Summit Power Caledonia UK Ltd | May 2018

Caledonia Clean Energy Project

Feasibility Study Phase 2 Final Report

SUMMARY VERSION

CALEDONIA CLEAN ENERGY PROJECT

Summary Version

This report Summary Version contains Key Findings, Executive Summary and a short version of the Project Description. It has been produced to aid dissemination to interested project stakeholders and other parties on a public basis as a non-technical report.

Report Key Findings

Why Caledonia Clean Energy Project Is Globally Unique

1. *A natural gas-fired plant with flexible output & carbon dioxide capture, to integrate renewables*

The Caledonia Clean Energy Project (CCEP) offers features of worldwide significance. This natural gas-fired plant will be capable of ramping its power output up and down as demanded within a wide range, whilst still capturing carbon dioxide (CO_2). For global climate and power grid purposes, this is a long-sought Holy Grail. It means the plant – without needing to be base-loaded – can provide firm capacity and flexible electricity dispatch to the power grid along with other electrical services, thus helping overcome the inherent intermittency of renewable energy sources such as wind and solar projects, without having to sacrifice carbon dioxide capture.

Until now, it has not been possible to take advantage of the desirable flexibility of natural gas-fired power plants to support renewables integration – and maintain system resilience – without having to accept significant amounts of undesirable CO_2 emissions. As this Report shows, CCEP can help resolve this long-standing technical, global climate, and grid conundrum.

Project Key Characteristics	
Scope of Project	Summit's preferred approach is to provide the Power & Capture plant, with the Transport & Storage (T&S) charged as a fee per tonne CO2; provided by others through a Public Private Partnership (PPP) or Regulated Asset Base (RAB) model, common for major infrastructure projects in UK. Summit could manage the development of T&S if required as an alternative.
Power & Capture Technology	Base Case: CCGT with Post Combustion Capture with leading vendors Alternate or Phase 2: Net Power Turbine
Plant Generating Range	605 MW to 1381 MW net output depending on selected configuration.
Plant Operating Range	Flexible and dispatchable wit max ramp rate of 88 MW per minute
Plant Emissions	Carbon capture from the plant will be over 90%. Net emissions from the plant will be as low as 10% of an unabated gas CCGT plant. Captured CO2 would be up to 3.1 million tonnes per annum.
CO2 Transportation	95% of required pipelines for the project already exist and are suitable for re-purposing at lower cost and lower risk than new build assets, representing a saving of up to £440 million in capital costs. A short new connection is required from Grangemouth to the Feeder 10 transport pipeline that runs to St. Fergus. The disused Atlantic & Cromarty pipeline runs from St. Fergus to the offshore injection location offering an ideal technical solution.
CO2 Storage	The well characterised CO2 storage site in the Captain sandstone formation. The preferred configuration uses a new fixed offshore platform connected to the existing Atlantic & Cromarty pipeline and using in-field pipelines for

	additional injection and pressure relief wells. CO2 will be injected existing to the Captain sandstone formation. An innovative all subsea solution has been assessed as a potential alternative.
Delivery Schedule	Operational 2025 based on fast track development.
Commercial	The equivalent strike price for the plant ranges from £80 to £90 / MWhr subject to commercial models adopted in the UK. The CfD should be adjusted to reward flexible generation with payment for capacity and ancillary services.
Socio Economic Impact	Generated UK GVA ranges from £0.5 bn to £0.9 bn (total of direct, indirect and induced impacts) and total jobs in the range of 400 to 1,000 jobs (200 – 500 direct jobs). A societal cost benefit analysis of a potential UK East Coast CCS network highlights benefits through emissions reduction, inter-linked economies, clean industrial growth and health co-benefits, outweigh costs by 5:1

2. CCEP as "anchor tenant" for infrastructure that enables a CCS industrial cluster

CCEP can also serve as the "anchor tenant" for infrastructure that makes CO_2 Capture and Storage (CCS) possible for some of Scotland's largest chemical plants, refineries, and other industrial emitters, protecting valuable parts of the economy in the long term. Creating CCS "industrial clusters" has become a top priority of climate policymakers not only in the UK and Europe but also globally.

On a worldwide basis, industrial CO_2 emissions now nearly match – and, thanks to the decline of coal-fired power plants, will eventually overtake – those from the power sector. However, capturing industrial CO_2 emissions without a power plant to anchor the required pipeline and storage infrastructure will be difficult and often economically unfeasible. The issues are ones of efficiency (how to economically size the infrastructure and assure it is sufficiently utilised) and uncertainty (many industrial facilities have a short-term focus, may operate on a batch rather than continuous basis, and at the extreme may not even exist for a typical 40-year lifetime of any CO_2 pipeline and store). With a large and long-lived power plant to anchor the CCS infrastructure investment and operation, industrial CO_2 capture becomes more economic and practical as an add-on.

Around 80% of Scotland's large-point sources of CO_2 emissions are within 40 km of the existing Feeder 10 pipeline that would transport captured CO_2[1]. The Grangemouth industrial complex has the greatest concentration of emissions in Scotland and short connection routes to Feeder 10. With a multiple-source Grangemouth CCS cluster, there can be an efficient and steady operation to decarbonise industry and generate power. Once created, the Grangemouth industrial cluster and infrastructure can also link up with other clusters on the UK's East Coast, such as St. Fergus, Teesside, and potentially Humber.

3. Suitable pipeline infrastructure to reach recognised CO_2 storage capacity already exists

CCEP is unique in the UK – and potentially globally – because the pipelines for CO_2 transport, both onshore and offshore, already largely exist. In addition, it can access a North Sea CO_2 store that is exceptionally well-characterised, studied, and understood. Using existing

[1] http://www.sccs.org.uk/news/326-sccs-study-scotland-s-industry-clusters-hold-key-to-reducing-cost-of-uk-climate-action

pipelines significantly reduces the cost and risk of development – the cost of building equivalent new onshore (Feeder 10) and offshore pipelines (Atlantic & Cromarty) would be up to £440 million[2] and, even on an unconstrained fast-track schedule, would take around 5 years to permit, design and build. Retention and reuse of nationally significant infrastructure makes good business and climate sense, representing the most tangible cost reduction opportunity in CCS today.

CCEP Is Technically & Financially Feasible

This Report confirms that CCEP is economically valuable in UK terms and is both technically and financially feasible with a suitable commercial approach.

1. *Technical feasibility: Power plant & CO_2 capture system*

Four main types of flexibly operating natural gas-fired power plants with CO_2 capture are analysed in this Report. The Report shows that all types, including their CO_2 capture elements, are technically feasible, with two of the four using technology that is already available with a commercial warranty from global leaders in the power sector: these are a Natural Gas fired Combined Cycle plant with Post-Combustion CO_2 Capture (NGCC/PCC) and a Steam Methane Reformer (SMR) plant that uses natural gas as the feedstock to produce hydrogen (H_2) to be used as the fuel for a H_2-fired combined cycle power plant. The other types were CapSol's (ex Sargas) natural gas fired system with integrated "end of pipe" CO2 capture technology, and NET Power's Allam Cycle turbine. Across these four main types, fourteen different technical configurations were analysed, with the results presented in the Report.

2. *Technical feasibility: CO_2 transport via existing pipelines & offshore storage*

This Report builds on and improves (including with identified cost reductions) prior studies by top UK and international experts that have already established the technical feasibility of using existing pipelines onshore (Feeder 10) and offshore (Atlantic & Cromarty, and potentially Goldeneye) for CO_2 transport from CCEP to secure offshore storage in the Captain sandstone formation.

The Report shows the pipelines have sufficient CO_2 transport capacity to accommodate CCEP, plus a Grangemouth industrial CCS cluster, and (with some enhancements) a future link-up with other East Coast industrial clusters such as Teesside. Offshore, the Captain sandstone formation has sufficient capacity to store all these CO_2 emissions and a great deal more – an estimated minimum of 360 million tonnes of CO_2, at a rate of between 6 and 12 million tonnes per year[3].

The principal additions needed for the existing infrastructure are modest and technically unremarkable. They consist primarily of onshore CO_2 compressors at St. Fergus, a small new unmanned facility offshore to handle injection and any produced water from the process plus some short pipeline additions to tie the subsea system together. Innovative subsea solutions may offer further cost reduction opportunities.

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[2] Brownsort, PA, Scott, V & Haszeldine, RS 2016, 'Reducing costs of carbon capture and storage by shared reuse of existing pipeline—Case study of a CO_2 capture cluster for industry and power in Scotland' International Journal of Greenhouse Gas Control, vol 52, pp. 130-138. DOI: 10.1016/j.ijggc.2016.06.004 and Summit/Pale Blue Dot estimate.

[3] Optimising CO_2 storage in geological formations; a case study offshore Scotland CO_2 MultiStore project September 2015, http://www.sccs.org.uk/expertise/reports/co2multistore-joint-industry-project

CCEP Can Be Financially Attractive for Government, Consumers, and Investors

The Report dispels the notion that CCS, while necessary for climate, is nonetheless “too expensive” for the UK power system – or conversely, too unprofitable to attract private investment. Neither is a given. CCEP can be delivered at a very attractive power price, particularly given the valuable power system benefits that CCEP will bring and that renewable energy projects cannot. Moreover, at a price attractive to Government and the public, CCEP can also attract private investment and can be financially as well as technically feasible.

