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Expanding Eco-Visualization: Sculpting Corn Production

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A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Media Art and Text at Virginia Commonwealth University.

by

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This dissertation expands upon the definition of eco-visualization artwork. Eco-visualization (EV) is a subset of information visualization that concerns itself with visualizing data regarding the environment. EV was originally defined in 2006 by Tiffany Holmes as a way to display the real time consumption statistics of key environmental resources for the goal of promoting ecological literacy. I assert that the final forms of EV artworks are not necessarily dependent on technology, and can differ in terms of media used, in that they can be sculptural, video-based, or static two-dimensional forms that communicate interpreted environmental information. There are two main categories of EV: one that is predominantly screen-based and another that employs a variety of modes of representation to visualize environmental information.

EVs are political acts, situated in a particularly charged climate of rising awareness, operating within the context of environmentalism and sustainability. I discuss a variety of EV works within the frame of ecopsychology, including dynamic projects that are screen-based, such as EcoArtTech's *Eclipse* and Keith Deverell's *Building Run*;

and projects that do not rely on the screen but use a variety of materials and processes for the final presentation, including Andrea Polli's *Cloud Car* and *Particle Falls*; Nathalie Miebach's series, *The Sandy Rides*; and Natalie Jeremijenko's *Mussel Choir.*

The range of EV works provided models for my creative project, *Sculpting Corn Production*, and a foundation from which I developed a creative methodology. Working to defeat my experience of solastalgia, *Sculpting Corn Production* is a series of discrete paper sculptures focusing on American industrial corn farming. It addresses climate change and engages with specific datasets through sculptural form in a way that broadens the scope of EV. This EV also functions as a way for me to understand our devastated monoculture landscapes and the politics, economics, and related areas of ecology of our food production. *Sculpting Corn Production* is a foundation for future work through the development of concept, the exploration of process, the interpretation / translation of data, and the communication of information through form.

Introduction

This dissertation, *Expanding Eco-Visualization: Sculpting Corn Production*, stems from diverse research interests that connect my pursuits in contemporary art, data visualization, and ecology. In 2009, I first became aware that corn, in many forms, is in most of the foods on my plate, in the fuel for my car, and in manufactured objects in my environment. In addition, I was literally surrounded at the time by miles and miles of Ohio cornfields. Despite this seeming abundance, I heard about reports of food (corn) scarcity and of rising costs of grain worldwide. Many were going hungry with food prices having more than doubled. This realization sparked my curiosity about the American agriculture industry, specifically the production of corn and corn by-products. Fueled by a desire to see and understand how corn came to be such a dominant ingredient in food and consumer goods, I began searching for answers. A staggering amount of interrelated information is available from a variety of sources, and it is this information, and associated systems beyond factory farming, that continue to pique my interest. Visualizing these networks by drawing connections between disparate and unconnected data sets has produced new meaning and helped me to have a better understanding of the politics, economics, and ecology of our food production.

Information visualization is a popular topic in contemporary digital culture, and it is a key factor in business decisions, government policy, and art production. Data is being generated all around us all the time from every digital process. Systems, sensors, and mobile devices transfer information about the environment, from water temperature to wind speed, from energy consumption to air quality, from bat habitat to commercial fishing practices. But data is just substrate, a building block for further understanding. Alan Kay, a computer scientist, asserts, “the interesting future's not about data at all - it's about meaning" (2014). Making meaning by

finding surprising connections within environmental data is the strength of information visualization, and eco-visualization in particular.

Eco-visualization is a relatively new field. In this Introduction I set the scope for what I mean by eco-visualization and lay out definitions of my key terms. I will define eco-visualization as a sub-genre of information visualization and situate my assertion that the final form of eco-visualization artworks are not necessarily dependent on technology, and that in fact, the small amount of literature on the subject is too limiting in its definition. In expanding upon the literature I will provide brief introductions to the concepts I draw from ecopsychology, a driving force of environmentalism.

I offer a broadened definition of eco-visualization, through an overview of important areas of overlap and difference in eco-visualization: structural issues, including the content type of data sets both dynamic and static, and media both digital and non-digital; functional issues, including approaches to form; and aesthetic issues, including visuality, site-specificity, and the ways in which eco-visualization may offer a critique of contemporary cultural practices. Within this context, two categories of EV emerge. The first category includes dynamic projects that rely on the screen as a major element of the work. I discuss Martin Wattenburg's and Fernanda Viégas' *Wind Map*; EcoArtTech's (Leila Nadir and Cary Peppermint) *Eclipse*; and Keith Deverell's *Building Run*. The second category includes projects that do not rely on the screen but use a variety of materials and processes for the final presentation. I analyze Andrea Polli's *Cloud Car* and *Particle Falls*; Nathalie Miebach's *The Sandy Rides* series; and Natalie Jeremijenko's *Mussel Choir*. I discuss my own eco-visualization work, *Sculpting Corn Production,* as a foundation for my future work, and how it functions in regards to form and content in relationship to the field – a nascent field that is dominated by concerns of energy use, pollution,

and resource preservation. Finally, I conclude by articulating possible futures for eco-visualization.

