

GROWING CONCERNS ABOUT BIOCHAR SAFETY AND CARBON MARKETS

August 21, 2023



Photo Credit: Unsplash

By: Anja Chalmin

The Geoengineering Map Update summarises the latest developments on the Geoengineering Monitor Map highlighting new trends for civil society and climate justice movements to follow in their efforts to oppose geoengineering.

Critical Updates

- Sales of carbon credits from biochar have increased twenty-fold between 2005 and 2021, and the biochar market is expected to continue to grow rapidly due to the carbon market. Many biochar producers therefore cite the sale of carbon credits as a turning point for their biochar business. At the same time, **new information about biochar is raising concerns about the safety of its use on agricultural land, especially in large quantities, as biochar may be more contaminated with carcinogenic, mutagenic, and persistent pollutants than previously thought.** In addition, it is reiterated that biochar is not comparable to 'terra preta' and is being mis-marketed as such.
- Geoengineering companies interested in commercialising carbon credits present the geoengineering projects they initiate as safe and long-term CO₂ storage options – even though there are no independent studies to back this claim. **Possible concerns and risks are being concealed, even in the face of numerous studies raising concerns.**

Biochar: Growing carbon markets and growing concerns about safety of use

Biochar is produced from biomass by pyrolysis – a conversion process in which biomass is heated in the absence of oxygen to produce a solid, char-like substance. This proposed approach to carbon dioxide removal (CDR) aims to store carbon in the form of biochar, mostly in agricultural soils, and requires very large amounts of biomass. The sale of biochar-based carbon credits

has increased twenty-fold from 2005 to 2021 and market studies predict that the biochar market will continue to grow rapidly each year, with the sale of carbon credits having a particularly strong impact. It is therefore not surprising that more and more biochar producers are viewing the sale of carbon credits as a game changer for their biochar business and a catalyst for making biochar production financially attractive. In contrast to this development, there are considerations as to whether the approval of the use of biochar on agricultural land should be fundamentally reconsidered. The European Expert Group for Technical Advice on Organic Production (EGTOP), a permanent group that advises the European institutions on agricultural issues, has evaluated new evidence on biochar contamination. According to EGTOP, these call into question the safety of biochar use, as contamination with carcinogenic, mutagenic, persistent and soil-damaging pollutants could be higher than previously thought[i]. EGTOP also highlights that biochar is falsely promoted as being comparable to the 'terra preta' known from Latin America. This is not true, as biochar is produced using a technological process that is not comparable to the natural humification process that leads to the formation of 'terra preta'. The recent EGTOP report on biochar also points out that the climate impact of biochar can be highly variable, making its climate benefits questionable. A review of 259 studies by the Czech Mendel University in Brno also raised concerns about the long-term safety of biochar use and that high doses can have negative effects on soil and soil life, water availability and soil erosion. Despite these growing concerns, the number of biochar producers is on the rise. Most biochar producers are based in Europe, Australia and New Zealand. Some biochar producers in the northern hemisphere are planning to produce biochar in Latin America, Africa and/or South Asia. Most biochar research projects are currently funded in Europe - with most projects in the UK, Scandinavia, Germany, and Austria. New developments include burying biochar underground to 'store' carbon, producing biochar from digestate and bringing previously unused land into production to meet the growing demand for biochar biomass.

Ongoing research presented

ITALY: ICHAR UNDERLINES THAT BIOCHAR USE IS IRREVERSIBLE, CALLS FOR LONG-TERM TRIALS

The Italian Biochar Association (ICHAR) is a collaboration between research institutions and the private sector that aims to promote biochar research, and the use of biochar in agriculture to sequester atmospheric CO₂ in the soil and improve soil fertility. However, ICHAR points out that the effects of biochar on soils are irreversible: Once applied, biochar is difficult, if not impossible, to remove from the soil. The use of biochar therefore needs to be carefully considered, for example regarding potential pollutants. ICHAR also notes that many of the biochar trials have only been running for one or two years. These short-term trials allow some of the effects of biochar to be understood, but do not provide a long-term picture. ICHAR therefore calls for long-term trials to be conducted and funded.

