CO_2morrow: Shedding Light on the Climate Crisis

Marcos Lutyens, Andrew Manning and Alessandro Marianantoni

ABSTRACT

The CO_2morrow art project seeks to join the forces of scientific and artistic enquiry to aid our understanding of the climate debate and how humans are affecting the atmosphere through pollution. The authors consider the combining of art with science an essential means to help science find a voice for its concerns and discoveries and for art to have more of an impact on our society and the world at large. The project has involved the fabrication of a large-scale sculpture—placed at two U.K. sites—that highlights the correspondence between carbon dioxide (CO_2) emissions and damage to historic buildings through erosion and adverse weather conditions. CO_2morrow has laid the groundwork for a new initiative involving global data visualization and awareness of the climate crisis on a worldwide scale.

The problem of carbon dioxide emission is perhaps the biggest problem facing our planet.

—Omar M. Yaghi, University of California, Los Angeles

Why Did CO_2morrow Come into Existence?

The CO_2morrow project was spawned from the idea of increasing cultural awareness of society's impact on atmospheric CO_2 levels and the relationships of CO_2 levels to long-term heritage conservation. This art project ultimately resulted in the fabrication of a large-scale sculpture that has resided at two sites in the U.K. CO_2morrow was originally commissioned by the National Trust—an organization that preserves British buildings and the countryside in the U.K.; hence the sculpture's link to concerns about heritage conservation. This alliance of art and science that manifests changing CO_2 levels through changes in lighting pixels across the surface of the large-scale carbon fiber sculpture is just as much a sculptural beacon as it is a work that marks a pivotal moment in our collective consciousness. The art project resides as much in the work itself as it does in the changing psyches of those who engage in and are affected by the subject matter of climate change.

The impact of CO_2 emissions on the National Trust's properties was first brought to our attention by the investigations of Sarah Staniforth, who, as the Historic Properties Director of the National Trust, repeatedly highlighted the basic links between climate change and threats to conservation [1]. These factors, which many fear will worsen over the next few years, may cause untold maintenance and repair costs as well as irreversible damage to many of the U.K.'s National Heritage sites and in particular National Trust properties. The CO_2morrow project was originally designed to shed new and pressing light on issues raised by Staniforth and her colleagues at the National Trust.

There are two basic types of threats, the first kind perhaps more obvious than the other.

First, there are the direct effects of extreme weather conditions. If historical buildings are on the coast, they may be in danger from rising sea levels. If situated by a river, the property may be prone to soil erosion. In general, wherever their geographical location, properties may be exposed, for example, to the harming effects of wind-blown rain or excessive snowfall.

Secondly, one needs to consider how natural ecosystems are changing in a warming climate. In the U.S., for example, many bird species such as the fox sparrow and the snow goose are now moving north because it is warmer, but the insects they eat do not move north, so the insects are multiplying, destroying crops. Another instance of changes attributed to the warming climate is in Colorado, where the bark beetle is killing millions of acres of natural forest, whereas previously the beetles had been kept in check by cold winters, which reduced their numbers [2].

Viewed from another perspective, however, *heritage* can have a much broader definition: according to the *Oxford English Dictionary* [3], its definition is: "property that is or may be inherited." Earth itself right now is under threat. Some environmentalists use the populist slogan "Save the Planet," but this is misconceived, as George Marshall so eloquently described in his blog for the *Guardian* newspaper [4]. Earth will survive, no matter what we try to do to it. Whether the Earth will remain habitable for humans and other flora and fauna, however, is a very different question.

With these pressing ecological issues in mind, our team—artists Marcos Lutyens and Alessandro Marianantoni, with the scientific collaboration of climate scientist Andrew Manning—undertook the CO_2morrow project.

The Sculpture

The CO_2morrow sculptural form is inspired by the innovative research of Omar M. Yaghi [5], who has developed a

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Article Frontispiece. CO_2morrow sculpture, winter of 2010–2011 after record snowfall. Record snowfall neither proves nor disproves climate change. However, the increasing trend in extreme precipitation events such as snow or rainfall is consistent with climate change. This will lead to increased snowstorms in certain colder regions. (© Marcos Lutyens. Photo © Maureen Ritson.)

