Commercializing Carbon Capture

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A Business Perspective on the Greenhouse Gas Problem

- The size of the climate problem is so large that it may represent the greatest business opportunity ever – for those who create and deliver solutions.

- No solution will begin or succeed unless someone pays for the development work, investment and operation of the process. Realistic payment structures are essential. **Wishful thinking and words are not enough.**

- Pure carbon capture lacks disposal pipelines, licensed disposal sites, law around long term liability and a realistic carbon price. It is therefore impossible to build a business around this in Europe.

Politicians cannot afford to be brave. They need a technology to be proven at scale before any serious backing can be given. Equally the more expensive a project is, the harder it is for them to support. This is why virtually all large scale carbon capture projects have been delayed or cancelled.

Carbon capture and utilization (CCU) solves the political dimension of carbon capture because it means that practical demonstration of carbon capture can happen before large scale political support is required.

- Carbon capture can happen now as CCU
- It can start at relatively small scale with low capital cost.
- Delivers workable real world solutions
- Does not require government to build new payment structures.
- Product sales support the process.
- Commercial reality drives rapid improvement
- Many lessons learned from CCU will be applied to direct carbon capture.

CCU uses a low risk start that can be scaled up later when proven. This minimize risk.

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If you turn over enough rocks you will find something useful. We turned over a lot of rocks in our pursuit of a viable set of carbon capture reactions that would be viable to build a business around.

Open Cycle Reaction

$$CaSO_4 \cdot 2H_2O + CO_2 + 2NH_3 + 2H_2O \rightarrow CaCO_3 + 3H_2O + (NH_4)_2SO_4$$

(Gypsum) (Carbon dioxide) (Ammonia) (Water) (Calcium carbonate) (Water) (Ammonium sulphate)

Reaction Advantages:

- Output markets measured in tens of millions of tons.
- Reaction happens at ambient temperatures.
- Current routes to make PCC are very energy intensive. Our reaction releases energy.
- Current processes to make ammonium sulphate except as a neutralization by-product are expensive.
-The reaction products and starting materials are straightforward to separate and conserve.
-Gypsum is a widely available and a common soft mineral of low value.
-The reaction works at all carbon dioxide concentrations we have tested including that in air. Most carbon capture processes become highly inefficient at low carbon dioxide concentrations. *Our does not.*
- Calcium carbonate or chalk is a very stable carbon sink that nature has used for millions of years for carbon dioxide. This will make carbon verification significantly easier and eliminates carbon disposal insurance issues.