The Report finds that CCEP can be built and financed with reasonable returns to private sector investors at a power price of £80 - £90 per Megawatt-hour (MWhr) with suitable commercial arrangements. Moreover, this price understates why CCEP should be attractive to Government and the public: unlike other power sources, such as wind projects, CCEP will provide more than just electrical energy. CCEP will provide dispatchable power and provide firm electric capacity, also supporting the power grid through inertia, voltage and frequency regulation, ancillary services, potential battery charging, and importantly the potential to “black start” the grid in Scotland if there is a significant system outage.

In fact, it would be possible to set the CfD price for CCEP’s electric energy output (MWh) – which is all that intermittent renewable energy projects such as offshore wind provide – based on CCEP’s variable costs; this would provide an apples-to-apples comparison for the CfD prices paid for energy from different types of resources. To cover CCEP’s fixed costs, the CfD could provide an appropriate separate price for the amount of firm, dispatchable electric capacity (MW) and other grid integration and support services that CCEP will provide, such as voltage support, other ancillary services and blackstart capability.

CfD prices for intermittent sources of electric generation, such as renewable resources, can sensibly be expressed solely in terms of £/MWh (megawatthours). Dispatchable sources of generation such as CCEP provide much more than electric energy (MWh). For dispatchable resources such as CCEP, it is customary to enter into power purchase agreements (of which a CfD is effectively one species) under which there are separate prices paid for the energy (MWh) and the firm capacity (MW) that the project provides. There may even be a third category of prices and payments for ancillary services such as voltage and frequency support, and the like. The price paid for energy is generally expressed in £ or $ per MWh actually generated and delivered to the grid from the power plant. (A price expressed in £/MWh is also what is paid under CfDs for intermittent energy (MWh) from renewable resources.)

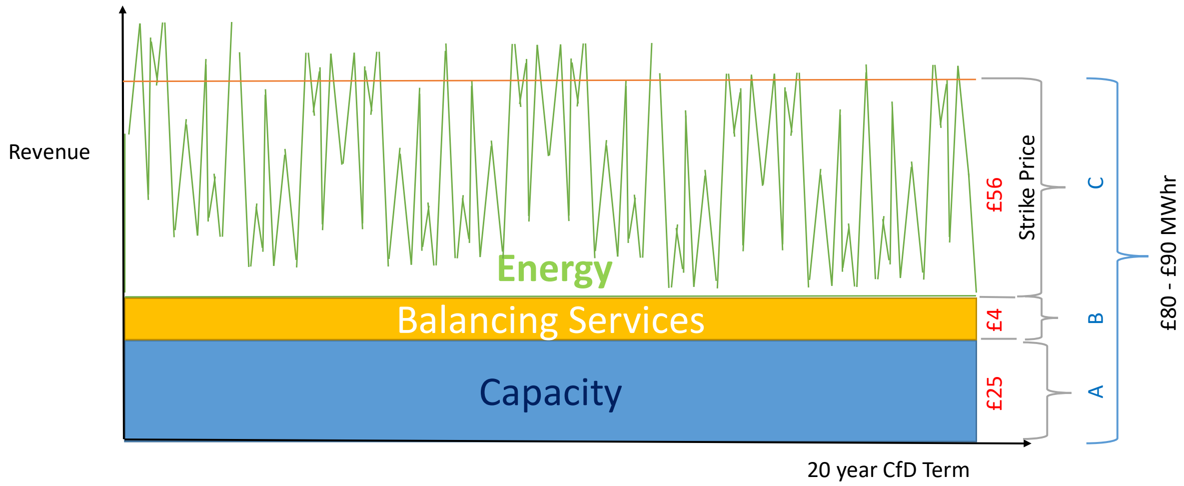
Payment for firm electric capacity, on the other hand – i.e., for the ability of the project, when called on, to provide energy on demand to meet the otherwise unmet portion of electric loads – is generally a fixed price expressed in £ or $ per megawatt/month (MW/month). That is, there is a fixed payment for the dispatchable capability of the project (its available capacity expressed in MW) that is paid each month, regardless of whether all, most, some, or none of that available capacity is actually called upon or not in any given month.

Under this customary contractual payment system, the plant’s projected revenues from sales of energy (MWH) plus the plant’s projected payments for firm capacity (MW) cover, in total, both the variable and fixed costs of the dispatchable plant, and make up the plant’s projected revenue stream. This projected revenue stream (plus any payments for ancillary services, etc.) is what is relied on by investors and lenders in financing the plant.

Following this customary contract form, CCEP's CfD price for energy (£/MWh) would be set to cover the plant's variable costs of producing energy (MWh), such as fuel and other expenses that depend on how much energy (MWh) the plant is called upon to produce. Because CfD prices for energy from offshore wind, for example, or other intermittent sources of energy, are also expressed in £/MWh, pricing MWh from CCEP in this manner for purposes of the CfD would facilitate apples-to-apples comparisons of per-MWh energy prices for CCEP and intermittent power sources alike. In both cases, £/MWh would be the CfD price paid for the same product – namely MWh, which is the only product that intermittent sources provide.

The CfD for CCEP would then contain a separate price for firm capacity (MW), which would be designed to cover the project's fixed costs. The capacity (MW) price would be a fixed amount in £/MW/month, escalating for inflation over time to the extent agreed upon. It would be designed to reflect the project's fixed costs of being able generate power and to provide firm capacity and related services to the grid.

The total amount of CfD payments for CCEP's energy output (MWh) combined with payments for its firm capacity (MW) would be the total cost of the CfD. This total cost would need to satisfy two tests: (1) Low enough to be acceptable to the Government, hence resulting in a CfD, and (2) high enough to attract the non-governmental debt and equity needed to finance the plant. If both tests are met, the plant can be successfully financed, built, and operated. This concept is illustrated in the following figure.



This approach will be further explored during subsequent phases of work.

With these features, CCEP will make it easier and less expensive to increase integration of renewable energy (and potentially battery storage) into the grid. A 2017 study by UKERC[4] indicates as penetration of intermittent generation increases beyond 30% (which is now common place in the UK), the additional cost of intermittent generation on the GB electricity system is likely to be upwards of £20/MWhr, important when comparing the cost versus the benefit of different approaches to energy and climate challenges.

[4] A systematic review of the evidence on the costs and impacts of intermittent electricity generation technologies, UKERC, Philip Heptonstall, Robert Gross, Florian Steiner February 2017

The principle of adopting a different approach to how system costs and benefits are valued has been highlighted recently in the independent UK Cost of Energy Review[5] which recommends an equivalent firm power (EFP) metric and a more effective carbon pricing policy – both of which are aligned to the approach promoted in this study and, if implemented, would help facilitate the development of CCEP.

Importantly, beyond electricity, CCEP will also make possible the capture of CO_2 from other industrial sources – a key global climate benefit no other power sector technology can offer – and help kick-start a new UK industrial sector and source of economic growth and well-paid jobs.

In addition, the Report shows that the power price for CCEP can be greatly reduced if the commercial approach to CCS is based on a full consideration of whole system cost, benefit and risk. The most basic of these would be to spread the key CO_2 transport and storage infrastructure costs – which basically are global climate costs, not power costs. This should be done on a long-term basis and over projected volumes of captured CO_2 from the multiple industry and power sources, rather than load all "up front" CCS infrastructure costs and risks on a single power plant. On a similar basis, any approach to front load CCS infrastructure costs onto industry alone, would be unlikely to succeed. A joined-up approach with power and industry can succeed.

Finally, as part of a more effective approach to carbon pricing, it makes common sense that there should be no additional liability incurred by any party from storing CO_2 – either geologically or via reutilisation - than emitting (i.e. storing) in the atmosphere.

CCEP's Other Socio-Economic Benefits

In addition to helping integrate renewable energy into the power grid and enabling CO_2 emissions to be captured from industrial sources, CCEP will make a major contribution to the UK and Scottish economies. As the Report shows, that contribution will take several forms, including creation of desirable high-paying jobs:

1. Supply chain development & related industrial jobs: Scottish and other UK companies can provide much of the design, procurement, construction, and operating expertise that CCEP and the CCS onshore and offshore infrastructure need. But in other areas – including areas the UK Government has specifically identified for further development to hasten CCS commercialisation and deployment – CCEP provides a key (essentially, the key) opportunity and impetus for realistic early success.

2. Gross Value Added (GVA): The Report indicates that during CCEP's design and construction phases (2018-2023), the range of direct GVA at a UK level would be £0.7 bn to £1.2 bn, with indirect/induced GVA ranging from £0.5 bn to £1.4 bn. Operation of the power plant and full CCS chain will provide additional GVA throughout the Project's life.

3. Jobs added: During construction, CCEP is expected to generate 1,200 to 1,800 jobs directly in Scotland and the rest of the UK. Additional indirect Scottish and other UK jobs during construction are estimated at 800 to 1,900 with additional induced jobs at 500 to 800. This represents a major multi-year employment boost, particularly for Scotland and the north of England.

