Sustainable materials – with both eyes open

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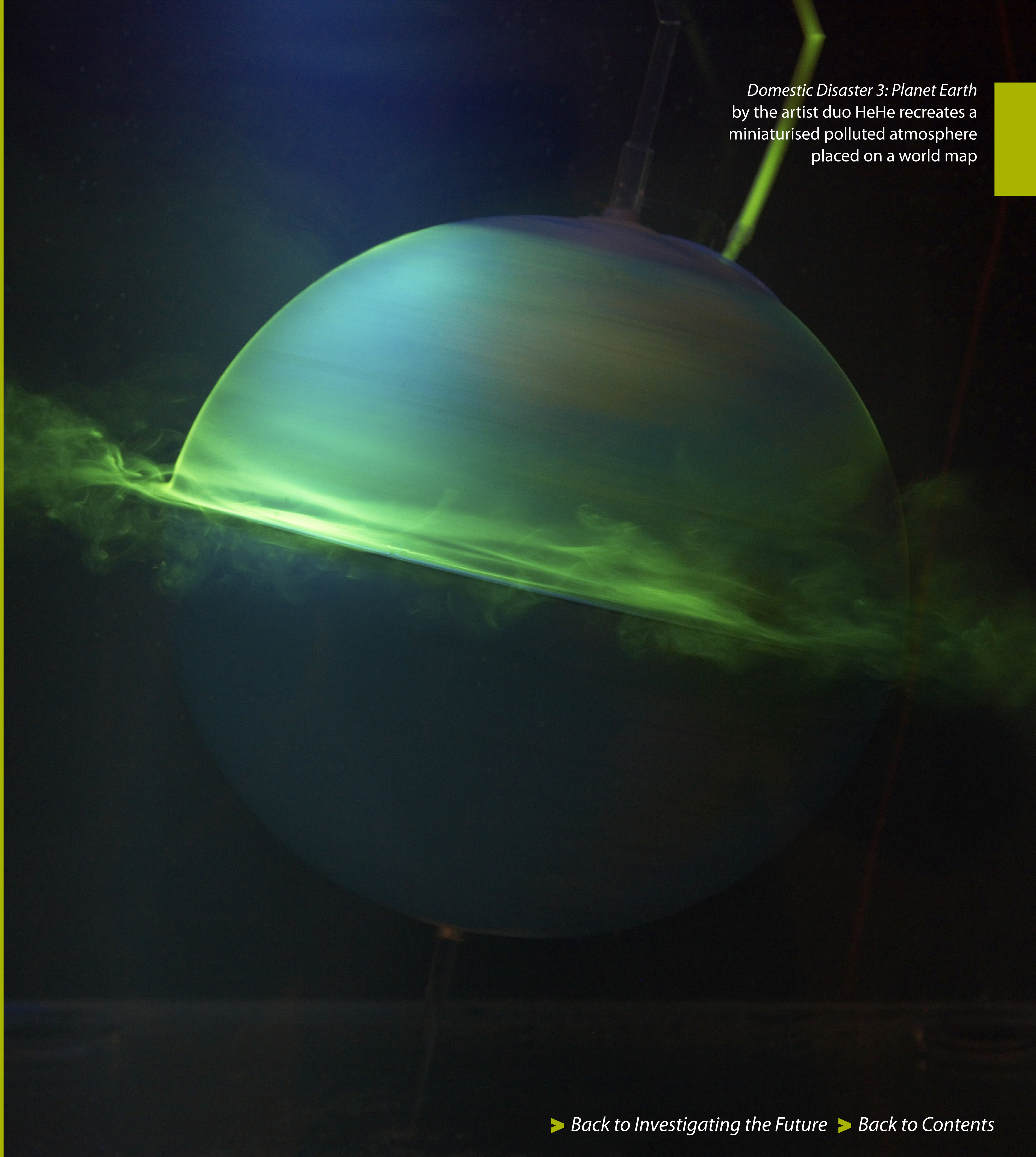

Domestic Disaster 3: Planet Earth by the artist duo HeHe recreates a miniaturised polluted atmosphere placed on a world map

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Dr Julian Allwood is a University Reader in the Department of Engineering, and leader of the Low Carbon Materials Processing Group. He is co-author of *Sustainable Materials – With Both Eyes Open* (2011). Interview by Wayne Visser.