Scope

Eco-visualization (EV) is a subset of information visualization that concerns itself with visualizing data regarding the environment. Early EV works were device-based objects displaying information from sensors, designed to read and relate granular information, and were primarily for individual users in their home and during their daily activity.[1] They evolved to screen-based works that relied on computers and the Internet as a live source of information; and there are a number of EV artworks that go beyond the screen as a mode of data presentation. It is precisely these projects without screens which exist beyond the boundaries set by EV literature that I claim to be EV in terms of both their content and function.

Analog, non-digital precedents to streaming data-presentations of environmental information date back to early cartography and map-making, where terrain-based information was delineated through line, color, and text. As a media practice, EV developed from within the broader field of information visualization, wherein complex systems of information are presented visually.

As an art practice, EV is rooted in Environmental Art of the early 1960s and 1970s,[2] noted for the works of artists like Robert Smithson, Agnes Denes, Walter de Maria, Michael

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[1] See *SNUPI*, Cohn et al., 2010; *ElectriSense*, Gupta et al. 2010; *ViridiScope*, Kim et al. 2009; *GasSense*,

[2] "Environmental art" is work that emerged in the 1960's that consciously broke from the constraints of the gallery to explore language and metaphor in the terrain of land and landscape. The Environmental Art movement developed from the evolution of thought on the environment, which considered the environment as a physical place and then as a broader concept, which includes ecosystems and related issues. Environmental art is associated with physical, external conditions and surroundings, and is used as an umbrella term that encompasses "eco-art." Eco-art is characterized by the interdependence of organisms, and addresses environmental issues and often involves holds collaboration and restoration as key facets of the work. Foundational sources include *Land and Environmental Art*

Heizer, Joseph Beuys, Hans Haacke, Nancy Holt, and Meg Webster. These artists addressed "nature" as a social construction, shattering the image of the natural world as an untouched entity once thought to be beyond human control. Since the 1970's, the potential for vast environmental change reasserted itself within the social imagination. As the discussion of environmental crises increased in frequency, concerns regarding rising global energy demands, increasing costs and limited natural resources contributed to a feeling of vulnerability and a shared concern for a healthy ecology. Our perception of our physical environment as lasting and steadfast began to erode:

> The resource triangle of water-energy-food, relatively stable for the past several generations, is now rapidly changing; under a business as usual scenario, the world will require 40% more energy and 70% more food by 2050. Increasing volatility and upward pressures on commodities and natural resources—most importantly water—is becoming the "new normal" that business planners and other organizations will need to confront. Overlaying these challenges are the significant issues of social equity and development. (World Environment Center [WEC], 2012).

The causes of environmental change, whether agreed upon as a result of human actions or otherwise, continue to be debated. However, there is considerable evidence that the Earth is facing global warming, and that we risk unpredictable, highly damaging impacts to our ecosystem.[3] It is beyond the scope of this Introduction to explore *why* there is a disconnect between scientific knowledge and public perception, except to acknowledge that there is a rift. Artists are actively addressing continuing environmental damage and change, and exploring ways to visualize environmental data in ways that are expressive, educational, and challenging.

(Kastner and Wallis, 2010), which documents the Land Art and Environmental art movements to the present. *To Life! Eco Art in Pursuit of a Sustainable Planet* (Weintraub, 2012) discusses the contemporary eco art movement.

[3] Although the public is becoming aware that climate change increases the likelihood of certain local disasters, many do not yet understand that there is a small but real chance of abrupt, unpredictable, and potentially irreversible changes with highly damaging impacts around the world. The public also believes that scientists are in disagreement, however, about 97% of climate scientists have concluded that humans are changing the climate (AAAS, 2014).

These aesthetically powerful artworks reformulate social space to support environmental awareness. One approach is through eco-visualization artwork.