IMPACT OF BIOCHAR APPLICATION ON FOREST SOIL / 20-FOLD INCREASE IN EMISSIONS TRADING VOLUME

The state-owned Norwegian Institute for Bioeconomy Research (NIBIO) has already conducted numerous research projects on biochar. In 2023, NIBIO published the report "Biochar in forestry. Status in the Nordic-Baltic countries". The report looks at the use of biochar on forest land and, like ICHAR, points out that long-term studies of biochar use are lacking. Evidence to date on the use of biochar in forest ecosystems suggests that, "*changes in greenhouse gas emissions are biochar-, soil- and tree species-specific*" and that "*changes in CO₂ emissions are variable (negative, positive or negligible)*". NIBIO also cautions that colouring can affect the climate change potential of biochar, as the dark colour can reduce the surface albedo, or reflection of solar radiation. The report describes that the volume of biochar carbon credits traded on voluntary carbon markets has increased sharply since 2017, and is expected to grow even faster in the coming years. Between 2005 and 2021, the market volume has increased twenty-fold, from 12 million tonnes of CO₂ equivalent emissions[ii] to 239 million tonnes of CO₂ equivalent emissions. Prices per tonne of CO₂ captured have also multiplied, making the carbon market for biochar production increasingly attractive. But also NIBIO points out that: "*the impacts of large-scale application of biochar on the greenhouse gas balance of soils, or human health have not yet been explored*".

EU / SERBIA / UK: IMPROVEMENT OF SOIL CARBON MEASUREMENT AND EASIER CARBON OFFSETTING FOR FARMERS

The EU-funded AgriCapture project is coordinated by the geoinformatics company GILAB in Serbia and carried out with thirteen European research partners. The aim of the project is to improve the accuracy and reduce the cost of measuring soil carbon by combining satellite imagery, agricultural data, and soil samples. The results of the project are intended to make it

easier for farmers to monitor the carbon content of their soil and be rewarded for doing so. One of the project's six (one- to two-year) agricultural trials is being carried out in Lancashire in the UK is investigating carbon measurement in combination with the use of biochar.

UK: SHORT-TERM STUDIES OF SOIL CARBON RETENTION ARE NOT THE ANSWER TO THE QUESTION OF DURABILITY

The Biochar Demonstrator, a four-year research project led by the University of Nottingham and funded by the UK Research and Innovation Fund, aims to demonstrate and trial biochar on a larger scale. The project will produce 200 tonnes of biochar and spread it over 12 hectares of farmland, grassland and woodland in the UK Midlands and Wales. The researchers are studying how much carbon is returned to the atmosphere in the form of CO₂ and how the biochar interacts with fertilizer, soil health, plants, and microbes at different application rates. The project is also not designed to determine the extent to which biochar can store carbon in the long term.

The Bio-waste to Biochar (B to B) project is also publicly funded and led by the University of Nottingham. The project goal is to research the production of biochar from digestate and to build the UK's largest biochar plant by 2025.

UK: UNDERGROUND STORAGE OF BIOCHAR AS A NEW BUSINESS MODEL

The Reverse Coal Project is being implemented with public and private funding, was initiated by Lapwing Energy Ltd, and will be carried out on the ~2,500 hectare Lapwing Estate. The land has been drained for agricultural purposes in the past and will now be re-wetted and planted with short rotation willow. High temperature pyrolysis will be used to produce biochar, heat, and electricity from the willow. The biochar produced will be stored underground at an undisclosed location. Reverse Coal aims to commercialize the concept by 2030, marketing one million tonnes of 'stored' CO₂ and promising "*long-term, easily verifiable carbon sequestration*". It is not transparent how this amount of CO₂ is calculated, how much short rotation willow is to be grown and harvested, and whether and how the cultivation, harvesting, transport, chipping, drying, and storage of the pyrolysed willow material is taken into account in the calculation.

GERMANY: INVESTIGATING THE SYNERGY OF BIOCHAR AND ENHANCED WEATHERING

The Pyrogenic Carbon and Carbonating Minerals (PyMiCCS) project, coordinated by the Institute of Geology at the University of Hamburg, is investigating whether the combined application of biochar and enhanced rock weathering has positive synergistic effects on soil properties, crop yields and the environment. The project is also investigating how best to combine the two methods, for example, the appropriate rock/coal combinations and whether the mixture with rock powder should be made before or after pyrolysis. The project will run for three years and is funded by the German Federal Ministry of Education and Research (BMBF).