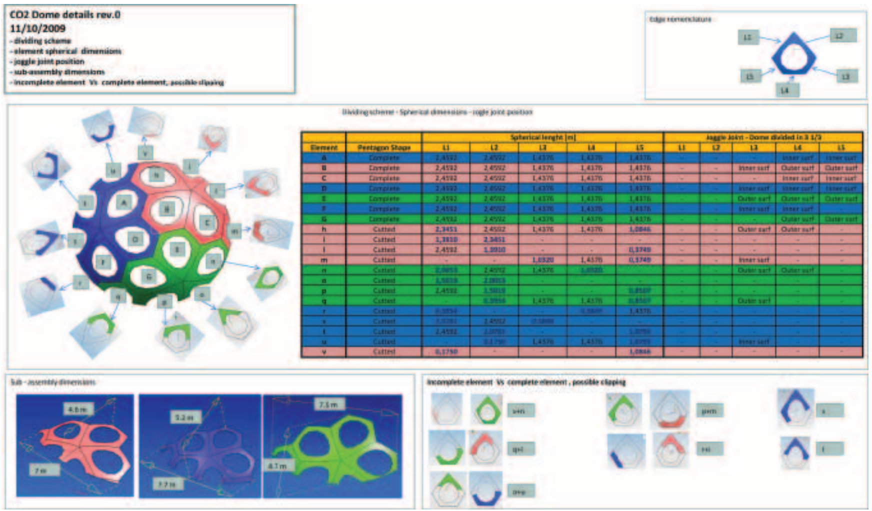
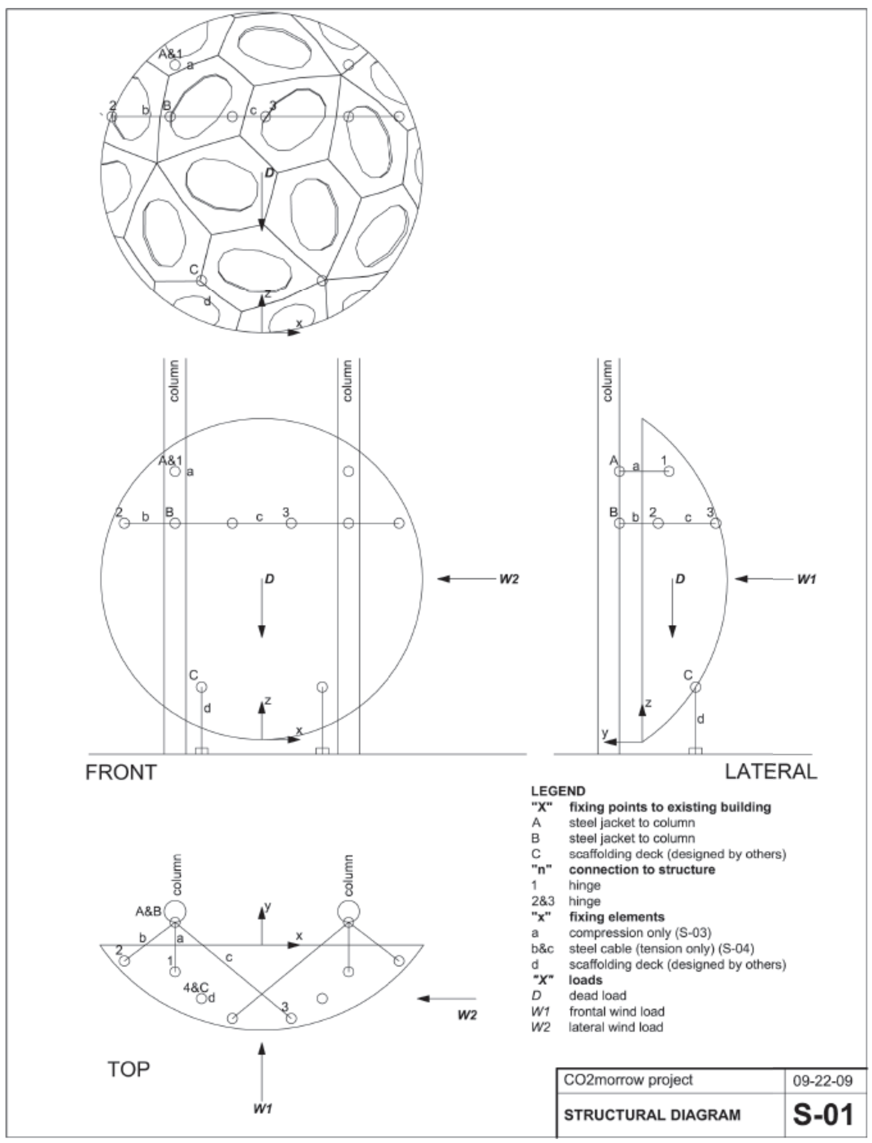


Fig. 1. Layout of pentagonal-hexecontahedron structure of the CO_2morrow sculpture. (© Marcos Lutyens. Image courtesy CO_2morrow team.)

Fig. 2. Engineering specifications for bracing the sculpture to the Grade 1-listed, 2-star building, designed in 1866–1867 by Sir James Pennethorne. The sculpture needed to withstand tropical-storm-force winds of 75 mph. Each panel was designed to handle 1,000 lb, with a maximum pressure point of 150–200 lb per sq in. (© Marcos Lutyens. Image courtesy CO_2morrow team.)



molecular sponge that acts as a carbon-scrubbing molecule based on metal-organic frameworks also known as MOFs for short. These crystalline compounds consisting of metal ions form a trapping device for CO_2 within their complex microscopic geometries. Figure 1 shows the layout of the resulting pentagonal-hexecontahedron structure that we derived from the MOFs.

The sculpture's material make-up is mostly carbon fiber, in reference to the way in which the MOF molecule devours carbon, reminding us also of the carbon exchange as it transitions from solid to gas and back again. The carbon fiber process involved molds that were computer routered and then vacuum infused in a very intensive process [6].