[5] Cost of Energy Review, Dieter Helm, 25th October 2017

4. Long-term jobs: Operation of CCEP, including the power plant, carbon capture facility, and the onshore and offshore CO_2 transport and storage infrastructure, are estimated to create direct long-term jobs in Scotland and the rest of the UK of 300 to 600, with 600 to 1,000 indirect and induced jobs.

Environmental Matters & Consents/Permits/Licenses

The key environmental impact of CCEP will be a global climate benefit: CCEP will capture the CO_2 from a natural gas-fired power plant, adapt and use existing infrastructure to make CCS practical and affordable, and both demonstrate and commercially deploy the capability to produce electric power while capturing CO_2 in a flexible operating manner that eases the power grid's difficult task of integrating and making the best use of renewable energy.

CCEP's local environmental impacts will be modest, both absolutely and relative to the Project's global climate benefit. There is no need for significant environmental trade-offs to gain that global climate benefit. The Report identifies three viable site locations in or near the Grangemouth industrial area. The area is heavily industrial already; indeed, that is what makes possible the additional climate benefits of an industrial CCS cluster. An Environmental Risk Assessment (ERA) indicates that suitable mitigation is possible for any cumulative local air quality and ecological impacts.

The Report catalogues all the consents/permits/licenses required for construction and operation of CCEP and the CCS transport and storage infrastructure. These are numerous – about eighty-five (85) in total, divided among the power plant, the onshore CO_2 transportation, and the offshore transportation and storage. It is recommended that government agencies work with CCEP's sponsors and stakeholders to identify opportunities to streamline and reduce cost and uncertainties associated with the consents, permits, and licensing process.

Policy & Fiscal Support

There is no disagreement among the best-informed climate agencies and experts that global climate goals – including those of the Paris Agreement – cannot be achieved without rapid commercial deployment of CCS on a worldwide basis. Bluntly stated, the climate depends on CCS, among other decarbonisation technologies. This is increasingly recognised everywhere. CCEP presents Scotland and the entire UK with the opportunity to step up to a globally-recognised leadership role on CCS – and at the same time, to kick-start an entire new industrial and economic sector at home, one replete with well-paid new jobs and significant GVA.

The great challenge is not technical feasibility or cost, as this Report shows. Thanks to its unique advantages, including existing pipeline infrastructure both onshore and offshore, CCEP is feasible and affordable. The key challenge is government CCS policy, and particularly maintaining constancy in that policy and establishing the necessary business models that will facilitate private sector investment.

The Report sets forth a specific plan for CCEP project development from this point forward. The plan is innovative and challenges previous approaches. Like other UK power projects, CCEP can be developed and financed on the strength of an appropriate Contract for Differences (CfD). To gain the investor confidence required to fund and commence the next stages of project development – taking the lessons of past UK CCS experience – a CfD needs to be negotiated early in the development process to enable capital to be raised to undertake the development process without undue risk.

There is no inherent risk to government in starting CfD negotiations for CCEP. The government cannot be bound unless and until it makes a CfD award. From an investor perspective it is impossible to determine with any confidence if a CfD would ultimately be available on acceptable terms, particularly when policy continues to evolve. A key conclusion of this Report is therefore that the CfD negotiation process is a pre-requisite of further project development activity rather than the other way around. That process will also illuminate the most important policy and commercial decisions necessary to make CCEP and UK CCS a success.

Key Risks

The key CCEP risks, as noted above and detailed in the Report, are not technical, environmental, or inherently financial. They are essentially risks of government CCS policy, and particularly risks of changes and inconsistency in CCS policy and supporting regulatory incentives/penalties. A legally binding long-term contract, in the form of a CfD that is satisfactory to government, the public, lenders, and investors, is entirely practical and will eliminate or make manageable most of the policy and related financing risks.

Financing large long-term projects requires that all identifiable risks be allocated to specific parties. The CfD and government policy can accomplish this risk allocation task. If project lenders are not required to take sovereign or unusual risks, and if equity investors have a reasonable prospect of risk-appropriate financial returns, then financing for CCEP can be obtained.

Conversely, to meet policy or political requirements of the government and public, appropriate CfD terms can also be determined. For example, the CfD “strike price” (i.e., price paid for CCEP’s power output) in £/MWhr can be adjusted if the CfD has a longer rather than a shorter term, since this allows repayment of the project debt to be spread over a greater number of years.

Some risks to CCEP can be mitigated by inter-governmental actions and agreements. The CfD can be drafted so that “Brexit” (or even potential Scottish independence) does not disturb its financial terms, for example. As noted above and in the Report, governments can also help streamline the consenting process and make it more certain and less costly.

CCEP will require some cooperation from third parties, such as those responsible for grid connections, power purchases and sales, and other physical or commercial project interfaces. The Report identifies these interfaces and methods for dealing with them.

The following table provides a high level summary of the assumed allocation of risk in the study.

Key Risk Allocation	Private Sector	Government
Policy, Change of Law and Fiscal Support (including UK / Scottish and EU interfaces)		X
Development pre-award of early CfD	Minority Share	Majority Share
Development post-award of early CfD	X	
Financing Risk	X	
Fuels and Utility Supply	X	
Fuel Price	Shared in CfD	Shared in CfD
Offtake Agreements for Power, CO2 and ancillary services	X	
Generating Plant - Specify, Design, Build and Performance risk	X	
Transport & Store - Specify, Design, Build and Performance risk	Shared	Shared
Cross chain risks including emissions – depends on cause	Shared	Shared
CfD Delivery Milestones - additional flexibility required to manage inter-related elements of the chain commissioning and operation.	Shared	Shared
CfD Merit order / Dispatch / Price Adjustments – plant should be operated and reimbursed to suit overall system requirements	Shared	Shared

Recommendations

The Report and its Executive Summary set forth a complete list of recommendations for next steps. That list is both a roadmap and the key purpose of the Report. As such, it should be reviewed in its entirety, rather than repeated in this Report Highlights section.

A key recommendation is that CCEP's sponsors should work collaboratively with Scottish and UK Governments on specific policy matters and commercial arrangements – all of which the Report identifies and lists – that will reduce the cost and increase the investment-worthiness of a CfD for CCEP. By commencing negotiation of the CfD, such policy matters and commercial arrangements can be identified and addressed with precision and without delay. This offers the quickest route to success for CCEP specifically and for the UK CCS sector in general since it avoids attempting to develop policy and/or commercial approaches in the abstract.

The Report contains additional recommendations that are broader than for CCEP alone. These include further cooperative efforts by all relevant parties, for example, to continue advancing the concept of a UK East Coast CCS network, one that eventually includes not just CCEP and the Grangemouth industrial CCS cluster but also St. Fergus, Teesside, and potentially Humber.

Executive Summary

This is the final report of the work undertaken and key findings of the Feasibility Study for the Summit Power Caledonia Clean Energy Project (CCEP or the Project) which has been undertaken with funding support from Scottish and UK Governments, Summit Power and Project/supply chain partners.

CCEP could export up to 1,381 MW of low-carbon electrical power to the electrical grid and, depending on the configuration, has the potential to also economically provide a slipstream of hydrogen for industrial, heat and transportation applications. For illustration purposes, if the slipstream was sized to only 1% of energy output, or 4,000 tonnes of hydrogen per annum for transportation applications, the daily production would be sufficient to fill 2,000 hydrogen fuel cell automobiles or almost 500 hydrogen fuel cell buses every day.

This study aims to provide a thorough examination of all issues and assessment of probability of business success in order to:

- Outline and narrow business alternatives and suggest new opportunities
- Identify how to enhance the probability of success by addressing and mitigating factors early on that could affect the Project
- Provide quality information for decision making
- Provide documentation that the business case was thoroughly investigated
- Promote alignment of stakeholders in support of the Project
- Assist in securing funding from investors, lending institutions and other monetary sources for the next stage of Project development

The Feasibility Study has been undertaken by Summit personnel supported by a wide range of advisors and technology providers.

In the preceding interim report (Q4 2016), ten economic scenarios were presented, built on the different technical configurations of coal feedstock Integrated Gasification Combined Cycle (IGCC) power generation, carbon dioxide (CO_2) capture, transportation and storage. This final report presents alternate, natural gas fed configurations. Fourteen additional unique economic scenarios are presented in this final report and result in a comprehensive set of combinations based on the different technical configurations.

The Feasibility Study findings confirm that CCEP represents an economically and technically viable project in at least five (5) of the evaluated natural gas with CCS scenarios. CCEP demonstrates scenarios that could be delivered with a Strike Price in the £80 to £90/MWhr Strike Price range (2012 Prices), assuming specified key changes in commercial approach to make the Project investable. The Project will take approximately four years to construct and commission from reaching a final investment decision, with analysis confirming that there are no significant technical constraints that would delay start-up date beyond 2023.

The following table summarises Summit's current assessment of risk for the five viable NGCC/PCC scenarios, along with two Steam Methane Reformer scenarios that may benefit from further analysis if there is sufficient policy and fiscal support in the foreseeable future to develop power, heat and transport solutions utilising hydrogen.