FINLAND/USA: TESTING OF NEW BIOCHAR APPLICATIONS

In 2023, Carbo Culture received € 2.3 million from the German Federal Agency for Disruptive Innovations (SPRIND) to develop new applications for biochar, such as adding it to concrete. Carbo Culture converts local waste biomass, such as walnut shells, into biochar, energy, and carbon credits. The company's pyrolysis technology (Carbolysis™) uses high temperature and pressure to convert biomass into biochar and syngas. Carbo Culture's first production plant was built in California in 2019. A new prototype production plant in Kerava, Finland, has been under construction since March 2023 and is expected to be operational in the third quarter of 2023. In 2024, Carbo Culture plans to start building a commercial pyrolysis plant in Finland, which is expected to be operational in 2025.

NORWAY: PUBLIC FUNDING FOR BIOCHAR TO REPLACE FOSSIL-CARBON IN METALLURGICAL INDUSTRY

In Norway, WAI Environmental Solutions has received NOK 47 million (~€ 4 million) in public funding to build a biochar plant at the Bergene Holm sawmill in Haslestad, which is scheduled to be operational in 2024. The plant is expected to convert 0.06 million tonnes of sawmill by-products and demolition wood into 0.009 million tonnes of biochar, 52 GWh of thermal energy

and 7 GWh of electricity per year. The biochar is intended to replace fossil-carbon as a reducing agent in the metallurgical industry.

Biochar carbon credits: selection of current and planned activities

SWITZERLAND / GHANA / INDONESIA: ITHACA INSTITUTE

The Ithaca Institute, based in Switzerland, was founded in 2009 and launched the European Biochar Certificate (EBC) in 2012. The Institute conducts research into the production and use of biochar and provides consultancy services for biochar and biochar-based carbon credit projects. It has conducted biochar trials at over 200 sites worldwide. The institute is currently developing biochar/carbon credit projects in Ghana and Indonesia, in partnership with chocolate manufacturer Barry Callebaut. *"The biochar being produced by farmers in Ithaca's trials has been awarded EBC certification".*

BIOCHAR NETWORKS IN AUSTRALIA AND NEW ZEALAND

In Australia and New Zealand, there are several associations which are active in promoting the production and use of biochar. The Biochar Network New Zealand (BNNZ) was launched in 2019. Its goal is to sequester 15 million tonnes of CO₂ equivalent emissions per year in New Zealand with biochar by 2030. In 2022, BNNZ has signed a Memorandum of Understanding with the Australia New Zealand Biochar Industry Group (ANZBIG) to jointly promote biochar in Australia and New Zealand. ANZBIG was launched in 2019 and focuses on biochar-related research, education, collaboration, and commercialisation activities. In June 2023, ANZBIG released its Australian Biochar Roadmap. According to ANZBIG, the actions proposed in the roadmap are designed to help grow the Australian biochar industry into a multi-billion-dollar industry by 2030 that is economically efficient and contributes to climate change mitigation in Australia. The roadmap calls for support measures to quickly maximise the emission reductions from biochar. According to ANZBIG, more than 50 million tonnes of Australian biomass residues are burned or landfilled each year. ANZBIG says this biomass should be used to produce biochar and for carbon sequestration. The Australia New Zealand Biochar Initiative Inc (ANZBI) is a network of farmers, scientists and other stakeholders and aims to provide a forum for exchange between researchers and practitioners in the field of biochar in Australia and New Zealand. ANZBI conducts biochar-related research, seminars, webinars and outreach events. The New Zealand Biochar Research Centre (NZBRC) was established in 2009 and is based at Massey University in Palmerston North, New Zealand. The NZBRC conducts research in the field of biochar. It focuses on soil science, pyrolysis technology, economics, and the use of biochar for greenhouse gas mitigation.

