# Written evidence from SeaCURE, University of Exeter, Plymouth Marine Lab and Brunel University London

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This is a response to a request for evidence, on behalf of the SeaCURE consortium and academics working in the area. We offer evidence from the perspective of an early stage, but rapidly maturing, $CO_2$ Air Capture project, supplemented with a wider view of what government can do to deliver the commercial conditions that will allow UK focused NETs to thrive after development in an academic environment.

## 1. SeaCURE

SeaCURE has developed and demonstrated all the components of a marine-based Negative Emissions Technology (NET) with the potential to be applied at very large scales. The system makes use of the natural behaviour of the carbon cycle: the 'sucking' of $CO_2$ out of the atmosphere in response to the atmosphere-ocean difference in $CO_2$ concentration generated by rising atmospheric $CO_2$ concentrations. We massively accelerate this process by stripping the $CO_2$ out of the seawater, so that the $CO_2$ concentration difference between the air and seawater is enhanced, and the rate and amount of $CO_2$ removed from the atmosphere is dramatically increased. Importantly, the concentration of $CO_2$ in seawater is much higher than that in air. This means that by processing one cubic meter of seawater, then releasing that water back into the surface ocean, we can remove as much $CO_2$ as would be stripped from 150 cubic metres of air by standard direct air capture, delivering huge space and process efficiency benefits. Furthermore, opportunities exist to roll out this approach offshore, facilitating massive scaling without presenting the land-use challenges of other methods, which should improve public acceptance. While we are refining the technology, we are confident that this can already be undertaken using 'off the shelf' engineering components. Assuming anticipated funding from the Government's Net Zero Innovation Portfolio is forthcoming, we will begin building a demonstration site to remove $CO_2$ from the atmosphere at a rate of 100 tonnes of $CO_2$ per year in 2022/2023, with the expectation that subsequent plants will be able to operate at a scale that will help us to achieve global carbon emissions targets. It is important to state that the operation of NETs will be a hugely significant market in the coming decades and that the UK has an opportunity to generate a significant competitive advantage in this field. Negative carbon emissions could become a cornerstone of the UK economy and deliver massive job creation if supported and facilitated by government now. There is a particular opportunity for the UK in marine-based NETs, given its large marine space, world leading expertise in marine science and technology, and its proud maritime heritage.

## 2. What contribution could NETs (through DACCS, BECCS, and/or other NETs) make to achieving net zero by 2050?

2.1. We know with confidence that $CO_2$ *can* be removed from the atmosphere via seawater.

2.2. We know in theory that we could do it at the scales required to deliver 1.5 or 2°C above preindustrial if there was the necessary capital investment, regulatory and licencing framework, and a mature carbon market or alternative mechanism to fund that carbon removal.

2.3. While we do not see any major environmental risks, commercial investment will require a transparent and comprehensive assessment of environmental risks and benefits of $CO_2$ removal at this enormous scale via seawater, as well as the various mitigation measures needed to address these. This is a vital area for immediate public funding.

2.4. To illustrate the scale of what is possible, and the scale of the costs:

2.4.1. To stay below 2°C above preindustrial, a middle-of-the-road scenario requires global $CO_2$ emissions to be below zero (i.e. sucking more $CO_2$ out of the atmosphere than we are putting in to it) by around 14 thousand million tonnes of $CO_2$ per year. What does this mean? In addition to completely decarbonising or offsetting $CO_2$ emissions from every aspect of human activity on the planet, this would still require us to pull out of the atmosphere approximately as much $CO_2$ as the whole of humanity was emitting around 1970, or around 1/3rd of what we are emitting globally today.

2.4.2. Preliminary calculations tell us that systems like SeaCURE operating across the global ocean such that they processed around 1% of the surface ocean's water per year could in theory deliver these net negative $CO_2$ emissions and keep the planet below 2°C above preindustrial.

2.4.3. However, undertaking any activity at this scale would incur significant environmental and societal costs. The balance of cost vs. opportunity has not yet been fully appraised, it is however a key focus of our ongoing work.

2.4.4. To illustrate one aspect of these costs that we can quantify with some confidence with work done to-date; if we were to build these units today to deliver the end-of-century global requirement for negative $CO_2$ emissions identified above, with proven and understood technological components, the energy consumption alone to run these units, irrespective of transport and storage costs, would be around 10 times present-day global electricity consumption.

2.4.5. Including known technology that we have reasonable confidence could be mature in ~10 years' time, this energy consumption drops to around 4 times present-day global electricity consumption.