Recommended for Further Study (Case Number)	Consent/Build Risk	Operational / Technical Risk	Market Risk - Products & Services	Policy & Regulation Risk	Commerical / Warranty Risk
NGCC/PCC (1 a/b/e)	Low	Low	Mid	Mid	Low
NetPower Allam Cycle (5 a/b)	Mid	High	Mid	Mid	Mid
SMR Hydrogen (3 a/b)	Mid	Low	High	High	Low

For any project configuration to be investable, future phases of development work must reduce areas of risk that are currently assessed at high or medium levels. For example, the NET Power configuration shows potential but currently has a high Operation/Technical risk since it has not been demonstrated to work even at demonstration scale. Proof of performance at commercial scale may not occur until after 2020. The NET Power Commercial/Warranty risk is assessed as Medium since it has yet to be determined if the product can be warrantied to the same level as the NGCC/PCC solution. This risk would be assessed as High if the backers of the NET Power technology were less substantial.

A post feasibility development plan has been developed as part of the Feasibility Study to provide a basis for funding the next phase of study on CCEP that would focus on these scenarios; refining the commercial and technical basis and identifying solutions to reduce the risk profile to low – i.e. investable levels.

UK / Scottish Government financial support would be required at the same rate as for this Feasibility Study, with the balance of contributions from Summit Power and its Project partners/supply chain. The post feasibility development plan would be conducted in phases, thereby allowing for several decision milestones during the course of the work. An initial preparation phase should be conducted to prepare for the successive phases, summarily known as a Pre-FEED phase. This phase would further refine the feasibility study and performs additional work to provide for more accuracy and clarity of the Project, in parallel with the development of the UK CCS deployment pathway and other CCS initiatives committed to in the Clean Growth Strategy. The post feasibility development plan should be further refined in conjunction with Project investors, Scottish, and UK Government.

Economic Assessment

A techno-economic model was developed for Summit by Mott MacDonald, to enable Summit to analyse the financial feasibility of a number of options for a power plant with CO_2 Capture and Storage (CCS). The model uses a combination of data from Summit, Mott MacDonald, Pale Blue Dot, technology providers and other industry consultants. The model was benchmarked against global industry data including public information from previous UK Front-end Engineering and Design (FEED) studies: Longannet, Peterhead and White Rose, as well as US projects including Summit's Texas Clean Energy Project. In addition, benchmark assessments were undertaken for scenarios using Steam Methane Reforming for hydrogen production and for innovative technical solutions offered by Capsol and NET Power. Offshore storage cost estimates developed specifically for this study were benchmarked against recent Energy Technologies Institute (ETI) and Scottish Carbon Capture & Storage (SCCS) studies. Economic risk analysis was performed by Summit based on this model.

The techno-economic model has three key functions:

- To calculate financial returns simultaneously for different scenarios.
- To examine the impact of changes in key model inputs and assumptions on the output of the model, through sensitivity and probabilistic analysis.
- To allow either:
    - The calculation of the Project's financial return at different confidence levels based on a given strike price assumption.
    - To calculate the required strike price for each option for a given level of financial return at a given confidence level.

Economic, sensitivity and risk analysis confirm CCEP scenarios that can be delivered with acceptable strike price and sufficient investor confidence in the £80 to £90/MWhr Strike Price range (in 2012 Prices) with limited changes in commercial approach. Four key policy / commercial changes could reduce Strike Prices by as much as £60 - £80/MWhr from the prior CCS Competition levels, reported to be close to £170/MWhr even with capital support.

- Socialised development and regulated charging model for CO_2 Transportation & storage, reducing cost and risk **up to [£35/MWhr lower]**
- Provide appropriate Contract for Difference (CfD) contract terms and tenor (at least 20 years) to underpin investment **up to [£24/MWhr lower**]
- Optimise flexible dispatch/capacity factor of plant **up to [£15/MWhr lower]**
- Reduce commercial risk arising from definition of clean electricity generation and cost of residual carbon emissions **up to [£6/MWhr lower**]

Other technical and commercial opportunities remain to further reduce the deployed cost of CCS in power and industry as future projects are deployed.

Socio Economic

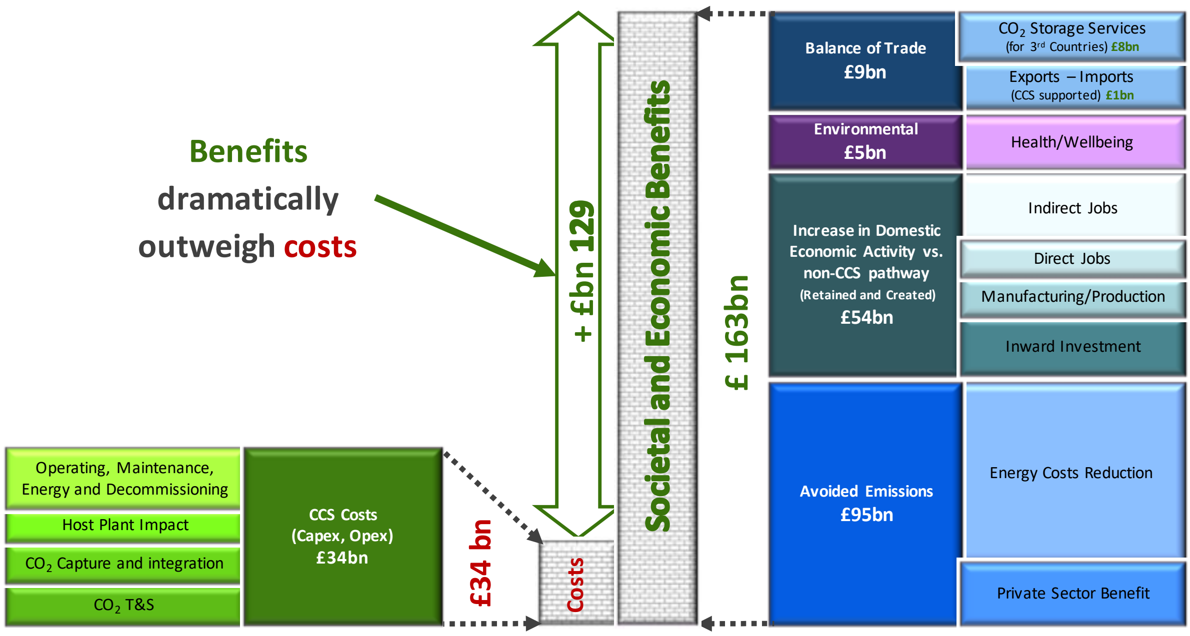
Societal Cost Benefit Analysis Summary

As part of the Feasibility Study an analysis was undertaken into the value of Carbon Capture and Storage ("CCS") investments along the East Coast of the United Kingdom, represents a new approach to evaluating the economic and societal benefits associated with the deployment of CCS. The analysis considers a phased evolution of CCS Investments providing essential decarbonisation options with discrete investment/decision points along the way.

A key finding from the quantified *societal cost benefit analysis* is that a viable evolution of a UK network of CCS investments that could result in a 5:1 payback to the UK economy. Dedicated CO_2 infrastructure would link clusters of major industry and power generation in Scotland, Teesside, the Humber region, and the South East, to CO_2 transport and offshore storage (T&S) infrastructure in the UK Continental Shelf (UKCS), potentially growing to a capacity of 75 $MtCO_2/y$ by 2050, which would be required to meet the Committee on Climate Change central scenario. Investments can proceed in discrete phases of around 5 years with each phase building on and using the infrastructure established in previous phases. Around 70% of that capacity would be required to decarbonise industry, transport, and heat.

The societal cost-benefit analysis considers direct investments in CCS as well as the impact through *linked economies,* including power generation, energy intensive industrial sites (chemicals & pharmaceuticals, petrochemicals, iron & steel, cement and fertilisers), hydrogen production plants, fuel refineries and gas processing plants. The potential for reduced activity in the industrial sectors, due to rising carbon costs, was also considered. Further, the potential for income from providing CO_2 storage to other European countries was also considered.

In economic terms the estimated cumulative benefit of the modelled CCS Investments to the UK economy outweigh the costs by an estimated £129bn, assuming operation of the network and CCS investments through to 2060. In the same period, around 225,000 jobs could be created or retained and around 1.5 Gt of CO_2 captured and stored.



A standalone analysis considered the discrete implementation of only the early phases of the network between 2020 and 2025 assuming there were no further CCS developments. The resulting benefits still outweigh the costs by a factor of 2:1. This means that the first CCS investments can be delivered on a "no regrets" basis whilst also providing valuable options for the future. On this basis, a delay in deployment until the 2030's will only serve to limit future options and increase the challenge of meeting carbon reduction targets.

Project Specific Socio-Economic Analysis

The CCS supply chain in the UK has strengths in several areas related to the construction and operation of CCS plants. UK companies have the necessary expertise in the design and construction of CO_2 capture systems and CO_2 pipelines and have the necessary skills for the design, construction and operation of depleted oil and gas fields. In addition, the supply chain has strengths in environmental and legal services and in the power sector including balance of plant components. However, the UK supply chain is less well developed in the different areas required for the construction of CCEP, including the engineering, design and manufacturing of gas and steam turbines, air separation units or steam methane reformers (each relevant to one or more of the scenarios considered). Certain of these areas of the supply chain have been identified by the UK Government as targets for further development in the future to encourage the early commercialisation and deployment of CCS in 2020 and beyond. The industrial strategy is more fully described in the report issued by Summit Power issued October 2017[6];

- The range of Gross Value Added (GVA) which could arise from the construction of CCEP in Scotland is expected to be £0.4 bn to £0.8 bn. In addition, the construction of the Project is also expected to add £0.2 bn to £0.6 bn in indirect GVA and £0.1 bn to 0.3 bn of induced GVA across the different economic sectors in Scotland. These impacts are expected to occur during the design and construction phases nominally between 2018 and 2023. Additional GVA will also occur from the operation of the power plant and the full CCS chain.
- During the construction phase, CCEP is expected to generate 1,000 to 1,300 jobs. In addition, between 700 and 1,500 indirect jobs and 400 to 700 induced jobs are expected to be created across the Scottish economy.
- The construction of CCEP will also lead to GVA and jobs in the rest of the UK. The analysis shows a GVA range of £0.5 bn to £0.9 bn (total of direct, indirect and induced impacts) and total jobs in the range of 400 to 1,000 jobs (200 – 500 direct jobs).