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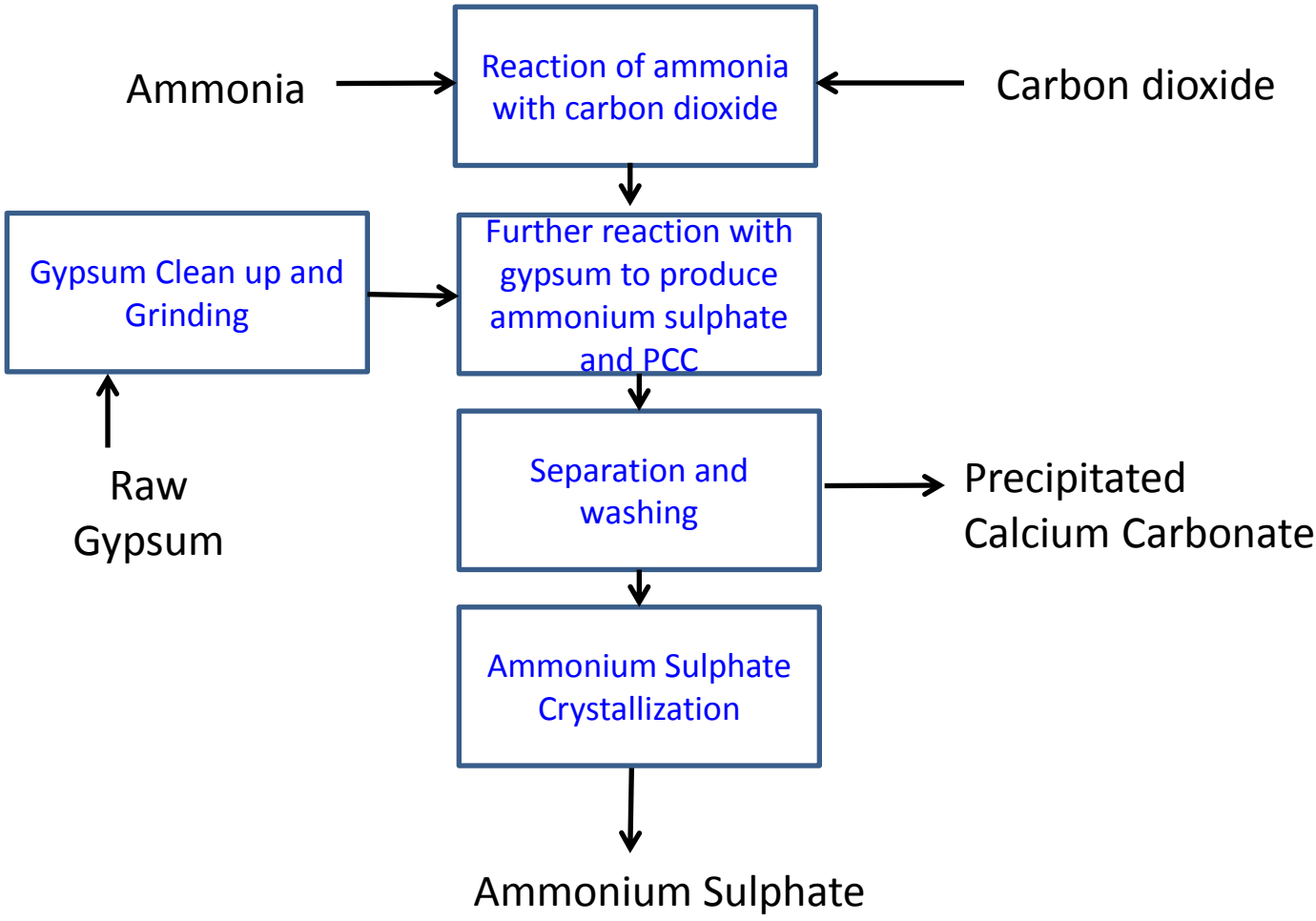
Open Cycle Process



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Market Analysis

Calcium Carbonate

- Global *market* for *Calcium Carbonate (excluding cement)* is 96 million tons per annum.
- Global PCC market is 16 million tonnes, GCC market is 80 million tonnes.
- Global calcium carbonate market value is expected to grow at 6.20% annually (2016-2020) driven by robust demand from paper and plastics end-use sectors.
- UK market for calcium carbonate products is 2 million tonnes.

Ammonium Sulphate

- Global market is over 26 million tons of ammonium sulphate per annum.
- Primarily used as a fertilizer to supply nitrogen and sulphur to crops.
- The world market for nitrogen fertilizers expressed as ammonium sulphate is over a billion tons per year.
- Sold as liquid solution, fine crystal, large crystal or blended with other fertilizers.

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Feed Stocks

Gypsum:

- Large deposits of gypsum found in many parts of the world. Very plentiful soft mineral.
- By-product of scrubbing flue gases at power plants.
- A listed waste that can not go to normal landfill. Large recycled gypsum streams are available.

Ammonia:

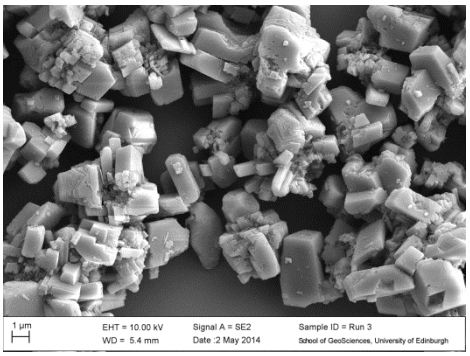
- Ammonia is produced via the Haber Bosch process from the nitrogen in the atmosphere.
- Underpins the majority of the world's nitrogen fertilizer production. Sold as either a gas or as a gas dissolved in a liquid.
- Production plants to produce ammonia spread across the world.