The Intergovernmental Panel on Climate Change (IPCC) estimates that global greenhouse gas reductions of 50–85 per cent will be needed by 2050 to avoid dangerous climate change, representing a radical shift away from today's fossil-fuel-derived economy.[1] This begs the question: is such a reduction achievable, and if so, how? This is one of the key challenges tackled through the research of Dr Julian Allwood and his Low Carbon Materials Processing Group (LCMPG) at the University of Cambridge.

Allwood believes that we need to face the facts and find scalable solutions, rather than token gestures that make very little impact. In the opening chapter of his new book, *Sustainable Materials*, Allwood cites plastic grocery bags in the UK as a case in point. He notes that plastic accounts for about 1 per cent of the UK's CO_2 emissions, and plastic carrier bags make up 1 per cent of plastic use. Hence, even if all plastic bags were scrapped – and assuming their substitute were carbon neutral, which is unlikely – we would only be addressing 0.01 per cent of the UK's carbon footprint.

By contrast, says Allwood, "our aim is to look for solutions, and our number-one guiding principle is about scale – we want to make sure that we identify options for change that are big enough to make a big difference." Allwood's research team starts by quantifying which economic activities generate the most emissions. It turns out that 64 per cent of global CO_2 emissions are energy- or process-related (the rest are from deforestation, agriculture or decay); and 35 per cent of these emissions are from industry, 31 per cent from buildings and 27 per cent from transport.

In terms of buildings and transport, Allwood believes that there are still significant gains to be made from improved designs and technologies – perhaps as much as 75 per cent in energy savings. This is especially true for 'passive systems' which provide more final services for each unit of useful energy. He concludes that technical solutions for energy-efficient cars and houses are known, and their implementation depends on political will and public motivation. The same is not true, however, for industrial emissions, where many systems are already highly optimised, and where demand for materials is anticipated to double in the next 40 years.

[1] Keeping the concentration of CO_2 equivalents in the atmosphere between 445–490 parts per million with a corresponding average global temperature increase of between 2.0°C and 2.4°C

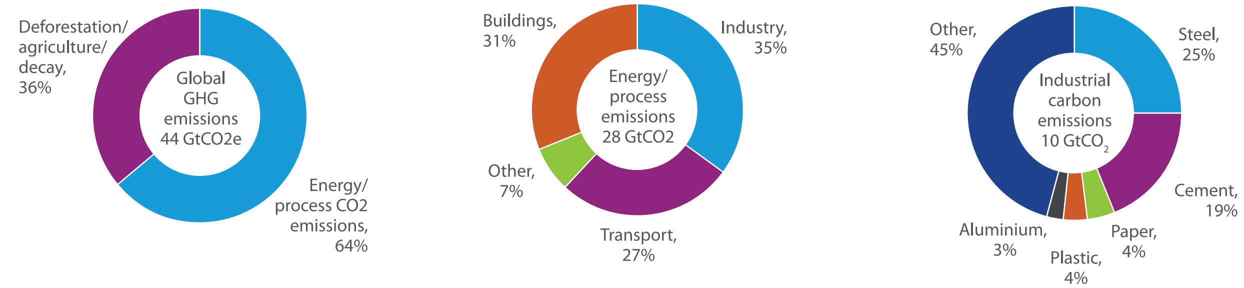

Figure 1: Sources of global CO_2 emissions. from *Sustainable Materials – With Both Eyes Open.*

For most materials used to provide buildings, infrastructure, equipment and products, global stocks are still sufficient to meet anticipated demand; but the environmental impacts of materials production and processing, particularly those related to energy, are rapidly becoming critical. In this case, it is not energy efficiency, but rather material efficiency that represents the biggest opportunity. Material efficiency – which essentially means delivering the same required services with less primary production – could allow greater cuts, at lower cost.

Here, too, it is important to focus on the biggest sources of impact, namely the five materials that contribute 55 per cent of global CO_2 emissions from industry and 20 per cent of global CO_2 emissions from energy use and industrial processes. Allwood's LCMP Group has predicted emissions scenarios to 2050 for five materials: steel, cement, paper, plastic and aluminium. Specifically, in their Reference scenario – which includes implementing all known and emerging best available technologies globally, raising recycling to the maximum possible, and securing 20 per cent decarbonisation of all energy – industry still fails to deliver the minimum 50 per cent emission cuts required by the IPCC.

