of negative emissions credits in the UK ETS would allow participants to offset a portion of their emissions by purchasing negative emissions credits.

In its optimal form, this would provide a single compliance market for carbon, allowing emitters to choose the most cost-effective option between abating their emissions or purchasing negative emissions credits or other allowances.

* **Creation of a GGR obligation scheme**

A GGR obligation scheme (sometimes described as a ‘Carbon Takeback Obligation’) would require emitters from certain sectors to purchase negative emission credits to compensate for a fixed percentage of their emissions. Where obligated parties do not purchase sufficient negative emissions credits to meet their obligation, they are required to pay a penalty (the buyout price) for each remaining tonne of CO2.

There are several advantages to creating a GGR obligation scheme. It would leverage private investment in GGR technologies by creating a stable source of demand for negative emissions from hard-to-abate sectors, enforcing the polluter pays principle and relieving the burden on the taxpayer. The level of the obligation could be set in line with target levels of GGR deployment and can be raised over time. The market would encourage competition and drive efficiency. Furthermore, the UK has a track record of using obligation-based schemes to support decarbonisation, such as the Renewable Transport Fuel Obligation (RTFO) and the now-retired Renewables Obligation (RO).

However, while a GGR obligation would create a market demand for negative emissions credits, such a scheme would be very difficult to implement in the early years of deployment and would not directly guarantee the supply of negative emissions credits to meet demand.

***Voluntary market options***

In voluntary markets, demand will be comprised of businesses and other actors who choose to purchase negative emissions credits to meet corporate targets and other sustainability goals. However, as voluntary markets by their nature do not require businesses or hard-to-abate sectors to invest in negative emissions, demand for credits is likely to be significantly lower and more uncertain than in a compliance market. This could mean that the taxpayer bears a greater share of the costs of early projects.

Two voluntary market approaches are explored in this section:

* **Delivering GGRs through existing voluntary market bodies and verifiers**

There is a growing focus on the engineered negative emissions credits in voluntary markets with a demand for credits that provide permanent and verifiable removal of CO2 from the atmosphere. This has helped to finance a range of early demonstration projects including Direct Air Carbon Capture and Storage (DACCS), Bioenergy with Carbon Capture and Storage (BECCS), and biomass carbon removal.

*Risks Associated:* Large-scale GGR projects are high-cost infrastructure projects of high strategic importance to the UK’s climate goals and will potentially receive government support. As a result, it may be less desirable for the Government to rely on sales through private market platforms that are not under formal regulatory oversight.

* **Establishing a central government-designed market for engineered removals**

Establishing a government-designed voluntary market for engineered GGR projects would require the appointment of a regulatory body responsible for setting and enforcing standards for monitoring, reporting and verification (MRV) and awarding negative emissions credits.

***The Government’s current position***

The Government will undertake further work to determine the most appropriate market infrastructure for engineered GGRs – including the balance between compliance and voluntary markets, and how this may evolve over time to deliver the Government’s objective of a strong liquid market for carbon removals.

## **Section 4: Accounting and sustainability frameworks**

This section sets out the importance of accounting and sustainability frameworks to ensure that GGR projects deliver verifiable, permanent and sustainable removals of CO2 from the atmosphere. It explores key considerations in relation to the monitoring, reporting and verification (MRV) of engineered GGRs, and explores high-level principles that might be applied to ensure their legitimacy.

***Approach to MRV for initial GGR projects***

It is important to establish a set of robust MRV standards for any future market for engineered GGRs in order to preserve market integrity while instilling investor confidence. There will be challenges such as how to treat removals of different storage durations within the same market.

## **Section 5: Applicability across different GGR technologies**

This section considers the applicability of the proposed Greenhouse Gas Removal (GGR) business model across different technologies, and how it might interact with other policies and business models under development.

***Direct Air Carbon Capture and Storage (DACCS)***

A major advantage of the technology is its ability to remove carbon dioxide directly from the ambient air, without reliance on sustainable biomass supply or significant land use requirements. It is estimated that at least 18Mt of engineered removals from DACCS will be required annually by 2050 in order to reach net zero, while early deployment at scale will also be required to achieve Carbon Budget 6.

However, DACCS faces a set of risks and challenges which may have implications for future policy. These risks include:

* **Early stage of development:** This remains unproven at a large scale and is considered to be at an earlier stage of technology readiness than BECCS.
* **Higher costs:** The estimated cost of producing negative emissions in the near term via DACCS is likely to be significantly higher than for others.
* **Energy requirements:** While DACCS does not rely on biomass, the processes are highly energy-intensive and depend on the availability of large quantities of low-carbon energy; hence the plant operating costs would be highly sensitive to changes in energy prices.
* **Lack of co-product revenue:** Compared to BECCS, DACCS does not produce a co-product and the economics of the plant will rest solely on negative emissions revenues.