Carbon Dioxide:

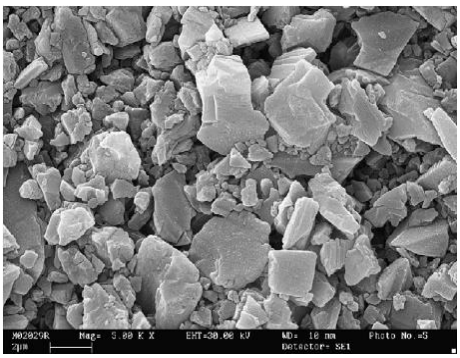
- Virtually any combustion emission stream potentially should work with our process.

PCC: Size and Structure Matters

PCC has very specific crystal structures as opposed to ground chalk or marble. PCC looks very different under the microscope. The crystal structure gives it very specific and useful properties.

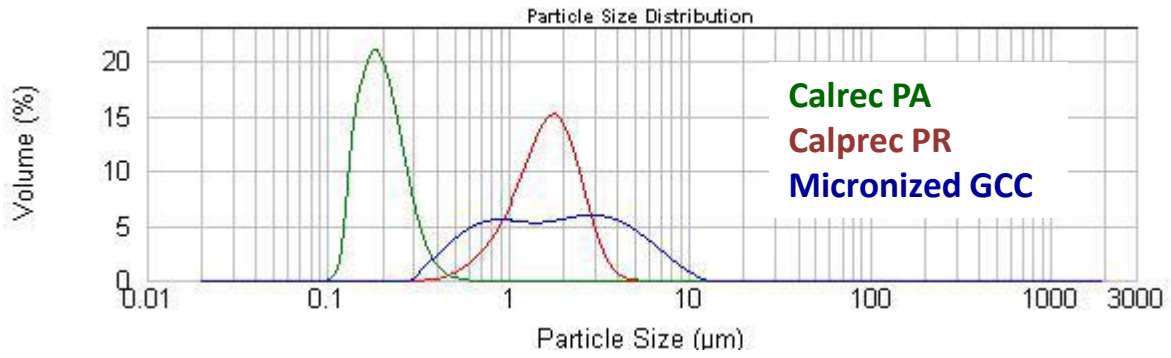


PCC produced from our process.



Ground calcium carbonate

Market suitable PCC has very tightly defined particle distribution. GCC has a much broader particle distribution. We are anticipating producing PCC with a particle distribution similar to Calprec PR. This type of PCC has the largest market application for filling paper. We have produced PCC with similar particle distributions using our process. Prices for this type of PCC vary from £250 per ton as a slurry to £450 per ton dry. Very fine particle PCCs such as Calprec PA command higher prices but their markets are smaller.



Existing Calcium Carbonate Products

PCC

+ Purity ~99%+
+ Brightness up to 99%
+ Low abrasivity
+ Tight particle distribution
+ nano to micron sized particles
+ Regular particle shape

GCC

+ Purity ~96%+
+ Brightness up to 95%
+ High abrasivity
+ looser particle distribution
+ Micron sized particles
+ Irregular particle shape

Current PCC and GCC production requires high purity chalk, limestone and marble sources. NONE EXIST IN THE UK.

Our process can use any gypsum source and can be modify to use any chalk source. The UK has plentiful supplies of both.

Current Status

- Research & Development largely complete
- Performing revision of Basis of Design (following cost driven design changes)
- FEED study started but now on hold until revised Basis of Design is completed.

Next Steps

- Restart FEED study.
- Demonstrate integrated process
- Detailed design and procurement
- Build Plant

Target is to have commercial scale plant operating by end of decade.

