“Mineralisation : How to trap CO_2 into useful rocks”

December 15th 2020, virtual workshop

Q&A session

Questions for Paula Carrey (PC), Carbon8 Systems

Q1: How does the purity of CO_2 impact upon the material produced?
PC: We have seen no impact on the product related to the purity of the CO_2.

Q2: Are the any compounds or contaminants that are critical to control/remove from the CO_2 stream prior to material production using your technology?
PC: We anticipate that high SO_x might impact on the process, but we have not found this as a problem so far.

Q3: What is the capture rate of the Carbon8 process ?
PC: This depends on the residue being treated – we are using approximately 50% of the CO_2 delivered to the process – and in the case of Cement residues can use up to 300 kg CO_2 per tonne of residue

Q4: What effect does controlling the exotherm have on rate of reaction?
PC: Controlling the exotherm has a positive effect on reaction because the solubility of CO_2 in water is greater at lower temperatures

Q5: Is your process direct carbonation or indirect carbonation?
PC: Direct, calcium phases in the residues are carbonated directly

Q6: Do you use any acid or salt solvents in your carbonation process?
PC: No

Q7: When CO_2 gets mineralised directly from flue gas, what happens to the impurities initially contained from the flue gas?
PC: We are stripping the CO_2 from the gas and the remaining gas passes back into the flue stack

Q8: What is the Business Model of Carbon8 ? Selling Equipment ? Selling licences & technology ? Operating plants turning waste into construction materials bases ?
PC: Carbon8 does not want to be operating plants so is selling licences and the technology – we build the plant, install and commission then charge a licence and support fee.

Q9: What is the overall cost per tonne of CO_2 sequestered ?
PC: Because we are saving the residue producer disposal costs we can SAVE up to €$_2$00 per tonne of CO_2 captured

Q10: How movable is the deployment? Can it be relocated to different plants in the vicinity if desired?
PC: The plant requires a connect to the flue stack if using flue gas directly but can operate on pure CO_2 with CO_2 from tank. Other infrastructure is also required such as a silo and fixing of product conveyor – all of which take a

couple of weeks to set up. So yes could be moved to different plants but would probably be easier to bring residue to the one site, need to consider the amount of residue available at a plant with the throughput of the system at the moment in the order of 1_2k tonnes per year

Q11: What are the typical operating conditions for a technology like the CO_2ntainer? (temperature, pressure). And how is this energy typically provided on site ?
PC: The energy required is simply that to drive the mixer and conveyors etc as the technology operates at ambient temperature and pressures

Q12: The key question should be the "product/end of waste" status of the final output : could you elaborate a bit ?
PC: Unless the residue is classed as a by-product, the product has to be approved through an end of waste procedure which varies across Europe. In the England, aggregate manufactured from APCr from EfWs has gained "End of Waste" approval from the English EA for use in bound applications.

Q13: When using the aggregates they are consumed. Does this mechanical action cause CO_2 release? What is the real "storage" time of such materials?
The CO_2 is permanently bound chemically as calcium carbonates which will only release the CO_2 if it is put in acid or heated to beyond 550ºC in the same way as Limestone is stable over geological timescales.

Q14: What about the sequence of operations for C8S Container after the 15 minutes carbonation process is over? How the down-time is managed? E.g.: more containers in parallel...
PC: The throughput of the containers is balanced again the production of residues at a site – if there is more residue then yes we can install more containers. After the main treatment process the material the product is screened and then needs to dry out for a day or two before use

Questions for Mieke Quaghebeur (MQ), VITO and Andy Van Cauwenberghe (AvC), ORBIX

Q15: Are there any physical or chemical requirements that must be met in order to use a material as building materials?
MQ: There are both environmental and technical criteria to which material used in building materials or the building materials themselves need to comply. Environmental criteria are in the Flemish region of Belgium based on leaching limits. Guidance values exist for the total content (chemical composition) of certain metals. There is no harmonized legislation on EU level when it comes to environmental properties. The technical criteria are based both on performance (compressive strength, water absorption,….) and composition (amount of cement used, type of aggregate used,….). For the technical criteria harmonized standards exist for certain type of construction materials (eg. concrete pavers).
AvC: For carbonated building blocks we obtained a certification in the Netherlands where we succeeded on fire tests, frost/defrost, second life, …

Q16: Which is the classical range of CO_2 concentration of the stream required to react in the ORBIX conversion process ?
MQ/AvC: Usually between 45 and 100%. At the moment we are doing tests for building blocks at a lower percentage and want to go to 25% into the near future.

Q17: The composition of the local steel slags of Ghent differed from what Orbix usually used, requiring the process to be somewhat adapted. Does this make it difficult to create a constant product? Or is this not a limitation in any way?
MQ/AvC: It is not difficult to produce a constant product. The process is able to deal with variations of the input material as long as the materials is generated by the same production process. You must realize, however, that the steels slags produced in Ghent are generated during the production of carbon steel. They are very rich in $Ca(OH)_2$ and contain a limited amount of Ca-silicates. The steels slags used by Orbix are generated during the production of stainless steel slags and are rich in Ca-silicates. These slags are produced in a different type of steel plant and both materials are therefore quite different.