Additional GVA and jobs will also be created during the operation of the power plant and the full CCS chain. The analysis shows that about 300 - 600 direct jobs will be created in Scotland during the operational phase (100 - 150 jobs related to the power/CO_2 capture plant). In addition, 600 – 1,000 indirect and induced jobs will also be created across the Scottish economy as a result of these direct jobs. Additional socio-economic opportunities exist through related activity such as the development of a hydrogen-based industrial, heat and transportation sector and through the use of CO_2 for enhanced oil recovery that are not included in the above figures.

[6] http://www.ccsassociation.org/news-and-events/reports-and-publications/clean-air-clean-industry-clean-growth/

Policy & Fiscal Support

The general case for and benefits of CCS have been subject to extended debate.

The UK Government's advisers, the Committee on Climate Change (CCC), consider that "Carbon capture and storage (CCS) is likely to be a crucial part of the least cost path to decarbonisation in the UK". CCS also has a crucial role in decarbonising heavy industry where there are limited options, and the Energy Technologies Institute report the costs of meeting the UK's 2050 climate change targets would "almost double without CCS".

Notwithstanding this, significant uncertainty presided over the future of CCS in the UK throughout the preparation of this study. The reasons for this are well summarised in the House of Commons Energy and Climate Change Committee reports entitled *"Future of carbon capture and storage in the UK, Second Report of Session 2015–16"*[7] and in March 2016 the House of Commons Energy and Climate Change Committee report entitled *"Investor confidence in the UK energy sector, Third Report of Session 2015–16"*[8]. Events since 2015 have undoubtedly resulted in the largest risks to CCEP being government policy and fiscal support, and continued change thereof. A new UK CCS policy was outlined in the Clean Growth Strategy, announced 12th October 2017[9], which included commitments that could advance CCS in the UK. It is imperative that a deployment pathway is developed through 2018 to allow investors to assess if there is a route to market in the UK or not in the foreseeable future.

Like other power generation projects in the UK, CCEP can be financed on the strength of an appropriate Contract for Difference (CfD). In recent years, energy project development investment was able to be attracted, pre CfD award, based on an assessment of the:

- risk/return profile of project delivery – FEED, construction and operations;
- the probability of being awarded a CfD; and
- The risk of counter party default.

Following the changes since 2015, the ability of investors to assess the probability of a successful CfD award has been significantly reduced. Importantly, the ability of investors to understand timescales has also been significantly diminished.

This places the award of a CfD (or equivalent) at the forefront of any investment decision in project development, particularly given that pre-FID project investment may reach £50M for a large energy project in the UK.

Summit considers it essential to ongoing development investment that early and firm commitment is made by government in the form of a binding CfD or similar arrangement as a first step to advance project development. Without this Summit consider it unfeasible for investment to flow into CCS project development, as would be the case in any other economic sector.

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[7] https://publications.parliament.uk/pa/cm201617/cmselect/cmenergy/497/49701.htm
[8] https://www.parliament.uk/business/committees/committees-a-z/commons-select/energy-and-climate-change-committee/inquiries/parliament-2015/investor-confidence/publications/
[9] https://www.gov.uk/government/publications/clean-growth-strategy

Technical Assessment Power Generation & CO_2 Capture

The Feasibility Study has confirmed viable alternative technical configurations for the Power Generation & CO_2 Capture elements of CCEP. It is recommended that further development is undertaken in accordance with technical and commercial recommendations in this report for:

- Natural Gas Combined Cycle (NGCC) power plant with Post-combustion CO_2 Capture (PCC) configurations of various sizes and equipment
- A NetPower configuration that combusts natural gas and oxygen in a specialty turbine resulting in a compressed and fully separate stream of CO_2 with no need for separate post-combustion CO_2 capture equipment

and, subject to confirmation of policy support for deployment of hydrogen in heat/transport

- Steam methane reforming (SMR) to produce a high hydrogen concentration fuel for a hydrogen-fired gas turbine design, along with a possible slipstream of hydrogen which could be used for industrial, heat and transportation applications

Technical Assessment CO_2 Transportation and Storage

Analysis of CO_2 transportation and storage configurations indicates technically viable lower cost alternatives than previously identified. The detailed analysis of CCEP specific solutions included in this report and in addition a wider solution for a UK East Coast CCS network is more fully described in the report issued by Summit Power in October 2017[10], included as Appendix 3.

The Project-specific base case development option for Transportation and Storage of the CO_2 from Grangemouth is as follows:

- The conversion of Feeder 10 from natural gas to CO_2 operation is assumed.
- A short new pipeline routing from Grangemouth to Feeder 10.
- The existing offshore 78 kilometres (km) 16” Atlantic & Cromarty pipeline will be reused so no landfall is required.
- A new unmanned minimum facilities offshore platform and jacket will be installed close to the existing termination point of the Atlantic & Cromarty pipeline.
- Subsea daisy chain tiebacks from three CO_2 injection wells will be required, one into the Goldeneye reservoir located around 40 km from the platform and two into Captain sandstone saline formation located around 10 km from the platform. Total injection of c. 4 million metric tonnes per annum (MTPA) is possible, with later expansion potential.
- A naturally producing water production relief well is required flowing at 20,000 barrels per day (BPD) drilled between the Goldeneye and Captain injection wells. It is assumed the water must be routed back to the platform for treatment and monitoring prior to overboard discharge.

[10] http://www.ccsassociation.org/news-and-events/reports-and-publications/clean-air-clean-industry-clean-growth/

It is therefore fundamental to the ongoing viability of CCEP that a mechanism is identified to secure the future of essential national assets for CCS including the Feeder 10, Atlantic & Cromarty, and Goldeneye pipelines.

Dispatchable and Flexibility Generation

The share of energy produced from renewable resources is growing rapidly. The output of wind and solar power is highly variable, and depends on factors such as weather conditions and time of day. With this growing share of renewable power, which now has priority access to the grid, fossil fuel-fired power plants will have to increasingly shift their role from providing base-load power to providing fluctuating back-up power to meet unpredictable and short-noticed demand peaks that renewable sources cannot respond to, in order to control and stabilise the grid. Fossil fuel-fired plants should be able to operate both at the lowest load possible and at the highest possible efficiency. Moreover, these plants will be required to operate across the entire load range with high load-change rates, and even operate in start/stop mode with full turndown and very fast re-start, all at minimal (lifetime) fuel consumption.

In order to better understand the operational flexibility, Summit analysed the turndown and rate of load change capability of the integrated NGCC/PCC plants. The results of the analysis are globally significant, and indicate that CCEP is capable of a significant level of energy turndown, while maintaining emissions limits and without deleterious wear-and tear of the equipment. Similarly, the plant is capable of a fast and efficient rate of load change, and the reaction time of the plant related to changing conditions on the transmission grid is very robust. Summit concludes that CCEP offers operational flexibility and efficiency, within certain limits, without any significant increased wear-and-tear or increased cost for equipment maintenance.

Analysis indicates that the Power Plant could operate at fast ramp rates up to 88 MW per minute[11] within the 60% to 100% load range, with potential to extend this flexibility to a 50% to 100% range, subject to more detailed analysis during pre-FEED and subject to confirming warranty support of technology providers. This opens up the opportunity to move gas fed CCS power generation away from base-load, offering much better system integration potential with intermittent renewables.

Permitting Assessment

Permitting requirements for the full chain Project have been assessed. The number of Main Consents, Permits and Licences Required for CCEP is:

Power Generation & CO_2 Capture	26
Onshore CO_2 Transportation	34
Offshore CO_2 Transportation and Storage	25
Total	**85**

The consenting requirements for the full chain Project are costly, complex, time consuming and require significant commitment from a wide range of stakeholders. Project consents, permits and licences have no inherent value without a Contract for Difference (CfD). UK

[11] Case 1e: 2x1 GE 9HA.02, heat soaked and fast ramp via "Automatic Generation Control"

practice has been to require consents prior to CfD auction/negotiation eligibility however this approach is not financially viable for CCEP since it requires c. £10 million expenditure where there remains significant political and regulatory risk. Summit therefore recommend commencing a fast-track consenting process following award of a negotiated CfD. Prior to commencement of any permitting processes, a review is recommended of all Consents, Permits and Licences with government agencies to identify an appropriate fast-track and cost-effective approach.