The sculpture is not just an inanimate object; it also translates atmospheric data values into a visual representation. For Phase I of the project, which comprised the display of the sculpture at the GSK/Royal Academy of Art in London and subsequently at the star National Trust property in Northumberland, Seaton Delaval Hall, the data used were historical and came from a sensor deployed at Weybourne on the Norfolk coast. CO_2 and oxygen levels were mapped onto the surface of the sculpture as a color gradient scale, with blue representing a higher concentration of oxygen and magenta a higher concentration of CO_2. The resulting color value was also affected by wind direction at the time of the measurement. The drifting levels of oxygen and carbon dioxide are represented on a low-density matrix of 1,440 LEDs placed on the rims of the sculpture openings as well as the inside of the sculpture. The visualization is structured in three narrative scenarios, each 3 minutes long. The sculpture displays the condensed data over time, varying the time periods sequentially: First it visualizes 1 year's worth of data, then data over 1 month and finally 1 day's worth of data; then it reverts to the whole-year data visualization and repeats the same cycle.

The aluminum flaps on the surface of the sculpture not only replicate the MOF molecule's structure but also help to reflect the changing light outwards.

For Phase II of the project, we are currently investigating the possibility of teaming up with a cluster of science and environmental departments at a major university in the U.K. so as to generate cross-disciplinary investigations into the ramifications of climate change.

In terms of the design process, we aimed to imbue the sculpture with meaning from the ground up. As a metaphor of sampling and iteration, the modular carbon-fiber structure is based on a single geometrical component. Inspired by Buckminster Fuller, our design team chose a unique oblong isosceles pentagon with an aperture in the center as the base element for the sculpture's tessellated form. The tessellation of a sphere with non-equilateral pentagons is not an obvious choice, but it worked for us from both a structural and aesthetic standpoint.

This made the manufacture economically feasible, since the 8.5-m-diameter sculpture, with a surface area of about 80 sq m and weighing 500 kg, was built with just one 3.5-m-long mold. The modular approach also simplified transportation and adaptation to each of the chosen sites.

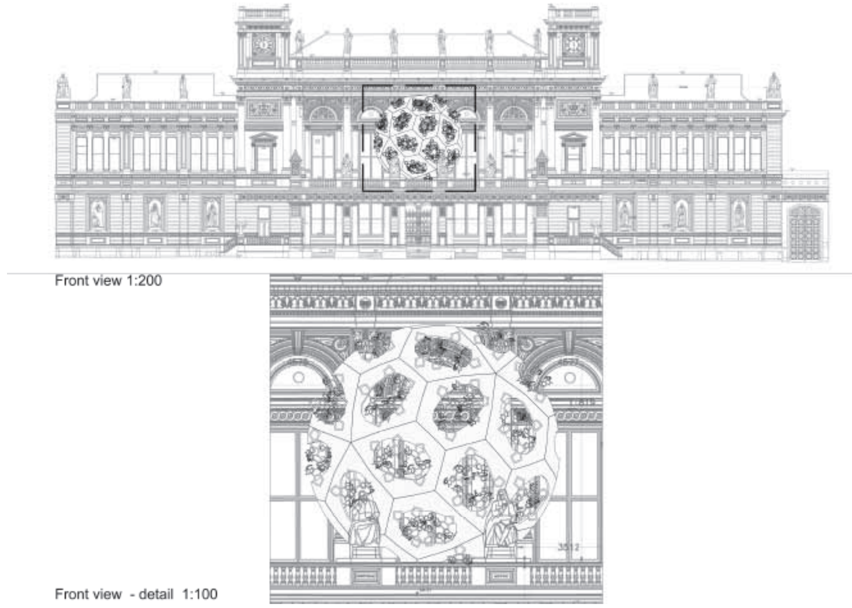


Fig. 3. Placement on façade of GSK, Royal Academy of Arts, London. (© Marcos Lutyens. Image courtesy CO_2morrow team.)

With the generous contributions of architect Roberto Castellani, structural engineer Francesco Chiesi, composite engineer Riccardo Bagagli and civil engineer Marco Piana, who worked closely alongside the artists, as well as master carbon fiber fabricators Simon and Jane Jenner and CNC milling specialist Matthew Lewis [7], the sculpture was a unique engineering and architectural achievement.