Q18: Regarding the CO_2 requirement, how much CO_2 a typical unit will require per year ?
MQ/AvC: This depends on the size of the production unit and the type of the input material but if you make a material consisting of 100% carbinox you will need around 17.000 ton of CO_2 to produce 100.000 ton of construction product. Normal vibrating presses have a capacity of about 100.000 to 150.000 T depending on the dimensions of the building product.

Q19: I assume that the mineralisation process is carried out by using energy from fossil fuels. If so, how the CO_2 uptake is balanced with the CO_2 release from the mineralisation process itself ? How the CO_2 uptake compares to the amount of CO_2 emitted by the industry?
MQ/AVC: A detailed LCA study was done on the process and showed that the CO2 uptake during the process is more than the CO_2 emitted during the production. Even if you assume that all energy needed during mineralisation will come from fossil fuels.

Note from André Bardow, ETH Zürich: In our LCA study on CO_2 mineralisation , we assumed heat provision by natural gas and the current European electricity mix – which is still largely based on fossil fuels. In this case, indirect emissions from energy use contributed from about 0.4 $kgCO_2$-eq to almost 1.5 $kgCO_2$-eq per kg of CO_2 stored depending on the CO_2 mineralisation pathway, see: https://doi.org/10.1039/D0SE00190B

Q20: Where in Ghent can we see the Vito/Orbix pavement ?
MQ/AVC: You can find it in the Leeuwstraat (in front of the building of the Arteveldehogeschool)

Q21: Are the examples "demonstration-projects"? and does exist a real production plant already for building blocks ?
AVC: Orbix has a pilot plant with a high pressure and a vibrating press. Here we can make smaller production rate for several different types of products. We are in the last phase with several industrial producers where industrial tests are ongoing. Certification will start up soon and hopefully production can start end 2021/beginning 2022

Questions for Akifumi Takigawa (AT), Mitsubishi Corporation

Q22: Where the "gama-$_2$CaO.SiO$_2$" comes from ?
AT: Currently γC2S is produced from calcium hydroxide by-products emitted through the acetylene gas production process in Japan by Denka who holds the core IP. γC2S can be produced in foreign countries the same way where calcium hydroxide by-products (such as acetylene production sites) are available.

Q23: HOW MUCH MORE is the cost of the Carbon negative CONCRTETE compared to 'normal concrete blocks'

AT: The cost will depend on the size of the concrete and the amount of target CO_2 reduction volume. In Japan, a thin formwork panel which reduce 80% of the CO_2 compared to a normal concrete is produced at a 10% cost increase, and is commercially available already used in Japanese infrastructure. A larger thicker block or 100%> CO_2 reduction will obviously cost more.

Questions for André Bardow (AB), ETH Zürich

Q24: A great talk about thermodynamics - but whenever we mention Direct Air Capture, we ignore the Second Law of Thermodynamics - Are the politicians going to repeal the Second Law so that DAC can be performed at large scale and be economically viable?

AB: The second law does not prohibit direct air capture. I agree that more concentrated CO_2 sources are preferable economically and also from an environmental viewpoint. Such CO_2 sources will also be available in the future (e.g., cement, waste, biogas). For a longer discussion, see this article: https://doi.org/10.1039/D0EE01530J

Q25: Besides GWP which other categories were taken into consideration in the LCA studies?

AB: The question is important since CO_2 mineralisation does indeed lead to trade-offs in environmental impacts. To quantify this effect, we studied 18 environmental mid-points using the ReCiPe method for life cycle impact assessment. CO_2 mineralisation increases impacts related to energy use if the current energy mix is employed. Even assuming wind power, CO_2 mineralisation increased 6 out of 18 impacts due to mining such as metal depletion and freshwater consumption. Results would change for other feedstocks such as wastes.

Questions addressed in general

Q26: what about the end of waste status when using APCr for concrete or concrete blocks? is the question solved for all EU countries if not what are the favourable countries

PC: Most EU countries have some sort of process for approval of treated wastes as products, the materials must also meet the requirements of the construction products directive. *See also Q12*

Q27: Could you please comment regarding the presence of heavy metals on those residues ? I mean do you need pre-treatment before carbonation to remove heavy metals ?

PC: Carbonation is good for reducing the availability of some heavy metals – particularly lead, nickel, zinc, barium. Some of the metals which form oxyanions such as chromium, molybdenum and selenium have variable behaviours depending on their speciation. There are some companies that have been looking at "mining" APCr for example for its heavy metal content

Q28: Could someone comment on the status of commercial mineralisation of Mg-based feedstocks, which has only been discussed today from a LCA perspective ?

PC: Many Mg-based feedstocks are derived from natural resources such as ultra-basic or basic rocks olivines and serpentinite, etc. These materials need to be "activated" before they will react, both chemically and physically – the process has reached only pilot stage as far as I am aware.