2.4.6. Further development can be expected to reduce this further, but not by orders of magnitude.

## 3. At what technological stage are current NETs, and what is the likely timeframe that will allow NETs to be operational at scale in the UK?

3.1. The SeaCURE system is an early-stage technology. We have to-date proven the concept through experimental and modelling work. If funding from the

Government's Net Zero Innovation Portfolio is forthcoming, we are confident that we will have constructed a demonstration plant capable of continuous operation by the end of 2024. This plant will operate at a rate of 100 tonnes of $CO_2$ removal per year and is intended to be a proof-of-concept before large-scale rollout.

3.2. A plant built conservatively for continuous operation today, from mature components, is projected to have operational costs in the region of £300 per tonne of $CO_2$ removed (not including $CO_2$ storage costs).

3.3. We have plotted a clear pathway to halving these costs as newer technology matures and when the plants are produced at scale. Routes have been identified which could reduce these costs further.

3.4. The timeframe for taking this system to operational use at scale in the UK is likely to be determined by progress on investment and wider political, regulatory and societal challenges rather than the timescales for technological maturity. These barriers are discussed below.

## 4. What are, and have been, the barriers to further development of NETs? How can such barriers be overcome?

4.1. A clear regulatory environment needs to be developed rapidly within which marine NETs can work economically. Due to the urgency of the problem, this needs to be done in parallel rather than subsequently to the work described below.

4.2. Government funding is likely to be required in several areas to ensure that marine NETs can operate at scale within the existing environmental regulatory framework:

4.2.1. Demonstration of the ability to robustly account for the removed carbon.

4.2.2. A comprehensive assessment of the environmental impact of these systems across the different locations in which they are likely to be rolled out.

4.2.3. Assessment of low cost (financially, energetically and environmentally) marine based $CO_2$ *storage*, separate from marine $CO_2$ *removal*.

4.2.4. Work on public perception into the large scale roll out of these systems, and a better understanding of how to address any potential public concerns.

4.3. Excess renewable energy production. Large scale operation of these systems requires that there is significant surplus renewable energy beyond that required to decarbonise the UK energy sector, including capacity for new electricity users arising from decarbonisation of other sectors. This is a logical consequence of the massive energetic costs of removing $CO_2$ from the atmosphere.

4.4. Once the full evidence is in place for the net environmental benefit of these systems, legislative barriers need to be removed to provide a simple or more facilitated process for required permits and licences, similar, for example, to that which is in place for large infrastructure projects.

4.5. A mature carbon market, or a publicly underwritten minimum negative carbon price which can cover the costs of NETs, will be required to give commercial investors confidence to fund the scale-up.

4.6. An ideal framework to stimulate the UK negative emissions market is likely to be a 'feed-in-tariff' like approach, as applied during the early days wind power generation, into which activities like SeaCURE can bid with certainty. The government would act as a "carbon bank", reselling the negative emissions credits to polluters at a price driven by the regulatory environment the government decides to create. Providers of NETs need to be insulated from carbon market uncertainties as they go through scale up, to make it easier to secure funding (if revenue is known, investors can focus attention only on costs and delivery risks). The wind example was highly successful, providing a market which encouraged investment and innovation, leading to very rapid reductions in cost. This model is also flexible, in that 'feed-in-tariff's' can be scaled up or down depending on the volume of unabated emissions the government decides to accept over time. Government can always ensure that it can dispose of the acquired NET credits by tightening carbon rules to drive up carbon credit prices and/or by reducing 'feed-in-tariff' allocations going forward

4.7. Commercial funding alone using the carbon market approach will not keep us below 1.5 or 2°C. Staying below these levels of warming requires us to address our historical $CO_2$ emissions by going well below net-zero. This cannot be funded through companies paying to offset ongoing carbon emissions but must, almost certainly, be delivered as a public good to address historic emissions.

4.8. At very large scales, international cooperation will likely need to be reached about governance of all forms of NET systems.

## 5. What, if any, are the links and co-benefits to other technological innovations, such as sustainable aviation fuel or sustainability in the energy sector?

5.1. There are a lot of synergies between SeaCURE's marine-based NET and green hydrogen. In the future it is likely that the two systems could be combined to reduce the cost of both.

5.2. The SeaCURE process, and other similar approaches, will consume large amounts of electricity. Once the capital costs of plants decreases it may well make sense to run these systems to utilise, and therefore buffer, the excess production associated with a high-renewable-mix energy sector. Such an approach creates a commercial incentive to oversizing the build out of intermittent renewable energy production to meet the UK's core energy requirements with minimal reliance on expensive energy storage.