AUSTRALIA: RAINBOW BEE EATER PTY LTD SELLS CARBON CREDITS FROM PROPOSED BIOCHAR PROJECTS

Australian company Rainbow Bee Eater Pty Ltd (RBE) is a pyrolysis technology manufacturer founded in 2008 by Peter Burgess. RBE has developed the ECHO2 pyrolysis plant, which produces syngas (for heat and power) and biochar from organic waste. The first commercial ECHO2 module is operational since 2021 at the Holla Fresh project in Tantanoola, South Australia. By the end of 2023, six ECHO2 modules are expected to be operational at Katunga Fresh in Victoria. Since 2020, RBE has sold carbon credits to Microsoft (400 million tonnes) and Shopify, among others, and *"is the first Puro.earth carbon removal certified biochar producer outside Europe"*. Although RBE and Katunga Fresh's biochar project is not yet fully installed, the companies have already sold carbon credits for the project through the Puro.earth carbon marketplace in 2023.

MORE AUSTRALIAN BIOCHAR PRODUCERS INTERESTED IN SELLING CARBON CREDITS

Energy Farmers was founded in 2010 by Tom Vogan and Euan Beamont to develop pyrolysis technology and test the use of biochar in horticulture, agriculture and industry. The company produces biochar from a variety of waste streams and feedstocks including poultry waste, crop residues, municipal green waste, sawdust, wood shavings, macadamia shells, grain dust and African boxthorn. In addition to commercialising biochar products and technology, the company is also interested in generating carbon credits. Australian company Pyrocal Pty Ltd, which also develops biochar and pyrolysis technology, is also interested in an additional income stream based on carbon credits.

AUSTRALIA / PAPUA NEW GUINEA: UPROOTING 3,000 HECTARES OF SAVANNAH FOR BIOCHAR PRODUCTION

Australian Pacific Bio Fuels Holding Pty Ltd (PBFH) was incorporated in 2021. The company has acquired 3,000 hectares of savannah land in Papua New Guinea. From September 2023, PBFH aims to grow industrial hemp on this land to produce and export bioethanol, biodiesel and biochar. The project is also expected to generate CO₂ certificates, which are already on sale for € 90 each on the CO₂ marketplace Puro.earth. Puro.earth says that without the CO₂ certificates, the project will not be financially viable. American consultancy SACL is helping to finance the project, describing it as a “reinvestment in local communities”. It is difficult to see how local communities in Papua New Guinea will benefit if large areas of land are lost to intensive monoculture plantations. The project generates climate-relevant emissions through land conversion, tillage and other agricultural works, fertilisation, harvesting and transport. In addition, the natural vegetation of the savannah is destroyed and can no longer sequester carbon.

PHILIPPINES: BIOCHAR PRODUCTION & RESEARCH AT SAMBALI BEACH FARM

Sambali Beach Farm is a biochar producer and works closely with the Philippine Biochar Association (PBiA). The farm serves as a demonstration farm for PBiA on the use of biochar in agriculture and construction projects. Biochar is produced from agricultural waste. The farm promotes biochar “for trapping carbon and other greenhouse gases forever in the soil”.

USA: CHARM INDUSTRIAL AWARDED >US\$ 150 MILLION FOR UNVERIFIED UNDERGROUND INJECTION OF POTENTIALLY HIGHLY CONTAMINATED PYROLYSIS OIL

Charm Industrial uses a pyrolysis process to convert biomass into biochar and pyrolysis oil, and injects the oil into geological formations to ‘store’ carbon. In 2021, the company temporarily stated in the FAQs on its website that the injections were being carried out in the Permian Basin. Although the injections have been taking place since 2020, there is no publicly available information on the exact location and extent of the injections. There are also no studies on the environmental footprint of the whole process, including pyrolysis, the origin and handling of the biomass, and the handling of the pyrolysis oil, such as transport and injection into geological storage. Nor are there any studies on the long-term behaviour of the pyrolysis oil after injection into geological repositories and on contamination with pollutants that may result from the pyrolysis process. In June 2023, the San Francisco-based company raised US\$ 100 million in funding from General Catalyst, Lowercarbon, Exor Ventures, Kinnevik, Thrive Capital and Elad Gil. In May 2023, the company signed a US\$ 53 million purchase agreement with the Frontier carbon market. For this amount, Charm Industrial is expected to “store” 0.112 million tonnes of CO₂ underground in the form of pyrolysis oil on behalf of Frontier’s buyers between 2024 and 2030. In the same month, the company signed a contract with JPMorgan Chase for the “removal and storage” of ~0.029 million tonnes of CO₂ equivalent emission by 2030.