"Eco-visualization" is a term coined by artist Tiffany Holmes in 2006, which was further developed in later essays. Holmes is a producer of EV artwork and a Professor in the Art and Technology Studies Department at the School of the Art Institute of Chicago. She regards EV as a distinct genre within information visualization:

> Eco-visualization offers a novel approach to display the real time consumption statistics of key environmental resources for the goal of promoting ecological literacy. Therefore, eco-visualizations could be data-driven animations that display ecological information of any sort in real time. (2007).

In its nascent stage of development, Holmes describes the art form in multiple ways ranging from the specific: EV is "the visual display of vital ecological data," to those that are open to interpretation: EV "can take many creative forms" (2006). In early publications, Holmes holds that EV does not need to be site-specific; rather, it can successfully be deployed in a variety of spaces with "interdisciplinary methods of raising environmental awareness with portable software and technology" (2006). Holmes' concept of technological portability was a good starting point, but an undeveloped concept as stated. I find it difficult to believe that an EV artist could "plug into" an existing data stream and produce meaningful, contextualized, site-specific visualization that would be just as strong if "plugged into" another setting. I say this because I am making assumptions about this hypothetical situation in that the EV imagery would be relatively unaltered from space to space. In this scenario, each site's context, situations and needs could be vastly different from one another. However, Holmes' idea of extending EV to broader contexts or public spaces beyond a singular instance of exhibition indicates the potential broad-audience accessibility of the art form. In subsequent writings Holmes introduces context

as an important aspect of EV: "artists have a fundamental role to play in creating work that 'translates' site-specific environmental data" (2007a).

The concept of site-specificity is a moving target, addressed in part by the art historian and curator Miwon Kwon. Kwon articulates that early site-specific artworks were directed by their context and were either interruptive or assimilative in nature. An interruptive model is one where the artwork functions as a critical intervention into the existing code of the site. This concept is contrasted with an assimilative model, where the artwork is integrated into the existing environment, producing a unified space of cohesion. Site-specific artwork relates to its physical determinants, including the proportion and shape of rooms, plazas, buildings, and parks, and their associated conditions, including changeable traffic patterns, lighting, and ventilation. Cultural framework also defines a *site*: the social matrix of class, race, gender, and sexuality of the viewing subject define the phenomenological parameters of the space. *Site* encompasses interrelated spaces and economies that are open to social, economic, and political pressures, including spaces of art practice (studios, museums, and cities), art history and criticism, and the global market exchange. Kwon asserts that to be site-specific is to decode and / or recode the institutional conventions in order to expose their hidden motivations, revealing the ways that social institutions manipulate art's meaning thereby controlling its cultural and economic value (88). Site-specific art has evolved to anti-visual modes, including informational, textual, expositional, and didactic practices; it has also developed into the immaterial, including gestures, events, and performances, such as the artist collective Midwest Radical Cultural Corridor's *Monsanto Hearings*.[4] Site-specific artwork is a critique of culture that is inclusive of non-art

[4] The "Monsanto Hearings" are public tribunals wherein the court is a theater to build public understanding. People and communities present testimony regarding the harmful impact that the Monsanto corporation has on food, farms, communities, and ecosystems. Existing law, however, has strict limits on who has "standing," the right to

spaces and non-art issues,[5] including urgent social problems such as the ecological crisis (Kwon, 91).

Concern over the environmental crisis brings us back to EV. Almost five years after asserting that EV could be site-specific, Holmes further refines her definition by stating that EVs are "art and design works that translate ecological data into easy-to-understand images and sound...[promoting] sustainability through a shared experience of a real time happening that is controlled by a computer or associated electronic technology" (2011, 1). Holmes elaborates on EV, stating that it is a collaborative, interdisciplinary practice that shares environmental data.

A number of EV researchers have offered their general characterizations of EV by drawing from Holmes' research. Their definitions range from physicality (EV existing as objects of technology and as modes of representation) to causality (EV as a social function).

1. **Technological Device:** Eco-visualizations function as any kind of interactive device targeted at revealing energy use in order to promote more sustainable behaviors or foster positive attitudes towards sustainable practices (Pierce et. al, 2008).
2. **Technological Device:** EVs shift focus away from frequently hidden engineering solutions toward the design of graphical interfaces and systems to actively persuade participants to reduce their consumption through dynamic feedback. (Odom, 2008)
3. **Mode of Representation:** Eco-visualizations are various forms of representation methods such as text, pictures and diagrams in the field (Kim et. al, 2010).
4. **Promoting awareness:** Eco-visualizations create energy awareness by using different phenomena that illustrate energy use (Lofstrom, 2011).