## 6. What are the trade-offs between availability of land and availability of sustainable biomass to make NETs a viable option in and beyond the UK?

6.1. SeaCURE and marine NETs more widely offer a significant opportunity here. Plants produced at scale will operate most efficiently offshore, with little or no impact on land availability. This is particularly important for the UK as a maritime nation and SeaCURE, along with other marine-based NETs, represent a significant opportunity for the UK to become a leader in this burgeoning sector. Opportunities exist here for the large marine spaces surrounding British Overseas Territories, as well as the repurposing of historic oil and gas fields.

## 7. What are the options for the storage of captured carbon, whether onshore or offshore?

7.1. The default option for storage is in geological reservoirs. A particular opportunity exists for SeaCURE here to repurpose existing oil and gas infrastructure, allowing us to extract the $CO_2$ at the site of storage.

7.2. Opportunities exist to store $CO_2$ in the deep ocean, where it can either be dissolved into deep ocean water that will not return to the surface for hundreds of years, or stored on the seabed stably in liquid form for millennia. Strong theoretical arguments can be made for both approaches, though in the past the use of the deep sea for disposing of other waste products (radioactive waste) has met with public opposition. Significant activities would be required to generate the evidence to build a case to do either at scale.

## 8. What other drawbacks for the environment and society would need to be overcome to make NETs operational?

8.1. For large scale rollout, rigorous marine spatial planning would be needed to minimise any potential impacts on other marine users. This requires work to be done quickly on the various potential risks and co-benefits of such technologies. In the early phase of scale up, it is likely that plants will be located to deliver co-benefits, for example to mitigate the impacts of ocean acidification on particularly sensitive ecosystems of industries, but at the scale required to deliver the necessary global negative emissions, society will have to back the approach almost exclusively on its $CO_2$ removal merits.

8.2. At present, existing NET has not presented any significant adverse publicity. While further work is required in this area, it appears readily accepted that NETs are an essential component in achieving global emissions targets.

## 9. Given the proposed role of NETs in climate change modelling, is there a danger of over-reliance on these technologies in net zero strategies?

9.1. Yes. If the desire is the keep temperatures below 2°C above preindustrial, NETs are our only realistic option to do what is necessary and take our global emissions well below net zero. However, utilising NETs to decarbonise industries that could, however unpalatably, be decarbonised, is likely to be a suboptimal use of NETs and is far less likely to attract public support.

9.2. Large scale early expansion of energy intensive NETs drawing renewable energy from the grid, or competing for renewable energy infrastructure, could slow down the decarbonisation of our energy sector if renewable energy role out is too slow.

## 10. How should the UK Government support the further development of NETsMassive renewable power rollout that goes beyond meeting present-day energy requirements.

10.1. Supporting the technical development of high-volume $CO_2$ storage and the reduction of regulatory barriers in achieving this. International cooperation may be beneficial here, but it is important not to simply dump the issue elsewhere and to ensure that all solutions are fully environmentally compliant and properly governed.

10.2. Fast-track planning and environmental consents once robust assessment of environmental impacts has been carried out.

10.3. Tax incentives, such as no VAT on negative carbon emissions.

10.4. Commitment to underwrite a minimum negative carbon price to make NETs viable before carbon taxes are increased to the required level.

10.5. Strategic development of the UK's Emissions Trading Scheme to incentivise early investment in NETs, as well as to facilitate international sales of carbon offsets.

10.6. Commitment to purchase negative carbon emissions as a public good, signalling the UK's commitment to go below net-zero, as is almost certainly required to limit warming to less than 2°C above preindustrial.

## 11. What policy changes, if any, are needed to ensure the UK gains a competitive advantage and remains at the cutting edge of this sector?

11.1. All the suggested strategies noted in Section 10.

11.2. Once the required environmental impact work has been funded and completed, regulatory barriers to marine NET deployment needs to be removed with licencing easily permitted, or moved under central government control as is the case for large infrastructure projects.

11.3. Feed-in-tariff like government purchase of negative carbon emissions at a guaranteed price (see section 4).

11.4. Commitment to public purchase of negative carbon emissions to begin to address historic carbon emissions would kickstart this sector in the UK, leading to a competitive advantage and make the UK and UK industries the international destination for purchase of negative carbon emissions. This represents a huge economic and societal opportunity to for the UK.

11.5. Amendment to the Climate Change Act to include NETs as contributing to the UK's Net Zero targets.

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