Based around our general artistic concept, the design and manufacturing

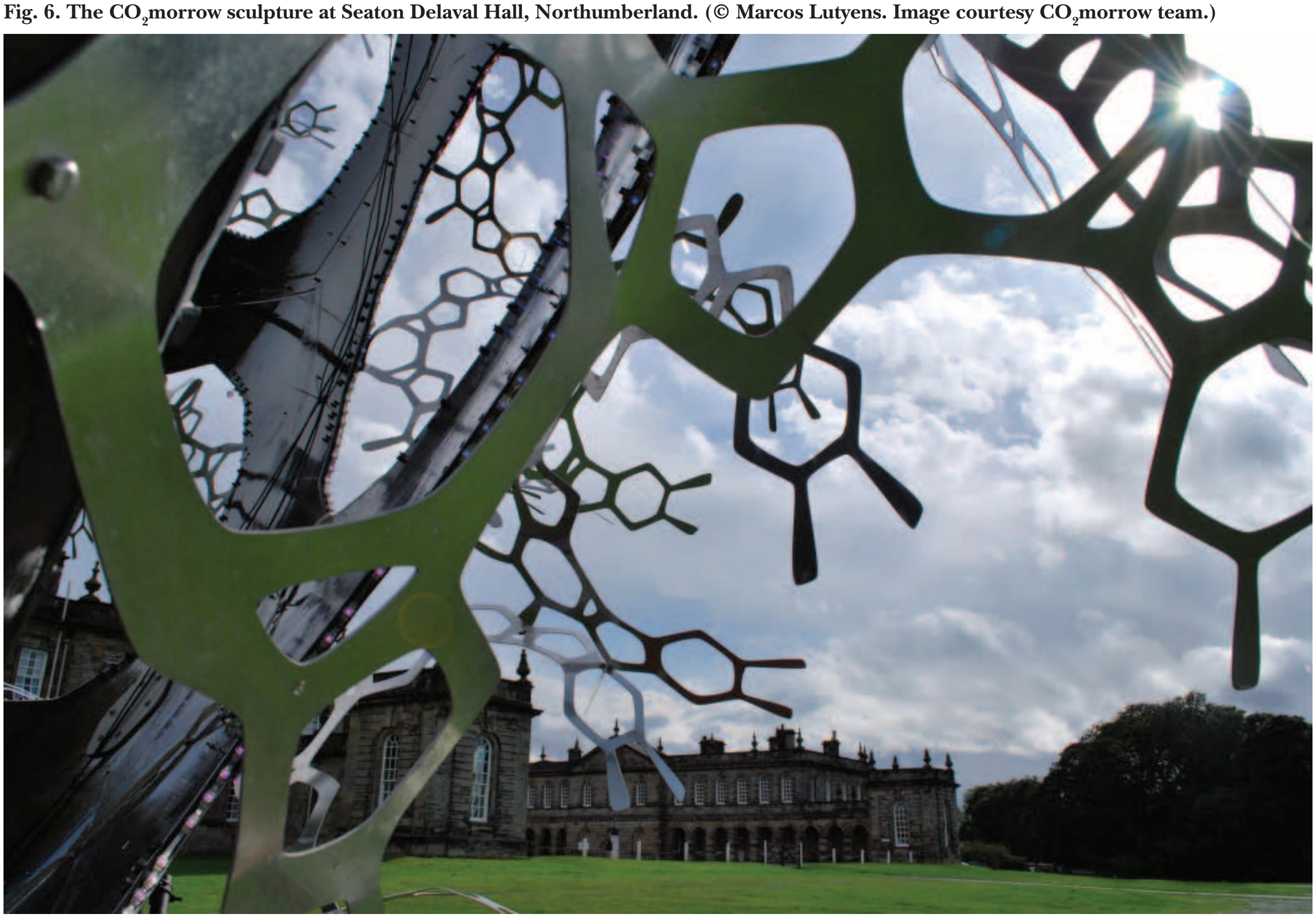
Fig. 4. Arrival and assembly by our team and the installer, MDM Props of CO_2morrow at Burlington Gardens, London. (© Marcos Lutyens. Image courtesy CO_2morrow team.)

Fig. 5. Steeplejacks affixing the metal-organic framework flaps to the sculpture. (© Marcos Lutyens. Image courtesy CO_2morrow team.)

process took shape via a constant flow of exchanges between art, science and technology. Thanks to the professionalism of those involved, we were able to steer the process along, triangulating between artistic goals, physical limitations, time constraints, financial considerations, material availability and specifications, manufacturing techniques and safety concerns. What made it all the more challenging was that our team was spread out between the U.S., U.K. and Italy.

Another huge challenge—in the case of installing the piece at its first location, the GlaxoSmithKline (GSK) wing of the Royal Academy of Arts on Burlington Gardens in London—was the acquisition of the necessary planning permits and the meeting of code requirements that the sculpture be self-supporting and able to withstand a tropical-storm force wind load of 136 km/h over a 6.5-m-high portico on a Grade 1, 2-star–listed building. The engineering specifications for bracing the sculpture to the rear part of the building, designed in 1866–1867 by Sir James Pennethorne, can be seen in Fig. 2. Each panel was designed to handle a 1,000-lb load with a maximum pressure point of 150–200 lb per sq in.

Fig. 6. The CO_2morrow sculpture at Seaton Delaval Hall, Northumberland. (© Marcos Lutyens. Image courtesy CO_2morrow team.)