Transferable Learning

- Commercial operation of carbon capture at gas plant emission CO2 concentration (3%)
- Demonstration of carbon capture scrubbing down to 3000 ppm CO2. Standard power plant carbon capture designed to go to 13,500 ppm CO2. This slip ultimately defines the total carbon budget that can be burned. Going lower has large positive impacts.
- We could demonstrate carbon capture at a bio fuel fired power plant (BECCS) but carbon credits do not exist for these plants. This requires urgent government attention as all carbon plans require the use of BECCS.
- Use of an ammonia based capture sorbent under non chilled conditions .
- Our work on the reverse reaction is likely to lead to direct mineralization reactions to store CO2. This would completely avoid pipelines, storage sites and long term liability.

Teesside: The Perfect Place

-A well integrated deep water port with excellent road and rail connections.
- Redcar terminal has ship to managed pile loading and unloading systems.
- Ammonia is produced locally and distributed by local gas network.
- Local power generation with opportunity to capture emissions and earn carbon credits.
- Large local anhydrite (calcium sulphate) deposits as alternative feed stock instead of gypsum if production expands.
- An environment that seeks to help manufacturing succeed rather than move abroad.

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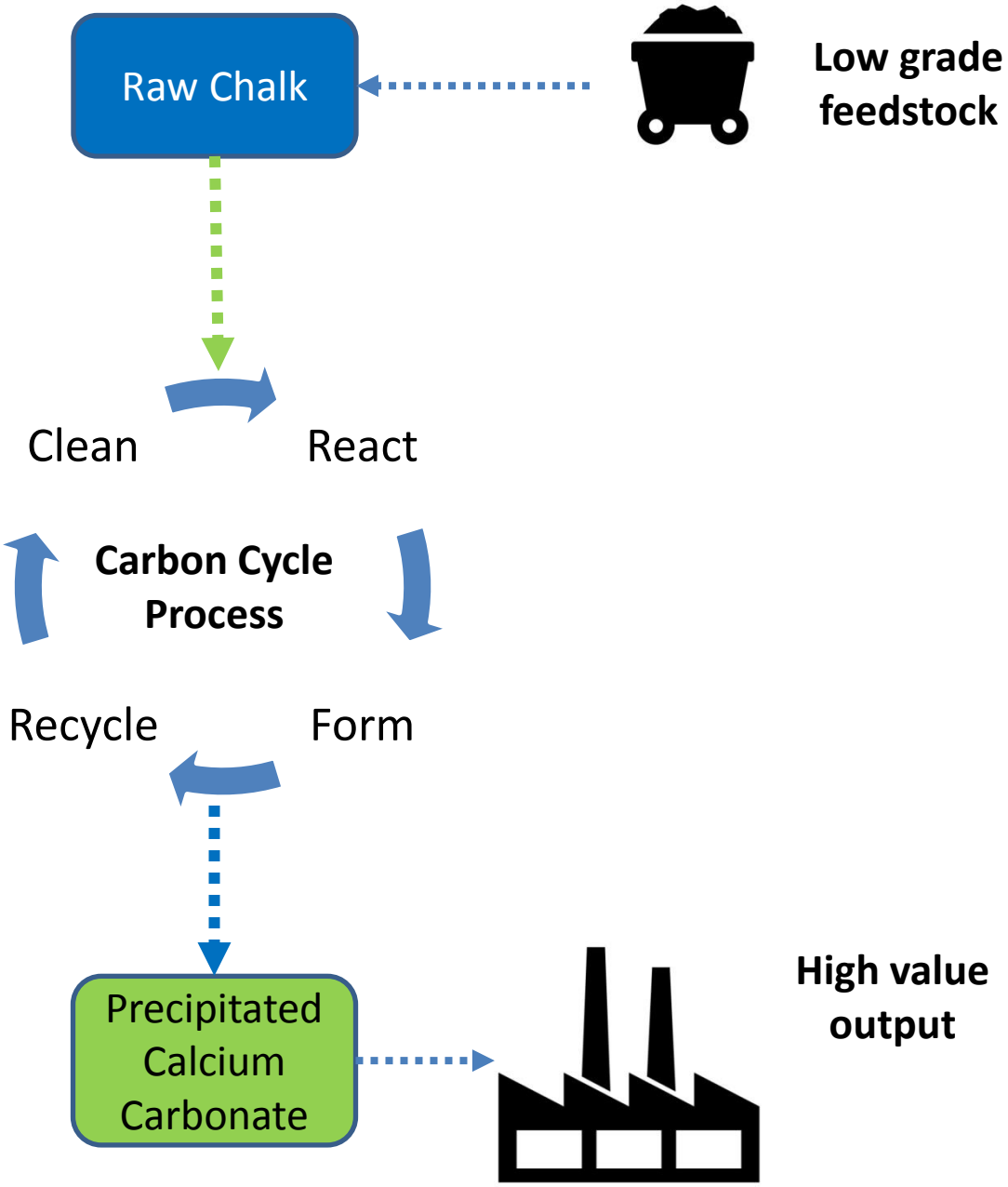
Chalk Process