These payments are being made despite the lack of an independent assessment of the suitability of underground pyrolysis oil injection as a permanent carbon sink. There is also no transparency on Charm’s own greenhouse gas emissions, no comprehensive environmental impact assessment including a residue analysis of the oil. It cannot be ruled out that the pyrolysis oil, like biochar, is contaminated with PAHs and other carcinogenic, mutagenic and persistent pollutants, posing a long-term threat to groundwater quality, soil and soil life.

SPAIN / CAMBODIA / EGYPT / SOUTH AMERICA: CARBON CREDITS A ‘TOTAL GAME-CHANGER’ FOR BIOCHAR MARKET

Husk Ventures was funded in 2017 by Heloise Buckland and Carol Rius. The biochar producer is based in Barcelona, Spain, and produces biochar at a rice mill in Kampong Thom, Cambodia. In addition to biochar, Husk Ventures sells carbon credits through the Patch carbon market. What the company told Reuters in an interview about the impact of carbon credits on the biochar business is true of many other biochar companies: „Buckland at HUSK describes carbon credits as “a total game changer”. “We certified with the EBC (European Biochar Certificate) in 2019 and started selling the credits at \$ 30 a tonne. Within one year, we tripled that. We’ve now sold at \$ 200 a tonne and we are sold out until the last quarter of 2023. So, there’s a huge demand.” Husk Ventures has applied biochar to more than 2,600 hectares of land, aims to “put 1 Mt of carbon back into the soil by 2025”,

plans to scale its operations in Cambodia and expand into Egypt and South America.

EUROPE / USA: BLOOMBERG PHILANTHROPIES FUNDS URBAN BIOCHAR PROJECTS

After funding a biochar plant in Stockholm in 2017, Bloomberg Philanthropies announced funding for additional urban biochar projects in seven US and European cities, including Lincoln, Nebraska; Minneapolis, Minnesota; Darmstadt, Germany; Helsingborg, Sweden; Sandnes, Norway; Helsinki, Finland and Cincinnati, Ohio. The aim of the project is to produce biochar and 'store' carbon. These urban projects are not accompanied by environmental and health impact monitoring.

SWEDEN: THE EMPHASIS IS ON SHORT-TERM HIGH YIELDS – POSSIBLE LONG-TERM RISKS TO SOIL QUALITY ARE NOT CONSIDERED

EcoEra is a biochar producer based in Östra Tommarp, Sweden, founded in 2009 by Bengt-Erik Löfgren, Sven-Olof Bernhoff and David Andersson. In addition to biochar, the company produces heat, and has been offering carbon credits for sale since 2018. EcoEra's aims "to remove carbon dioxide from the atmosphere at an industrial capacity". Marketing takes place through the Puro.earth carbon market for € 535 per CO₂ Removal Certificate (CORC). Puro.earth states that "each CORC represents a volume of 1 (one) tonne of CO₂ Removal". EcoEra and Puro.earth paint a very positive picture of biochar. The scientific concerns about potential long-term soil damage caused by biochar, as outlined in the introduction to the chapter, are completely ignored.

GERMANY: BIOCHAR PRODUCER WITH A FOCUS ON CARBON CREDIT REVENUE

Novocarbo has commissioned its first two pyrolysis plants in Germany in 2018 and 2022, and has been selling CO₂ certificates since 2019. A third plant at a German site is expected to be completed in 2023. The company produces biochar but focuses on marketing CO₂ certificates.

GERMAN BIOCHAR-FOCUSED CARBON MARKET

German Carbonfuture GmbH was founded in 2020 by Andreas Hölzl, Hannes Junginger and Matthias Ansorge. The company sells carbon credits and finances carbon sequestration projects. Since its inception, Carbonfuture has raised more than eight million Euro in two rounds of funding. Since 2020, the company has been selling carbon credits to Swiss Re, Microsoft, and Klarna, among others. In October 2022, Carbonfuture signed a five-year contract with Indo-Danish MASH Makes for 0.05 million tonnes of CO₂ equivalent emissions.