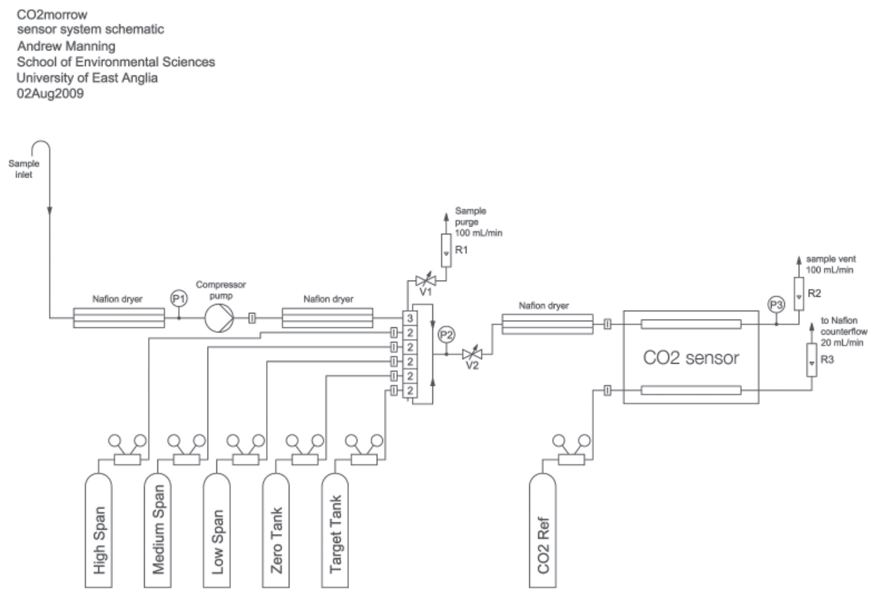


Fig. 7. Sensor system schematic showing complex process of measuring CO_2. (© Marcos Lutyens. Image courtesy CO_2morrow team.)

The design process includes the integration of the idea of recycling. Even though the sculpture is highly durable due to the carbon-fiber infusion technique, we have factored in the possibility of recycling it. This task would be undertaken by Karborek, an innovative company that recycles composite materials, and the fiber would be reused for a new art piece. This concept replicates similar reuse principles of the nanotech MOF molecules that can be reused to combine with other nanostructures or emptied out, making it ready to capture more carbon dioxide [8].

One of the most critical aspects of complex productions such as CO_2morrow is the propagation of design choices at every level. For instance, in our case, with time as a central issue, the workflow included complex planning aspects such as research into potential sponsors, which led us to alter our design approach radically and track down specific core materials from sales departments as far afield as Canada, Switzerland and Italy. Even an apparently smaller task—masking the sculpture in preparation for its final coatings—became a painstaking process that took over 24 hours to complete. Similarly, we were constantly weighing choices, such as how to affix the 1,440 LEDs to the sculpture within a very limited time frame, and how that would affect the coating strategy. Even though we finished the sculpture in time, the last 48 hours were an exhausting round-the-clock effort.

At the GSK Royal Academy

Our "oversized molecule" nested almost parasitically or like a stray virus (Fig. 3) on the facade of the GSK, Royal Academy building, as part of the exhibition "earth: Art of a changing world."

Figure 4 shows the sculpture being assembled on the street by our team and the installer [9]. Next, lifting the sculpture into place on the portico of the Burlington Gardens building was extremely challenging, to say the least, as we had to deal with gale force winds and road closure limitations and needed steeplejacks to rappel over the side of the sculpture in order to affix the MOF flaps (Fig. 5).

Once the sculpture was in place (Color Plate A), we fine-tuned the lights to change from blue to magenta in response to the data input: magenta meaning higher CO_2 levels and blue meaning lower.

The exhibition was well received—just ahead of the U.N. Climate Change Conference 2009 (Cop 15) [10]—and included such celebrated artists as Tracey Emin and Antony Gormley.

At Seaton Delaval Hall

The sculpture was subsequently placed on the front lawn of Seaton Delaval Hall (Fig. 6), a star National Trust property designed by Sir John Vanbrugh in 1718. Its placement underscores the link between Seaton Delaval and nearby Blyth. The two places were connected by the coal industry from the 17th century onwards. Now the region is known for a leading role in green technologies [11].

The winter of 2010–2011 brought record snowfall to Seaton Delaval Hall and the sculpture (Article Frontispiece). Record snowfall neither proves nor disproves climate change. However, the increasing trend in extreme precipitation events such as snow or rainfall is consis-

Fig. 8. Multiple array of precalibrated compressed air tanks for calibration of CO_2 intake. (© Marcos Lutyens. Photo © Francis Ware.)