Expected open cycle plant build cost is £15 to 20 million pounds.

- 40 tons of CO2 captured per day
- 191 tons ammonium sulphate
- 91 tons of PCC

Open Cycle is profitable but dependent on:

- Price of ammonia
- Price of ammonium sulphate
- Price of PCC

If we do not secure reasonable prices for ammonia and ammonium sulphate, we will operate the chalk cycle instead. This will only make PCC and will be highly profitable.

The Team and Advisors

- **David Sevier** – Director. David has 25 years' experience in chemical and water treatment technology. He is the inventor of the Carbon Cycle process. BSc. Chemistry

- **Ian Thaxter** – Director. Ian has extensive experience in general business management, project management, commercial negotiation, IT and logistics . HNC Mechanical and Aeronautical Engineering

- **Mike Frith** – Director. Mike has extensive experience in general business management, sales, project management and commercial negotiation. Owner and MD of a £1m+ turnover water treatment company. He is an Incorporated Engineer.

- **Stephen Armstrong** - a senior chemical process design engineer who has worked on many projects from initial concept through to construction and operation.

- **Jeffrey Price** – Jeff is a management consultant that provides strategic advisory services to clients concerning energy and environmental technologies, markets and business strategy. BS Engineering Physics, MBA.

- **Bill McAuley** - a senior chemical process engineer with decades of experience including designing and operating complex chemical process plants at a senior level.

An Arc of New Intellectual Property

- We have found a new simple method of purifying low grade gypsums to pigment grade gypsum. Multiple uses foreseen.
- Our reverse cycle reaction work is unique and will have multiple applications to a number of industries.
- Process specific detail discovered that holds key to open process found.

Ultra low energy carbon capture process granted as patent GB2513353

This process creates full cycle carbon capture with the exception of electricity to run the fans and pumps using power plant waste heat at 35 to 40^0 C. *Expected to be the lowest energy carbon capture option.* **Required frameworks must be exist before this can be commercialized.**

We seek to work with/continue to work with:

- Ammonia suppliers
- Ammonium sulphate purchasers
- Ammonium sulphate by-product producers
- Gypsum producers
- The British Government
- Teesside companies that have waste heat above 60^0 C.
- Teesside companies with waste carbon dioxide who seek to reduce their carbon footprint.
- Investors with vision and useful skills
- Users and agents for PCC and GCC

Our process creates a way forward for carbon capture to go forward and be commercialized as carbon capture and utilization this decade. The lessons learned will reduce future political and commercial risk to support carbon capture while creating jobs in a region of considerable need.

Our development work has been supported by:

- The British Government (DECC)
- The Canadian Province of Alberta (CCEMC)

Advised by Sir Edward Davey