To counteract these challenges, adaptations to the negative emissions revenue support scheme or supplementary policy support can be considered. These include:

* **Higher strike price:** A higher strike price to cover high opex and capex costs, guaranteeing a higher price per unit of negative emissions for the developers.
* **Energy price risk-sharing:** Due to the sensitivity of DACCS to energy prices, contract adjustments may be needed to mitigate the risks of energy price fluctuations.
* **Front-loading capex payments:** The contract mechanism could frontload support for capex, covering the capital costs in a condensed period. This could also reduce the cost of capital for the project due to the shorter repayment period.
* **Capital support:** There are potential benefits to providing direct capital support to initial DACCS projects, through instruments such as low-interest loans and loan guarantees.

***Bioenergy with Carbon Capture and Storage (BECCS)***

When undertaken sustainably, BECCS can deliver negative emissions because carbon sequestered in biogenic material is captured and stored after the energy production process, resulting in a net removal of atmospheric CO2.

The forthcoming Biomass Strategy, due to be published later this year, will further detail the Government’s position on future biomass use and policies needed to support biomass use across the economy in meeting net zero.

* **Power BECCS**

The Power BECCS business model is focused on the co-benefits of power and negative emissions and as such it will be subject to the established regulatory frameworks in relation to biomass and power generation markets. However, there may be common considerations in relation to the negative emissions market frameworks explored through this consultation

* **BECCS in Industry**

There is a role for BECCS in the industrial sector, particularly the cement, glass and paper industry, where the use of sustainable biomass combined with carbon capture and storage (CCS) could deliver negative emissions alongside the decarbonisation of these industries.

* **BECCS in the waste sector**

Residual waste management is a challenging sector to decarbonise. The waste management sector is comprised of a diverse range of technologies such as; Energy from Waste (EfW), Hazardous Waste Incineration (HWI), and Advanced Conversion Technology (ACT)/Advanced Thermal Treatment (ATT).

Carbon capture and storage (CCS) is the main decarbonisation option for many of these technologies. Installing CCS within these facilities can result in negative emissions due to the presence of biogenic material in household and commercial waste streams.

Municipal Solid Waste (MSW) feedstocks contain a large proportion of *biogenic waste, which produces biogenic CO2 after incineration/gasification in EfW and ATT/ACT plants*. As well as generating negative emissions as a result of biogenic CO2 capture, these processes support fossil CO2 abatement from the waste sector and the production of energy vectors such as electricity, heat, hydrogen, or liquid or gaseous renewable transport fuels.

* **Hydrogen BECCS**

Analysis for the Net Zero Strategy indicates that around 2.7 MtCO2 of negative emissions from BECCS Hydrogen could be needed annually by 2035 in order to achieve the Sixth Carbon Budget.

The Government is developing a hydrogen business model to stimulate private investment in new low-carbon hydrogen projects and help achieve our ambition of up to 10 GW of low-carbon hydrogen capacity by 2030, subject to affordability and value for money.

The model aims to provide revenue support to hydrogen producers to overcome the operating cost gap between low-carbon hydrogen and high-carbon counterfactual fuels. The model will also provide volume support through a sliding scale in which the strike price will be higher if hydrogen offtake falls. The business model is designed to apply to a broad range of hydrogen production technologies and operating patterns, including hydrogen BECCS routes such as biomass gasification with CCS.

* **BECCS Biofuels**

The production of liquid and gaseous biofuels could be combined with CCS to deliver negative emissions. Some biofuel production plants (e.g. fermentation processes) already regularly capture CO2 that would otherwise have been emitted as part of their production process. More advanced and developing technologies, such as gasification, could provide a stream of CO2 for capture and sequestration.

* **BECCS Anaerobic Digestion and Biomethane**

Anaerobic digestion (AD) is a process whereby organic materials are broken down by microbes in the absence of oxygen to produce biogas, which can be used for the local generation of electricity and heat. This biogas can be upgraded to biomethane by removing CO2 and other gases and adding propane. Biomethane is chemically identical to methane and can be injected into the gas grid as a direct replacement for natural gas.

The use of organic materials/biomass in the production of biogas, when coupled with a capture process for the removal of CO2 to create biomethane, offers an opportunity to produce negative emissions. Biomethane can be used in several key sectors of the economy such as transport, clean heat and hydrogen production. This section focuses on the production of biomethane and not its usage.

At this time, the industry is supported primarily via the Green Gas Support Scheme (GGSS). This replaces support for biomethane injection under the Non-Domestic Renewable Heat Incentive, which closed to new applicants on 31 March 2021. The scheme provides tariff support for biomethane produced via anaerobic digestion and injection into the gas grid. Producers receive tariff payments for a 15-year lifetime and the scheme is open to new build AD plants.

The GGSS provides revenue certainty for new projects for the production of biomethane. Participants are required to meet a greenhouse gas emission saving threshold of 70% against its fossil fuel comparator, using a published methodology, which includes consideration of any emission savings from carbon capture and geological storage.

However, the scheme offers no incentive for plants to install carbon capture and storage technology to deliver negative emissions. A revenue support mechanism for negative emissions could provide this incentive. This would provide a stable additional revenue stream for AD plants, which could be combined with revenue from the GGSS as the schemes would cover different costs. We will continue to develop our policy position on the interactions between the GGSS and any GGR support to avoid perverse outcomes such as double subsidisation.