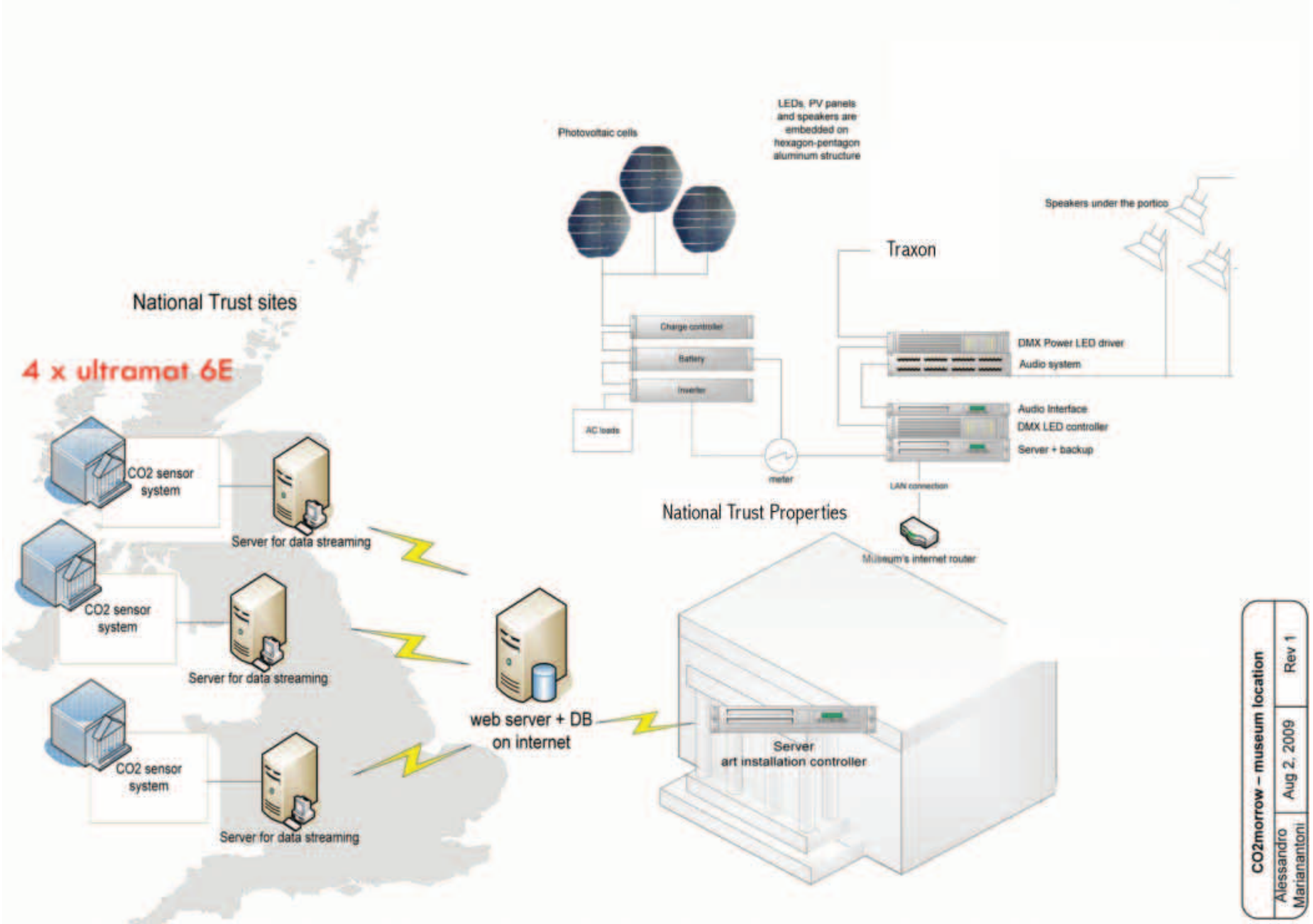


Fig. 9. CO_2 data network for CO_2morrow. (© Marcos Lutyens. Image courtesy CO_2morrow team.)

tent with climate change. And this will lead to increased snowstorms in certain colder regions.

The Context of CO_2morrow: Contemporary Art and Living Systems

The CO_2morrow project aligns itself with a type of art practice based on social and ecological concerns. Central to this approach is the use of data aggregates that enable the general public to gain awareness of what is not immediately apparent. Although this data approach within the context of art has become more prevalent recently with the emergence of digital technology, its roots can be found in such initiatives as the Mass Observation Movement, started in the U.K. in 1937. This movement originated through the convergence of art and social research and was designed to show how public information can be generated through more pluralistic channels rather than through the few traditionally used public media outlets.

Intermedia artists who work with generative strategies related to data representation include Aaron Meyers, known for his granular data mapping work at Eyebeam, a leading art and technology lab in New York, as well as social technology artist Usman Haque, known for his work *Sky Ear* [12], and Mark Hansen, creator of the *Listening Post* [13]. These artists represent one side of the data spectrum, mostly to do with social media and public interactivity. On the other side of the spectrum, closer to the CO_2morrow initiative, we can identify the work of Nathalie Miebach, who has been working on a series of public and personal weather observations to create data almanacs and musical scores. Her work "focuses on the intersection of art and science and the visual articulation of scientific observations. Using the methodologies and processes of both disciplines . . . [she] translate[s] scientific data related to ecology, climate change and meteorology into three-dimensional structures" [14]. Along similar lines, though less concerned with data than social and ecological transformation, the Metabolic Studio, under the creative leadership of artist Lauren Bon and based in Los Angeles, has been working on a series of metabolic sculptures that meet at the intersection of ecology and social concerns. Their goal is to transform resources into energy, action and objects that nurture life. Their *Not a Cornfield* project, which involved the planting of a 32-acre cornfield near downtown Los Angeles as a way to help convert a toxic industrial brownfield site to a state park, is a good example of the way in which this type of "reuse" art practice can have a transformative effect on the community and the environment.

In the elaboration of CO_2morrow, we also borrowed from ideas of reusability and recycling, as we retooled and repurposed snippets of programming code to make sense of the complexities of atmospheric data relating to environmental science.

Additional correspondences can be found between CO_2morrow and artists involved in social ecology, such as Fritz Haeg [15], who situate their work within the boundaries of the "normal," provoking people to change their daily habits by, for instance, converting their suburban lawns into Edible Estates, which are essentially vegetable gardens.

Fig. 10. Weybourne CO_2 sensor. (© Marcos Lutyens. Photo © Maureen Ritson.)

Science allied to art is uncannily able to pierce through our collective environmental autism, as seemingly abstract scientific knowledge and data are made accessible and understandable through art.