DENMARK / INDIA: RISKS SWEEPED UNDER THE CARPET FOR QUICK CARBON CASH (ONE EXAMPLE OF MANY)

The Indo-Danish company MASH Makes is a spin-off from the Technical University of Denmark and was founded in 2015. The company is a producer of biochar from agricultural and agro-processing residues. In October 2022, MASH Makes signed a five-year offtake agreement with the German carbon market Carbonfuture with the aim of sequestering 0.05 million tonnes of CO₂ equivalent emissions. The carbon credits are to be generated by converting crop residues into biochar through pyrolysis instead of burning them on the fields. The MASH Makes project will be implemented in Maharashtra, India, the exact project area is not yet publicised. This project is also an example of the fact that many manufacturers who want to profit from the marketing of carbon credits remain silent about the potential risks of biochar. The company aims to sequester gigatonnes of carbon using biochar. This means using larger amounts of biochar and therefore even greater risks to soil quality and soil life. Each batch of biochar is different, depending on the feedstock and pyrolysis conditions. As a result, each batch will contain different levels of persistent pollutants. Are they tightly controlled through laboratory testing and based on the latest knowledge? Or does contaminated biochar end up on fields? This would have irreversible long-term effects.

FRANCE / CAMEROON / BRAZIL: RISKS SWEEPED UNDER THE CARPET FOR QUICK CARBON CASH (ANOTHER EXAMPLE)

French NetZero, founded in 2021 by five co-founders, aims to scale biochar production in the tropics, with a focus on tropical developing countries. The company is producing biochar from coffee processing residues at two production sites – in Nkongsamba, Cameroon since 2022 and in Rio Casca, Brazil since April 2023. Two additional biochar production sites are expected to be operational in Brazil in 2023. In November 2022, NetZero signed a multi-year carbon credit purchase agreement with the Boston Consulting Group (BCG). NetZero states: *“Our goal is to reach, by 2030, a removal capacity of 2 million tonnes of CO₂ per year, and to continue our expansion beyond.”* The farmers/populations in Cameroon and Brazil bear the risks associated with applying such large quantities of biochar. This project is another example of how potential risks associated with large quantities of biochar are ignored and not taken into account during project implementation.

AUSTRIA: CARBON CREDITS INCREASE BIOCHAR PRODUCTION TENFOLD

Austrian biochar producer Sonnenerde GmbH has been producing around 200 tonnes of biochar per year since 2012. According to the company, the biochar is produced from plant residues. Sonnenerde has now announced that it will increase its annual capacity tenfold to 2,000 tonnes by the beginning of 2024. This will be achieved by selling carbon credits to carbon markets, including Puro.earth and Carbonfuture. In order to be able to fulfil the contracts with the carbon markets, Sonnenerde is building a larger pyrolysis plant since autumn 2022. The plant is financed with carbon credits – these can be purchased even before the plant is operational. The entry on Puro.earth makes it clear that carbon markets are the driving force behind this development: *„Without CORC revenue we will not realistically make net profit. Without CORC revenue the biochar price would be so high that we would not be able to sell it in the volumes we need to pay back the investment.”* How the extra biochar produced will be used has not yet been made public.

AUSTRIA: 5 % OF THE WORLD'S ANNUAL BIOMASS TO BE TURNED INTO BIOCHAR AND BURIED.

Reverse Carbon Mining GmbH (RCM) was founded in Austria in 2022 by David Unterholzner, Jürgen Brandner and Bahar Salahi. The company aims to use pyrolysis to convert wood, agricultural and food waste into biochar, which will then be stored underground. To meet the 1.5°C target, RCM suggests that five per cent of the world's annually regrowing biomass should be converted into charcoal and stored. Suggested storage sites include local deposits, artificial peatlands, submerged sediments, open pit mines and deep mines. The company proposes to use a digital platform to document how much biochar has been buried. The project is expected to be financed by the sale of carbon credits. RCM is currently working with a pyrolysis pilot plant in Austria (Next Generation Elements GmbH, in Feldkirchen) and is seeking sponsors and partners to build more plants.