Environmental

Environment and consenting matters have the potential to influence Project design and delivery timeline, which can impact Project technical and/or commercial viability. Summit has taken a risk-based approach to identify, quantify and propose mitigation for potential environmental and consenting risks as part of the Feasibility Study. The risk-based approach is reported in detail within an Environmental Risk Assessment (ERA) for the full chain Project. Several alternative locations in the area were considered and a comparative analysis is included in the study. Three suitable sites were identified in the Grangemouth area that are considered viable, offering similar advantages, and the final site selection would be made during pre-FEED subject to Project schedule and agreeing appropriate commercial terms with the site owner.

The proposed power plant locations in the Grangemouth area offers many benefits, including:

- Proximity to Grangemouth industrial complex offer potential synergies with industry
- Site footprint can accommodate different plant configuration options
- Site access is secure, controlled and not adjacent to publicly accessible areas
- Good connectivity to the electricity transmission system and short connection – 2.2 km
- Good connectivity to proposed CO_2 transport Feeder 10 pipeline – 2 route options of c. 15 km
- Planning Policy designation by Scottish Government under National Planning Framework 3 (NPF3) support a development of this type
- Adjacent to road, port and rail connection offers alternative or complementary logistics options

The main areas of risk on the site/local area are:

- Proximity to areas with environmental designations
- Interaction with marine environment – cooling options, flood risk, equipment life, etc.
- Air quality considerations due to existing industry emissions

Air Quality and Ecological impacts have been identified as potential higher risk areas through an Environmental Risk Assessment (ERA) process although it is considered that suitable mitigation will be possible. As a result, further assessment has been undertaken to inform the Feasibility Study and future phases.

Limitations of the ERA include the relatively limited engineering design and limited detailed information about the receiving environment at this stage of the Project development. In particular, there is less environmental information available on the electricity and gas grid connection options although these are considered relatively low risk.

An assessment of the CCEP greenhouse gas (GHG) emissions factor covering upstream emissions and generation of electricity was determined as ranging from 47 - 237 grams of CO_2 equivalent per net kilowatt-hour (gCO_2e/net kWh) with direct emissions of the NGCC/PCC plant itself identified as ranging from 37.9 gCO_2/net kWh to 46.2 gCO_2/net kWh depending on the configuration, in the steam methane reformer to hydrogen-fired combined cycle plant from 31.2 gCO_2/net kWh to 190.5 gCO_2/net kWh, and for the NET Power configuration, 0 gCO_2/net kWh.

These figures are based on 100% load conditions during abated operation. For the NGCC/PCC plant, this is approximately 90% lower than an unabated NGCC plant. There would be periods where the Power Plant may operate in unabated mode for reasons outside the control of the Power Plant itself, for example because of temporary outages in the transportation and storage system. Unabated operation may also occur temporarily during plant start up and shut down. This would increase net emissions for the Project from the abated full load case. Net emissions would be fully estimated once commercial operating parameters were established for the Project.

Keys Risks and Opportunities

A risk register has been prepared for the Project reflecting a qualitative assessment of risks and opportunities. The following is a summary of the top Project risks:

1. Political Risk: Major, frequent and unexpected changes in UK Government policy continue to affect the energy sector. Availability of CCS power project CfDs and lack of clarity over funding allocation remain critical risks.

2. Political Risk: Delivery plans, commercial arrangements and timelines were not included in the Clean Growth Strategy. Without these, investors remain unable to determine if there is a business case for further investment.

3. UK & Scottish Government political risk related to "Brexit" and Scottish Independence: Post Brexit arrangements are not established and are expected to develop over a prolonged period. The relationship between UK and Scottish government may change through the Brexit period. Any CfD for CCEP must remain financeable as the UK's relationship with the EU changes or if Scotland becomes independent.

4. Project Cost/Strike Price: End to end Project cost/risk comparisons are not on a like for like basis with other power generation options. The risk allocation for CO_2 transport & storage infrastructure may be too high for initial projects to carry. The CfD strike price may be unattractive to BEIS depending on metrics used to assess CCS project value.

5. Securing availability of existing pipeline infrastructure: Reusing existing pipelines can significantly reduce cost and risk however the availability of Feeder 10, Atlantic / Cromarty and Goldeneye pipelines is not secure, and they are threatened by decommissioning.

6. Financeability in the face of integration risks within the power plant or between the plant and CO_2 transport system, or between the CO_2 transport system and offshore storage. Project lenders will not take these risks. Allocation of lifecycle risk between UK Government, Developer and supply chain may not result in a financeable project.

7. Consenting risks: The Project will deliver low-carbon power. Nonetheless, environmental acceptability will need to be demonstrated successfully, as will the case for CO_2

transportation and storage. Environmental NGO support in the UK (as distinct from the US) is currently variable. Many major energy projects have been subjected to high consenting costs, legal challenges and protracted consenting periods.

8. Underfunding of early stages: Despite sums already invested in CCEP and the current feasibility work, early-stage energy project development risk in the UK has increased significantly, making the business case for additional investment difficult. This may result in a vicious circle where project feasibility is negatively affected by lack of investment in the development and pre-FEED and FEED stages.

9. Lack of Public Support: CCS is essential to achieving all reasonably established goals for limits on atmospheric concentrations of greenhouse gases, but CCS is not well understood (although not necessarily opposed) by the general public, linked to negative perception of fossil fuels, and perceived as too risky and expensive. Public hostility could adversely affect CCEP support locally or amongst NGOs.

10. Robust and Cost-Effective Intakes/Offtakes: High volumes of intakes/offtakes are required at the power plant site, requiring robust and cost-effective import/export arrangements to be in place. A gas and electricity grid connection are required and should be readily available based on analysis to date, however uncertainty of project timescales may risk these connections. Locational electricity transmission and use of system charges will disadvantage CCEP in CfD pricing compared to projects in lower charge areas.

Summary of Recommendations

Throughout the report, Summit has listed numerous recommendations for future action. The main recommendations are summarised below for convenience and easy reference. A detailed summary is included in Section 11, Summary of Recommendations.

Economics and Policy:

- Work with Scottish and UK Governments on key policy and commercial changes that could reduce Strike Prices and increase investability. These include:
  - An alternate ‘socialised’ development and charging model for CO_2 Transportation & Storage (T&S), reducing cost and risk. This should be developed to provide a suitable incentive for industrial CCS at Grangemouth and other UK east coast locations to share T&S infrastructure.
  - Provide appropriate CfD contract terms (20+ years) to underpin investment
  - Optimise flexible dispatch/capacity factor of plant, ensure revenues from ancillary services are predictable enough for business planning and raising finance
  - Reduce commercial risk arising from definition of clean electricity generation, particularly in relation to cross-chain default
- Confirm Strike Price ranges are acceptable in principle at Scottish & UK Levels using appropriate metrics that provide a fair comparison of value versus alternatives
- Confirm potential for policy support for hydrogen use for industrial & transportation applications, with particular focus on timescale and pricing/commercial risks, including stranded asset and system utilisation.
- Confirm validity of other key Summit assumptions relevant to economics/CfD.

- Secure the future of essential national assets for CCS including Feeder 10, Atlantic & Cromarty, and Goldeneye pipelines.
- Support advancement of a regional development strategy for Grangemouth cluster, exploring regional and sectoral financial assistance.
- Continue cooperative working on Industrial CCS (iCCS)/T&S with UK regions, including St. Fergus, Teesside and Humber.
- Subject to above, further develop Scenarios 1 and 5 in accordance with technical and commercial next steps:
    - NGCC with Post-combustion CO_2 Capture (PCC) - Scenarios 1a, b, and e.
    - NET Power (Allam Cycle) - a configuration that combusts natural gas and oxygen in a specialty gas turbine resulting in a compressed and fully separate concentrated stream of CO_2 with no need for separate post-combustion CO_2 capture equipment - Scenario 5 a and b.
- Additionally, we will monitor the demand for hydrogen and could additionally evaluate Scenario 3 in more depth if a market arises for significant volumes of hydrogen. At that point we would pursue hydrogen production, including technical/commercial optimisation of co-generation approach, Power Block sizing and Power Plant operability consistent with Scenarios 3 a and b.
- Agree and implement a funded pre-FEED plan in conjunction with Project investors, Scottish, and UK Government, in parallel with developing UK policy and fiscal support mechanisms and deployment plan.

Products and Services:

- Further refine the performance of the power plant in order to optimise the product outputs and ancillary services taking account of government policy support. The results will be input to the economic model in order to provide greater certainty around the economics of the Project.
- Develop commercial off-take contracts that support the economics of the Project.
- Further investigate black start economic case and technical capability, including interest from NGET and the potential development of a Local Joint Restoration Plan. Investigate additional ancillary service opportunities.

Production/Operation Requirements:

- Solicit interest from O&M services providers.
- Develop an inquiry package for O&M services provider participation in a Pre-FEED study.
- Develop draft contract documents to be used for Pre-FEED and for O&M.
- Further refine the required utilities, spare parts, consumables and chemicals that are required for O&M of the Project.

Technical Assessment:

- Further refine feasibility of a power plant cooling water solution and power plant layout.