For this project we choose to draw on data gathered by sensors that extend our reach with sensitivity that is calibrated in parts per million. Just as Kevin Warwick toyed with tying together, as he put it, "sympathetic" nervous systems at a distance by connecting his own feelings with his wife's through a wireless implant that detected and retransmitted their sensations [16], we are tapping into a broader consciousness of the world around us. The exercise is far from the seemingly utopian 1970s "back to nature" movement, with its well-intentioned and yet ecologically questionable Land Art works such as *Spiral Jetty* by Robert Smithson [17], but is linked to a dire need to better understand the often-invisible connections to our social and environmental surroundings.

When we search for clues in nature, as was explored in depth in Howard C. Hughes' *Sensory Exotica: A World beyond Human Experience* [18] we can find instances of how many sensory faculties we are missing. Indeed if we only had the olfactory acuity of the shark or bloodhound, the ultrasonic perception of the moth or bat, or the ultraviolet visual range of insects, we would be so much better informed about what is going on around us. Even in the prime of life, the healthiest of us are virtually blind and deaf to our surroundings. The reality of the world that exists around us would be much better perceived with the use of prosthetic devices that extend our sensory spectrum through networked detectors and sensors.

Perhaps we could envision ourselves growing into an extended nervous system that does not just permit us to adapt, but actively allows us to change the world around us for the better. Through an accretion of telematic or technologically enhanced social links, it is as if we, as a species, could become a seamless creature that functions like discrete and independent specialized organisms that nevertheless support each others' existence. The curious case of siphonophore colonies, the best known of which is the Portuguese Man o' War, is a good illustration of how a set of independent organisms work seamlessly together for the collective good.

Scientific Background

With these challenges in mind, our project includes pioneering work by the Climate Research Unit at the University of East Anglia, one of the only such research labs in Britain. This lab specializes in the use of highly sensitive CO_2 sensors and the subsequent mapping of atmospheric pollution. CO_2 is the primary greenhouse gas associated with climate change, and its tracking is essential to understanding the dynamics of our weather and its consequences.

The CO_2morrow project team has been working to promote the placement of precise and reliable CO_2 sensors, which measure to a resolution of +/-0.003 ppm (parts per million) and are intended to be deployed in a handful of sites around the U.K. Figure 7 illustrates the complex process required to measure CO_2 levels, and Fig. 8 shows the different precalibrated compressed air tanks needed to track changes in CO_2 levels.

These sensors are designed to give accurate readings of CO_2 levels. The data is studied for patterns and tendencies: scientific climate modeling methodology will be used to shed light on the issue of CO_2 and its relationship to heritage conservation. Figure 9 illustrates how the data is networked for linking in to the CO_2morrow sculpture.

Of special significance in this project is the fact that CO_2morrow is based in the U.K. and makes CO_2 measurements on U.K. soil. Within the climate science community, the U.K. is notorious for not taking measurements of CO_2. The irony is that the U.K. only started measuring CO_2 in 2004. Russia, China, Poland and Indonesia have all been measuring for far longer. New Zealand and Australia have both been measuring CO_2 for over 30 years. The main reason why we do not understand climate change as well as we would like is because we have not made enough measurements in the U.K. Finally, we are starting to see a change. We now have measuring stations just outside of Edinburgh and at Weybourne on the coast in Norfolk (Fig. 10), although both are about to run out of funding.

More sustained CO_2 measurements need to be made, and this is why sensing is at the center of the CO_2morrow project. This sensing work is also needed to verify the estimates of greenhouse gas emissions claimed by companies and governments. Currently, all such emissions are self-declared, with plenty of opportunity for fraud or under-reporting. Independent verification is urgently needed to build trust and to observe whether the reductions are having any impact. We liken the current method to going on a diet without weighing oneself. The most important constraint is the lack of sufficient atmospheric monitoring points. This is what we are trying to address by expanding the monitoring network. We already have several examples that indicate under-reporting of different greenhouse gases. It is only by continuing and expanding this work that we can hope eventually to educate policymakers as to its importance.

The success of treaties that follow on from the Kyoto Protocol will also be much more easily established if there are mechanisms for independent verification and the building of trust between nations.

A final, very important task is to engage with the public and build public knowledge and understanding of these issues. This is especially important after so much debate and controversy, such as what has come to be known as "Climategate," in which the scientific findings of certain University of East Anglia climate scientists were undermined by the negative spinning of hacked emails. With the CO_2morrow project, we are simultaneously addressing how to encourage public engagement, data transparency and network expansion.

There are two ways to try to address these issues. First, train scientists to be better at communicating their work: U.K. funding agencies have started pressuring scientists to do this, which is a good thing. And secondly, have scientists work together with artists on projects, which is likely to see more immediate results.

Broadly speaking, the entire purpose of art is to engage the public in some manner, whether by stimulating emotions and feelings or by provoking thought. Science is quite the opposite and is often communicated poorly to the general public.

Conclusion

The original debate was, "Is climate change real?" This was answered definitively by 1998. World-leading prominent figures such as Nobel Laureate Al Gore, Sir David King (former U.K. Chief Scientific Adviser) and James Lovelock (inventor of the Gaia theory of Earth) [19] have described climate change as the most urgent and challenging problem ever faced by humankind. The next debate was "Is climate change caused by us?" This was answered definitively by 2005. The Intergovernmental Panel on Climate Change (IPCC) assessment reports [20] have presented a clear, consensus opinion, from the largest body of scientists ever assembled in history, that climate change is directly caused by human actions emitting greenhouse gases into the atmosphere.