Further recent geoen지니어ing updates (selection)

GERMANY / BRAZIL: INPLANET GMBH (ENHANCED WEATHERING)

The German company InPlanet GmbH spreads finely crushed silicate rock from mines for enhanced weathering on agricultural land in south-eastern Brazil. InPlanet's core business is the sale of carbon credits, for example to the Carbon^x and Frontier carbon markets. According to InPlanet the *“carbon will be locked away for 1000+ years”* and there are *“no negative side effects to the environment”*. However, weathering processes can release pollutants such as heavy metals from mining products, which accumulate in agricultural soils. InPlanet recommends enhanced weathering for tropical regions with nutrient-poor soils. This contradicts evidence that both low and high temperatures limit weathering. Enhanced weathering poses risks to the environment and soil quality, but the potential damage is being swept under the carpet in the interests of selling carbon credits.

NORTH AMERICA / AUSTRALIA: ARCA (ENHANCED

WEATHERING)

Arca (formerly Carbin Minerals) is a Canadian company, a spin-off from geologists at the University of British Columbia (UBC) in Vancouver, founded by Bethany Ladd, Greg Dipple, and Peter Scheuermann. The company aims to accelerate and commercialise CO₂ mineralisation. Arca studies ultramafic rocks that are rich in magnesium and therefore react with CO₂ in a process called carbon mineralisation. This mineralisation is typically very slow and ultramafic rocks tends to be buried deep below the surface. However, ultramafic rock is a by-product of the mining of critical metals such as nickel and cobalt. As a result, Arca is looking to partner with mining companies to access the rock and plans to work with several mining companies in Australia and North America, including Vale, Poseidon Nickel, Blackstone Mineral and Talon Metals. Arca aims to accelerate the enhanced weathering process by crushing the ultramafic rock and using autonomous rovers to tumble the crushed material. Other pre-treatments to accelerate the CO₂ mineralisation process are also being investigated.

UK / USA: UNDO CARBON LTD. (ENHANCED WEATHERING)

The Scotland-based company UNDO Carbon Ltd. spreads finely crushed basalt rock on agricultural land for enhanced weathering and works with sites in the UK and USA. In March 2023, UNDO sold carbon credits to Carbon^x, a recently formed “*permanent carbon removal*” seller based in Paris, France. In April 2023, UNDO announced a contract with Microsoft to spread 25,000 t of crushed basalt rock on agricultural land in the UK.

USA: SIMONS FOUNDATIONS (SOLAR RADIATION MANAGEMENT)

The Department of Mathematics and Physical Sciences of the Simons Foundation has launched a call for proposals for a Solar Radiation Management programme. The US\$ 50 million programme aims to investigate and test materials for **Stratospheric Aerosol Injections** and **Cirrus Cloud Thinning** in the laboratory and to improve modelling approaches for SRM. Social science research and in situ field experiments involving aerosol release are excluded from the programme. The duration of the programme is expected to be five years with an annual budget of US\$ 10 million. Applications can be submitted by, for example, educational institutions, research centres and national laboratories.

USA: MAKE SUNSET (STRATOSPHERIC AEROSOL INJECTION)

Make Sunsets, Inc. was founded in October 2022 by Luke Iseman and Andrew Song and is based in Box Elder, South Dakota. The company aims to “*create reflective clouds in the stratosphere*” by releasing sulphur particles and claims that “*1 gram of our clouds offsets the warming that 1 ton of CO₂ emissions creates for a year.*” Balloons filled with helium and a small amount of SO₂ are supposed to rise into the stratosphere, burst and release the SO₂ particles. Make Sunsets aims to sell ‘cooling credits’ based on these flights. In April and May 2023, the company conducted further test flights in San Francisco Bay, Berkeley and Half Moon Bay and announced a new source of funding (Draper Associates, angel investors).

[i] The pyrolysis process can produce large amounts of organic pollutants, particularly PAHs, which are carcinogenic, mutagenic, persistent and toxic to soil life. PAH contamination in biochar may be higher than previously thought, and contamination with other pollutants such as highly toxic and persistent organic PCDD/PCDF has also become known. PAHs = Polycyclic aromatic hydrocarbons. PCDD/PCDF = Polychlorinated dibenzo-p-dioxins and dibenzofurans.

[ii] Carbon Dioxide Equivalent: takes into account the different global warming potentials of different GHGs