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make claims and be heard, and insists that damages be measurable in dollar value. In these hearings all living beings are potential plaintiffs, including writers, teachers, artists, researchers, farmers as well as any entities they might chose to represent (Midwest Compass, 2012).

[5] Investigating non-art issues includes examination of areas as far away from art as finance, biotech, geography, urbanism, psychiatry, and the electromagnetic spectrum; by bringing forth the "free play of the faculties" and the intersubjective experimentation that are characteristic of modern art (Holmes, Brian (2007).

Definitions one and two are oriented toward technological devices, and rely on interactivity or graphical interfaces that provide feedback to the audience. While the first allows that EV is dependent on an interactive device of some kind, the second suggests that EV is a computer-driven form. These first two definitions are in line with Holmes' original assertion that EV is associated with technology. However, the third and fourth definitions are the most relevant for this introduction and my discussion of EV beyond technological devices and computer-mediated visualization, and open the door to EV projects to be varied modes of representation beyond one limited to the screen.

Holmes looks to environmental art practice as the art historical context from which EV emerged, citing the artist Joseph Beuys as a main source of inspiration. For example, Beuys's site-specific 1982 project *7000 Eichen* (7000 Oaks) brought attention to the effects of ongoing blight in targeted areas within the German city of Kassel. Part sculpture, part urban renewal, the massive installation project combined live trees and basalt stone sculpture in areas of economic disinvestment. Trees were the defining metaphor for *7000 Eichen,* standing as elements of restoration and of time, in contrast to the basalt stone sculpture. Beuys stated that the tree-planting "will be a regenerative activity; it will be a therapy for all of the problems we are standing before.... I wished to go completely outside and to make a symbolic start for my enterprise of regenerating the life of humankind within the body of society and to prepare a positive future in this context" (Cooke, 2004:1). *7000 Eichen* was intended to bring attention to disenfranchised areas, including slums and places of abandonment. Beuys intended to raise ecological consciousness and ignite social change within Kassel by visually improving areas of blight.

Holmes directly referenced Beuys's physical tree-planting project with her digital site-specific project, *7000 Oaks and Counting* (Jennings, 2007). Located in the National Center for Supercomputing Applications at the University of Illinois at Urbana, Holmes's conceptually driven digital animation visualizes a mandala of tree images that grow and disappear corresponding to data reads of the building's carbon load. Less electricity used equals more radiating waves of trees. Rather than metaphors of regeneration, Holmes' trees were symbolic of "carbon sinks" - able to soak up carbon dioxide and safely store it in wood, roots, leaves and the soil though photosynthesis. As an early example of EV, *7000 Oaks and Counting* functions as immediate feedback for building residents. Among the previously stated definitions of EV, Holmes' work relates to the first two that state that EV is dependent on technological devices, and to the fourth, which asserts that EV promotes awareness.

The sub-genre of EV within the discipline of information visualization is evolving and moving beyond early predominantly screen-based works. A variety of modes of representation that visualize environmental information are indicative of our changing perception of the human impact upon the environment and ecology. These works range from screen-based works, as discussed in Chapter One, to interpretive sculpture, as discussed in Chapter Two. Such complexity can result from multiple, simultaneous datasets, but equally as well from abstract conceptual processes. If EV is to have a distinct character apart from other information visualization projects overall, we need a more discriminating definition — one that accounts for a range of modes of creation.

Stipulation

According to the generally accepted definitions previously articulated, EV is art that uses technology to reveal historical information and ecological data. This art may be a mode of representation including text, pictures, and site-specific diagrams. All EV promotes awareness. Less than a decade in development, this new field is an emerging interdisciplinary art practice characterized by the display and interpretation of real-time environmental data, human-use data, and scientific evidence. Hybrid in essence, EV artwork exists in physical and virtual spaces by making use of technological innovation to communicate information in a variety of ways. What all EV artworks have in common is that they use environmental information as raw material. I assert that EV artworks differ in terms of media used, in that they can be sculptural, video-based, or static two-dimensional forms that communicate this environmental information. They are creative interpretations of information that visually reveal statistical data and the effects of political and socio-spatial systems upon the environment. While creating arresting spaces and objects, the long-term goals of ecological artwork are to encourage environmental awareness, participant engagement, and a culture of sustainability. While some attempts have been made, researchers assert that the goals are difficult to measure for a variety of reasons, including time constraints and subject pool limitations. They look to evaluating EV works within a larger cultural context.