- Advance the sizing and design of a hydrogen production option, subject to confirming UK/Scottish interest in deploying hydrogen option for heat and transport in the foreseeable future.
- Further refine offshore cost reduction opportunities.
- Further develop CO2 storage development plan

Permits and Consents:

- Identify low cost and fast-track process for required permits, consents and licences.
- Further develop and refine the plan for permitting and consenting as development of the Project progresses and more detailed technical information becomes available.
- Actively commence the Consenting Strategy following confirmation of firm policy and fiscal support, and subject to award of a CfD.

Environmental Assessment:

- Further develop Air Quality Constraints Study to determine likely emission limits for Project.
- Initiate consultation with SEPA and Falkirk Council to identify potential risks and investigations into ground water and flood risk.
- Obtain final cooling load requirements, intake/outfall flow rates and water compositions to gain understanding of thermal plume and impacts.

Socio Economic:

- Support further development of the economic case for complementary CCEP/iCCS activity at Grangemouth.
- Support further development of the economic case for complementary Grangemouth, St. Fergus, Teesside and other East Coast UK CCS developments.

Commercial and Business Assessment:

- Develop a joint strategy between industry, regional, and national governments to define and implement a delivery model and contracting strategy for CO_2 transport and storage infrastructure, based for example on a Regulated Asset Base and/or Public-Private Partnership (PPP) approach. Establish a UK CO_2 Capture, Storage & Utilisation (CCUS) delivery body to manage specification, procurement and management of a CCUS system.
- Confirm respective roles of government and Power Plant developer during pre-FEED in relation to delivery of CO_2 transportation and storage infrastructure.
- Confirm the availability, and process to secure in a useable condition, essential T&S assets for CCEP including Feeder 10, Atlantic & Cromarty, and Goldeneye pipelines.
- Develop a more detailed Project development plan taking account of UK policy, fiscal mechanisms and timing.

IP and Research:

- Develop licence agreements for the technology providers.
- Further refine the selected research projects.

Anticipated Development Timeline

The following figure summarises the expected timeline for further Project development work including decision Stage Gates and assumed timeline for external activity. The timeline highlights the necessary interaction between external actions – essentially government driven - and Summit Power actions in terms of key stage gate decisions. It is imperative that a there is a commitment to work to a deployment plan and timescale if private sector investment is to be attracted.

Section 1.0 Introduction

1.1 Scope of Work and Participants

This is the final report of the work undertaken and key findings of the Feasibility Study for the Summit Power Caledonia Clean Energy Project (CCEP or the "Project"). The overall study scope of work includes:

1.1.1 Work Package 1 (Industrial Research)

- Complete a Basis of Design (BOD) for CCEP
- Analyse and set the configuration of CCEP to meet the BOD
- Create the scope of supply and the division of responsibility among contractors
- Complete the (1) heat and material balance, and (2) emissions and discharge calculations for the selected configuration(s)
- Prepare a detailed plot plan, i.e., fit CCEP to its site, including its inter-connections to necessary infrastructure such as rail, road, water transport, electric power transmission, carbon dioxide pipeline, feedstock supply, etc.
- Prepare (1) an initial cost estimate for CCEP, including financing costs, sufficient to allow computation of a strike price for purposes of a Contract for Difference (CfD), and (2) a complete schedule for consenting, financing, construction, testing, commissioning, and commercial operation of CCEP
- Complete, adjust, and modify the foregoing as necessary or appropriate, based on the Feasibility Study, financing considerations, etc., as identified in Work Package 2

1.1.2 Work Package 2 (Feasibility Study Reporting)

- Complete draft feasibility report
- Complete final feasibility report

1.1.3 Work Package 3 (Site Control)

- Obtain option agreements and/or exclusivity agreement(s) to assure control of the proposed CCEP plant site for the up-to-eighteen (18) month duration of effort on Work Packages 1 and 2. This objective was amended, since not cost -effective, following the cancellation of the UK CCS Competition and anticipated lengthy delay in re-establishing a CCS policy.

The focus of this final report is to document the key findings from work undertaken in support of Work Packages 1 and 2. Work Package 3 was suspended pending an updated policy and development timeline. Site related agreements will be advanced as necessary during post feasibility work.

In more general terms, this study aims to provide a thorough examination of all issues and assessment of probability of business success in order to:

- Outline and narrow business alternatives and suggest new opportunities
- Identify how to enhance the probability of success by addressing and mitigating factors early on that could affect the Project
- Provide quality information for decision making
- Provide documentation that the business case was thoroughly investigated
- Promote alignment of stakeholders in support of the Project
- Assist in securing funding from investors, lending institutions and other monetary sources for the next stage of Project development

The Feasibility Study has been undertaken by Summit personnel supported by a wide range of advisors and technology providers including:

- Arup
- Cansolv
- CapSol AS
- CH2M HILL Engineers
- CMS Cameron McKenna LLP
- Energy & Chemicals Consulting, LLC
- Forth Ports Limited
- GE Power
- Hargreaves
- Industria Mundum AG
- Mott MacDonald
- NET Power
- Pale Blue Dot / Costain
- Scottish Carbon Capture & Storage (SCCS)/University of Edinburgh
- Siemens Energy
- SNC Lavalin
- Three major gasification technology designers and suppliers
- University of Strathclyde

1.2 Dissemination of Feasibility Study Work

Key findings of the Feasibility Study will be disseminated publicly unless confidential in nature following completion of the work and as agreed with the study sponsors. Dissemination activities are expected to take place mainly through 2018.

1.3 Route-Map of Scenarios

This Feasibility Study includes analysis of various full chain power generation, CO_2 capture, transportation and storage configurations.

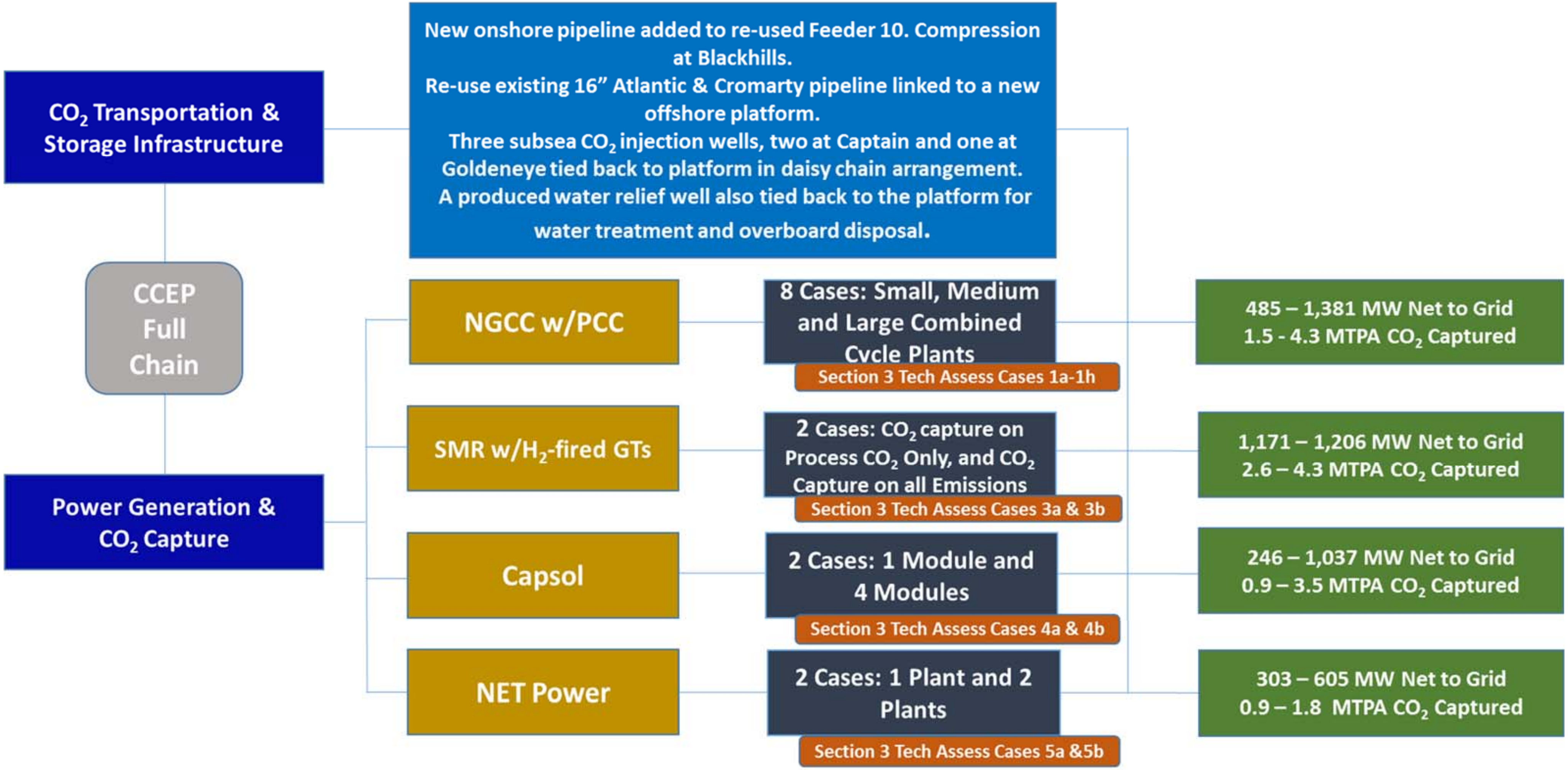
Fourteen economic scenarios are presented, built on the different technical configurations of power generation, CO_2 capture, transportation and storage and results in a comprehensive and complex set of combinations based on the different technical configurations described in Technical Assessment (Section 3).