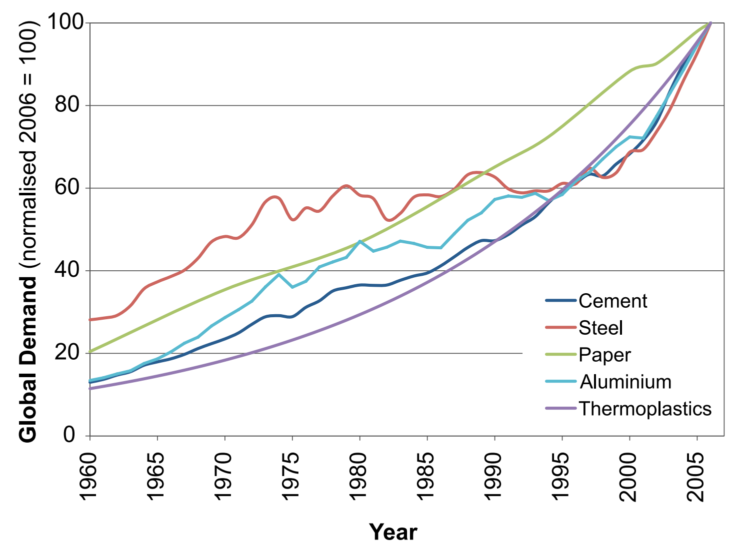

Figure 2: Normalised global demand for the five key materials since 1960, from Allwood et al, *Environmental Science & Technology* 2010, 44, 1888–1894.

Based on an analysis of strategies to improve material efficiency in these five key materials, Allwood's LCMP Group have created a 'Material Manifesto', which includes the following six actions to make the future of materials use more sustainable.

1. Use less metal by design

We could make big savings by optimising the design of metal components. The materials used by industry are often designed in a regular shape to make production easier and more efficient. But this means that they often use more material than they have to. The researchers calculate that if we can optimise beam designs, for example, to suit their use, we could make weight savings of up to 30 per cent – with a similar reduction in the emissions caused by production. Similar techniques could be applied to the production of components for cars, the 'rebar' used to reinforce concrete, and steel cans for food storage.

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"When you take a building down, the steel girder is totally reusable. All you need to do is unbolt it and clean it, because steel doesn't degrade with use."

2. Reduce yield losses

At least 25 per cent of liquid steel and 40 per cent of liquid aluminium never makes it into products. Instead, it is cut off as scrap in manufacturing. One extreme example is the aluminium wing skin used for aeroplanes: 90 per cent of the metal produced in this process ends up as 'swarf', or aluminium scrap. The researchers found that this is often the result of habit, rather than necessity. Clothing manufacturers have, for example, actually derived the algorithms needed to make sure that rolls of fabric are used to maximum effect. Manufacturers could do the same thing with the metal they receive. The team calculated that reducing yield losses through this and other techniques would cut CO_2 emissions by about 16 per cent in the steel industry and 7 per cent in the aluminium industry.

3. Divert manufacturing scrap

Scrap metal is usually sent for recycling, which means melting it (an energy-intensive process). In fact, it could just be used elsewhere. For example, most steel scrap comes from 'blanking skeletons' – the remains of sheets of steel after shapes have been cut out of them. About 60 megatons of steel are scrapped on this basis every year. We could effectively reduce scrap steel by half if these skeletons went to the manufacturers of smaller components instead, who can use what's left.

4. Re-use old components before recycling at all

Old components are often recycled when they could be re-used directly instead. Car dismantlers are an example of good practice, breaking up damaged or old vehicles and re-using the components. But steel in construction remains the biggest potential asset, and although the beams from dismantled buildings are usually recycled, they could often be used again straight away instead. "When you take a building down, the steel girder is totally reusable," Allwood says. "All you need to do is unbolt it and clean it, because steel doesn't degrade with use. Re-use means we can avoid all the energy of melting, casting and re-rolling old steel."

5. Extend the lives of products

Most demand for products in developed economies isn't to expand the overall stock, but to replace existing items. Fridges are a good example – we still need them but in the UK we destroy 33 per cent more fridges every year than we make cars. The researchers advocate modifying products rather than replacing them wholesale, and urging manufacturers to develop adaptable designs that would help this process. This requires a change in thinking and an end to planned obsolescence.