Yet progress by the world's governments to resolve or mitigate the problem has been very slow—so slow in fact that scientists now discuss the need not only to reduce greenhouse gas emissions but to actively "capture" greenhouse gases from the atmosphere and sequester them either in bedrock or under the ocean.

Presently we are getting a "free ticket," in that nature is sucking up half of the CO_2 we emit, thus drastically reducing the harmful consequences of our actions. This estimate is based on an analysis of 50 years of global carbon dioxide measurements conducted by Ashley Ballantyne of the University of Colorado. However, the earth system is so complex that we do not fully understand what nature is doing, and a strong chance exists that our free ticket may be taken away in the future. Thus, improving our understanding of these processes is crucial for better climate predictions.

The debate now is, "What to do about climate change?" And unfortunately, without exception, every government in the world is dragging its feet on this, and it is now almost too late to take effective action. This is why CO_2morrow hopes to provide a lens through which we can come to terms with and maybe even combat to some degree the climate changes that have become the biggest challenge of our era. The CO_2morrow project has inspired a subsequent worldwide initiative, which was initiated in autumn 2011 and project-managed by Martin de Heaver. This new project involves the placing of a worldwide series of sculptures in key cities such as New Delhi, Tokyo, Beijing, New York, Moscow, Seoul, Lagos and Rio de Janeiro. These larger sculptures, made of bamboo, carbon fiber and LEDs, will tie into global atmospheric data-sensing networks and will be accompanied by smaller sculptures and smartphone apps that will generate participatory sensing feedback from users around the world. This supplementary data will be fed back into the larger sculptures. In this way the "2" of CO_2morrow could come to signify "squared" as the potential of the project scales up to create change in the dynamics of the worldwide atmospheric crisis.

Acknowledgments

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References and Notes

Unedited references as provided by the authors.

1. Sarah Staniforth, "Conservation Heating to Slow Conservation: A Tale of the Appropriate Rather Than the Ideal," Contribution to the Experts' Roundtable on Sustainable Climate Management Strategies, Tenerife, Spain (April 2007) <www.getty.edu/conservation/science/climate/paper_staniforth.pdf>.

2. <www.nytimes.com/2008/11/18/science/18trees.html>. See also David D. Dunn and James P. Crutchfield, "Entomogenic Climate Change: Insect Bioacoustics and Future Forest Ecology," *Leonardo* **43**, No. 3 (2009) pp. 239–244.

3. *The Oxford English Dictionary*, Second Edition, Edited by John Simpson and Edmund Weiner. Clarendon Press. ISBN: 978-0-19-861186-8 (30 March 1989).

4. <www.guardian.co.uk/environment/blog/2007/oct/15/changethemessagetosavethe>

5. Omar Yaghi is UCLA's Christopher S. Foote Professor of Chemistry. See "Capturing CO_2," an interview with Omar Yaghi for CO_2morrow, <www.youtube.com/watch?v=GN5tseQ9NG8>.

6. The molds were computer routered by London Metropolitan Works and then vacuum infused by Morley Composites Ltd. in Cornwall. Without their generous donation of labor and contribution of expertise on infusion techniques we could not possibly have produced such a challenging undertaking with such professional results. Students from University College Falmouth also generously volunteered hundreds of hours to speed up the process of sanding and coating the carbon fiber.

7. Simon and Jane Jenner from Morley Composites Ltd; Matthew Lewis from London Metropolitan Works.

8. <http://yaghi.chem.ucla.edu/staticpages/yaghi>

9. The sculpture was installed by MDM Props Ltd.

10. Cop 15 Copenhagen 2009, <www.denmark.dk/en/menu/Climate-Energy/COP15-Copenhagen-2009/cop15.htm>.

11. "Northumberland wind turbine test centre gets £25m boost," BBC News Tyne and Wear (7 July 2011), <www.bbc.co.uk/news/uk-england-tyne-14060102>.

12. <www.haque.co.uk/skyear/information.html>

13. Nathalie Miebach, <http://futureeverything.org/art/nathalie-miebach-a-duet-of-blizzards-and-hurricane-noel-ii/>.

14. <www.stat.ucla.edu/~cocteau/>

15. <www.fritzhaeg.com/garden/initiatives/edibleestates/main.html>

16. <www.kevinwarwick.com/Cyborg2.htm>

17. George Baker (Author), Bob Phillips (Author), Ann Reynolds (Author), Lytle Shaw (Author), Robert Smithson (Author), Diana Thater (Author), Lynne Cooke (Editor), Karen Kelly (Editor), *Robert Smithson: Spiral Jetty*, University of California Press ISBN-10: 0520245547 (September 5, 2005).

18. Howard C. Hughes, *Sensory Exotica* (MIT Press, 2001). ISBN: 9780262582049 (February 2001).

19. James Lovelock, *Gaia: A New Look at Life on Earth* [Paperback]. Oxford University Press, USA. ISBN-10: 0192862189 (November 23, 2000).

20. S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.) Climate Change 2007: The Physical Science Basis Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 978 0 521 70596 7 (2007).

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