Eight 'base' economic scenarios are presented for full-chain solutions with a Natural Gas-fired Combined Cycle (NGCC) Plant with post-combustion CO_2 capture (PCC). In addition, six 'comparative' economic scenarios are presented for full-chain solutions with alternative technologies: 1) Two sizes of Steam Methane Reforming (SMR) with CO_2 capture to produce a high-hydrogen stream for combustion in a combined cycle power plant and/or use in heat and transport applications, 2) Two sizes of CapSol's StarGate250 natural gas-fired technology with its "End-of-Pipe" PCC technology, and 3) Two sizes of NET Power's Allam Cycle.

An additional scenario (originally numbered 2) was initially scoped for a Combined Heat & Power configuration. However, this was not further developed due an initial assessment that indicated insufficient and unpredictable heat demand in the local area.

The Route Map of Scenarios and Section References (**Figure 1**) below illustrates the basis for each economic scenario tested and reported on in this Feasibility Study as an introduction.

Figure 1 - Route Map of Scenarios and Section Referencing



1.4 Follow on to the Feasibility Study

The current feasibility phase of work was funded through the Scottish Government and UK DECC (now BEIS) grant of £4.23 million with the balance of the required matching contributions (c. £1.1 million) from Summit Power Group and key contractors and other participants in the form of Project development funds (and in-kind contributions).

Like other power projects in the UK, CCEP can be financed on the strength of an appropriate Contract for Difference (CfD), which will also require Power Purchase Agreements (PPAs) or other means to deliver power to the grid. In recent years, energy project development investment was, in simple terms, attracted - pre CfD award - based on an assessment of:

1. Risk/return profile of project delivery – FEED, construction and operations;
2. The probability of being awarded a CfD; and
3. The risk of counter party default.

Following many changes since 2015, discussed though this report, the ability of investors to assess the probability of a successful CfD award has significantly reduced. Importantly, the ability of investors to understand timescales has also significantly reduced.

This places the award of a CfD (or equivalent) at the forefront of any investment decision in project development, particularly given that pre-FID project investment may reach £50M for a large low-carbon energy project in the UK.

Summit consider it essential to ongoing development investment that early and firm commitment is made by government in the form of a binding CfD or similar arrangement. Without this Summit consider unlikely that investment will flow into CCS project development, as would be the case in any other sector.

Summit envisions the Project now moving from feasibility to Pre-FEED, where the various Project locations and configurations can be narrowed, focused, and studied, leading to a decision gate for Project investment. This Pre-FEED scope is detailed in Section 10 and is structured to provide a basis for timely decision making, and to maintain Project development momentum with a seamless transition from feasibility to the next phase.

As indicated in the Interim Report, the investment case for post feasibility development is dependent on several factors:

- Viable technical and economic options being confirmed by this study. We believe the results of this Feasibility Study confirm the viability of the technical and economic options.
- Firm and well-defined government policy and fiscal support over the period of Project development and delivery. Government has made significant steps in progressing policy and fiscal support. Certainly, there is more work to be done, but the progress to date points to a path toward continued development and delivery of the Project.
- Acceptability of identified technical and commercial risks for the proposed Project. Summit wishes to continue positive steps with government to analyse those risks, and find a way to mitigate and minimise those risks for all stakeholders.
- Acceptability of commercial risks for next development stage of the Project. We are confident that the information contained in this Final Report will confirm and justify a basis

for funding of the Pre-FEED stage of the Project. A phased and limited Pre-FEED stage is a way to minimise commercial risk for all parties whilst maintaining momentum.

- Building confidence with and confirming the interest of Project investors. The results of the Feasibility Study, and the conclusions and recommendations of the Final Report confirm that the Project is viable and feasible. Summit believes this will build confidence and confirm interest on the part of current and potential Project investors.

Subject to this, the expected Phases of further development are outlined below;

- Pre-FEED: The objective of the Pre-FEED is to advance detailed analysis of a short list of options to reach the required level of definition to advance a FEED study. At the end of Pre-FEED, a single technical configuration would be selected by the Project participants to proceed to a FEED Study (if necessary, and as discussed below), or directly to a design and build contracting and financing phase if beneficial. The Pre-FEED would be conducted in phases in order to stage and control the work as a UK CCS deployment plan develops, and allow off-ramp milestones in case the overall goals and objectives may not be achieved. At the end of each phase key metrics for performance, cost, risk and the overall probability of success will be assessed with Project sponsors to determine if it is prudent to proceed to the next phase. A description of the Phases and workscope is included in Section 10.

- FEED or Contracting phase, leading to FID: Raise the necessary financing for CCEP's FEED Study (if required) and related activities necessary to satisfy the CfD conditions and enable the Project to reach FID. This phase is expected to last approximately 2-3 years, including Permit and Consenting processes.

FID to Commercial Operation: A final investment decision would be dependent on successful completion of the FEED Study, permitting process, other investment criteria, and any conditions of the CfD. Finalisation of Project long-tenor debt and raising additional equity required to complete CCEP's financial structure would proceed in parallel.

It is desirable to immediately move to a Pre-FEED phase, based on a short-list of configurations. Timing in relation to the end of the Feasibility Study is important in order to minimize the time gap between Feasibility and Pre-FEED as much as possible. This is to maintain continuity on the Project, with no significant breaks in the time schedule and the risks inherent in laying off and then trying to rehire personnel and contractors.

Section 2.0 Project Description

The following preliminary Project Description has been produced to inform the Feasibility Study. It provides a summary of the current known design, construction, and operational aspects of the Project, including those relevant to environmental matters.

It should be noted that the Project design is at a relatively early stage and as such is subject to change. Site boundaries are for illustration only and do not form a proposed planning boundary. It should also be noted that this Project Description does not differentiate with respect to the commercial ownership boundaries of the infrastructure which is not set at this stage. This is to allow Summit to understand all aspects of the proposed infrastructure in the context of the feasibility report.

The Project Description is not intended to be exhaustive for every configuration option and potential combination, aiming to provide a high level non-technical explanation. It should be noted that the Technical Assessment Sections 3 & 4 also include elements of the Project Description for completeness and there is some necessary duplication between sections.

2.1 Overview

The proposed Caledonia Clean Energy Project (CCEP or the Project) could export up to 1,381 MW[12] of low-carbon electrical power to the electrical grid. The exact export capacity will be determined in part by the Feasibility Study, the selected configuration option, and subsequent design and commercial optimisation during pre-FEED.

The base case plant would be Natural Gas-fired Combined Cycle (NGCC) power generation technology, integrated with an amine-based post-combustion CO_2 capture (PCC) technology which captures circa 90% of the CO_2 being emitted from the combustion of natural gas. For this Feasibility Study, Summit has also evaluated several alternative power generation technologies and configurations, namely:

1. A combined heat and power (CHP) power generation plant, with extraction of hot water for local industrial, commercial, and/or residential heating (initial assessment only);
2. A hydrogen-fired power generation plant, which would use steam methane reforming (SMR) technology to convert natural gas to hydrogen (H_2), capture the CO_2 produced from that chemical process, and use the H_2 as the fuel for a modified combined cycle power plant, and with the potential for a slip stream of H_2 to be used for industrial or transportation use;
3. The CapSol StarGate250 natural gas-fired power generation and hot potassium carbonate-based CO_2 capture technology; and
4. The NET Power technology, based on the combustion of natural gas and oxygen in a modified gas turbine to produce a high CO_2 concentration stream (no separate CO_2 "capture" plant is required).

[12] Fourteen configuration options, which would have export capacities to 1,381 MW.

As part of Summit's Interim Report on the Feasibility of the Project, a considerable amount of work was completed on coal feedstock Integrated Gasification Combined Cycle (IGCC) configurations. The analysis indicated that the feasibility of developing an IGCC in the UK would be very challenging and have a low likelihood of delivery. The primary factors included a low investment return, the challenges associated with developing and consenting a new coal fed facility, and an unfavourable view of the Project by key stakeholders. For these reasons Summit ceased any further development of the IGCC case, and proceeded with feasibility analysis of the NGCC/PCC, the SMR combined cycle and the CapSol and NET Power configurations.

Similarly, one other configuration that Summit analysed was a Combined Heat and Power case (CHP). This case was deemed challenging in terms of feasibility. Lack of a firm steam host, Project economics, and other factors influenced the decision to cease further activities developing this configuration.

In all configurations, captured CO_2 will be transported via pipeline to Aberdeenshire and then compressed for transportation offshore via subsea pipeline for injection and geological storage deep underground, beneath the North Sea.

The main elements of the Project are described in this Project Description for the base case NGCC/PCC and include:

- The NGCC/PCC Power Plant
  - Power Generation, and
  - Post-combustion CO_2 capture, conditioning, and compression
- Project Infrastructure
  - CO_2 Transportation,
  - CO_2 Storage,
  - Water Processing,
  - Electricity Transmission Infrastructure, and
  - Natural Gas Connection, Transportation, and Supply.

Figure 2 - The Caledonia Clean Energy Project Overview