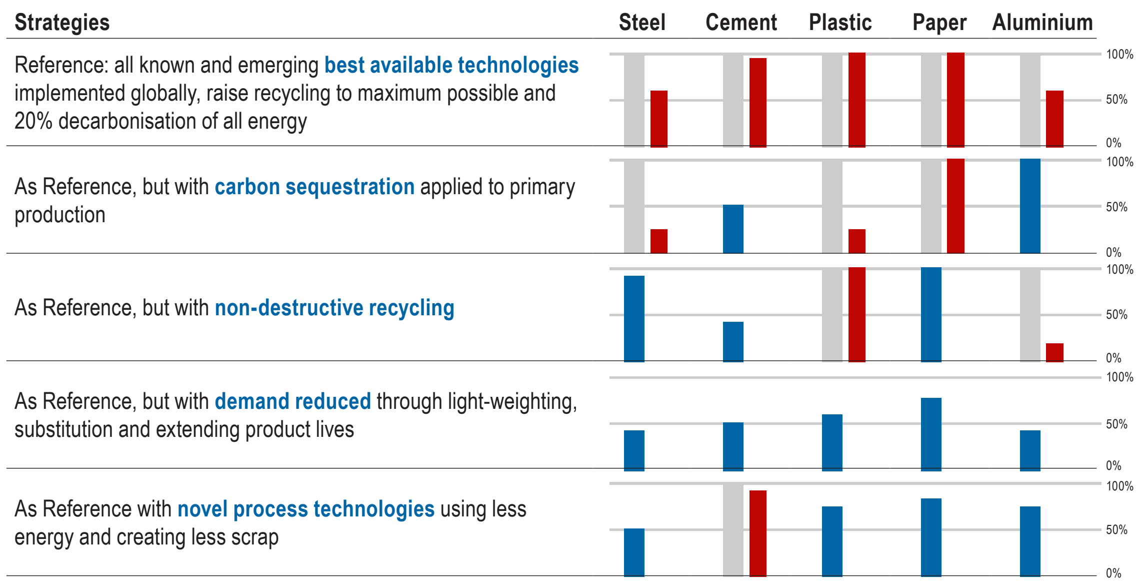

Figure 3: Predicted 2050 emissions for the five key materials under various future strategies. The blue bar shows how extensively the strategy must be implemented to reach the IPCC target. If 100 per cent implementation is insufficient, the red bar shows the excess emissions relative to the target.

6. Reduce final demand

The fall-back option that no policymaker would ever condone, except in times of war, is to reduce final demand. Yet it remains the case that we could be living with less stuff overall. In the UK, for example, we each spend 225 hours per year in the car. We have 28 million licensed cars with, on average, four seats in each. There are 60 million people. So each car seat is, on average, in use for 2 per cent of the year. We could reduce our overall stock to 7 million cars with ease. This is, of course, scuppered by the convenience factor of having a car when we need it. We may not want to make these changes to our convenient lifestyles, but that is not to say that we couldn't do it if we needed to.

In industrialised nations, material efficiency strategies have had little attention, mainly because of economic, regulatory and social barriers. However, evidence from waste management and the pursuit of energy efficiency suggests that these barriers might be overcome. Critically, however, different strategies are not equally effective for different materials. For instance, non-destructive recycling may have the most potential for steel and paper, while novel process technologies may be more appropriate for plastics. In general, reducing demand through light-weighting, substitution and extending product life appears to be a strong strategic option across the five materials.

Reflecting on his group's ambitious research programme, which resulted in the publication of *Sustainable Materials*, Allwood concludes: "We wanted to consider whether we could cut emissions by reducing the amount of stuff produced in the first place. Every aspect of our lives today depends on materials like steel and aluminium. If we want a sustainable future, we need to reduce the impact of producing them, and our biggest option for achieving this is to reduce our thirst for new material."

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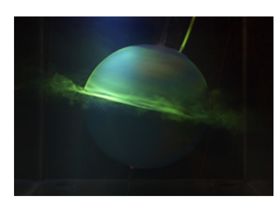

The artist duo HeHe, formed by Helen Evens and Heiko Hansen, create with *Domestic Disaster 3: Planet Earth* (2012) an unsettling installation, full of beauty and menace. Colourful and artificial, animated by a slow movement and accompanied by a sound choreography, this atmosphere echoes the research on fluid dynamics led by Jean-Marc Chomaz (CNRS, Laboratoire LadHyX, France). The work was commissioned for the Cape Farewell exhibition *Carbon 12: Art and Climate Change*. CPSL is proud to be collaborating with Cape Farewell, which works with artists and scientists on a cultural response to climate change. www.capefarewell.com