While EV projects aspire to the lofty ideals of promoting awareness, engagement, and sustainable behavior, there may be too much importance put on these particular goals while overlooking of other areas of cultural value. In stating this concern, I am not calling for more qualitative studies of EV audiences. I assert that EV projects can function beyond their existence

as commodifiable and potentially commercial objects.[6] In making this assertion, I am differentiating here between EV projects that visualize data and the EV artworks that exist as site-specific objects or discrete sculptures, which function both as a visualization of data as well as a critique of culture. The assessment of projects should include what the individual projects set out to accomplish, and whether this is interesting and valuable in the current context. Other important concerns include if the EV provides a unique perspective or uncovers something previously hidden, and if the EV engages with, and challenges its social, political and cultural context.[7]

EV work has expanded beyond the consumer device to examine a variety of ecological data in relationship to climate change. Some projects examine energy use, like Tiffany Holmes screen-based work like *7000 Oaks and Counting* (2006),[8] and Tega Brain's floor projection, including a hacked energy meter, *Kilowatt Hours* (2013).[9] Core ice samples are visualized in dimensional form with the collective Kuuki's *Distracted*.[10] Energy production is visualized with

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[6] There are a number of exploratory systems that visualize energy use that are considered EV projects: Uneo et al., 2006; Cohn et al., 2010; Cohn et al., 2010a; Gupta et al., 2010; Kim et al., 2009; Peterson et al., 2009; Spagnolli et al, 2011.

Consumer-level devices are becoming more prevalent for energy-use sensing: *Tendril*, 2015; *The Energy Detective (TED),* 2015; *Kill A Watt*, 2012; *Watts Up*, 2012.

For water-use sensing in the home: Campbell et al., 2010; Froelich et al., 2009; Kuznetsov and Paulos, 2010.

[7] Eco-feedback technology is an area of extensive research. For a comprehensive review of the field: DiSalvo et al. 2010. Other related studies include Froehlich et al.; 2012; Foster et al., 2012; Strengers, 2011.

[8] *7000 Oaks and Counting* makes use of real-time energy data to educate and encourage reductions of resource consumption in a public office building (Gladu, 2012).

[9] *Kilowatt Hours* measures and visualizes the real time energy use of its exhibition space. It is an energy clock and draws on visual conventions used for the measurement of time. Patterns emerge that can be traced back over recent hours but eventually become faded and obscured. Over time, the work forgets. *Kilowatt Hours* draws on a legacy of formalist cinema and contemplates measurement, feedback and memory as well as probing institutional transparency and the public availability of data (Brain, 2013).

[10] *Distracted* is a poetic interpretation of scientific ice core samples taken in Antarctica. An installation of acrylic tubes housing LEDs, resin bubbles, found organic matter and sensors, *Distracted* is an evocative and

the collaborative HeHe's large-scale projection, *Nuage Vert* (2008)[11] and Michael Pinsky's *Monometers*.[12] The health of the ocean and coral reefs are visualized in Lynette Walworth's *Rekindling Venus* (2012).[13] The environment of a waterway was sonified with *Flow* (2012).[14] The relationship between rainfall and consumption is visualized with *Drawing Water* (2011).[15]

EVs are political acts, situated in a particularly charged climate of rising awareness and human accountability, acknowledging that changing ecologies are not phenomena safe from human exploitation and intervention. EVs can work collectively to change attitudes toward the

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interactive experience, evoking ice, fluids and the notion of change. A number of data sets are used to create the abstract visualisation and sonification in the work, creating a unique context for understanding human presence and impact on the planet (Bracks et. al., 2011).

[11] *Nuage Vert* turns vapor emissions of an energy plant into an amorphous projection surface. The system uses a moving laser beam to draw the outline of the cloud issuing from the plant. It was developed in collaboration with experts in laser technology, computer science, electrical engineering, energy production, and air quality monitoring. Works like *Nuage Vert* connect people to the resources used, and the outside world from where those resources originate. *Nuage Vert* also has the ability to take the near unintelligible data of resource consumption and reinvent it in a way that actually allows consumers to gauge their collective use in order to begin conversation to challenge the ways in which they consume energy (Evans and Hansen, 2009).

[12] The four supporting columns of Belgium's highest wind turbines were transformed into meters monitoring the ecological impact of Kortrijk's annual all-night arts festival. The consumption of energy and water, and the production of noise and waste were indicated by two rings of projected light that moved up and down the turbines (Pinsky, 2009).

[13] An augmented reality project that uses digital platforms including the web, the smart phone to connect us to the world's coral reefs and their plight in a changing climate, it draws on real-time data, video and imagery (Wallworth, 2009).

[14] *Flow* was a tidemill - a floating timber structure on the River Tyne that generated its own power using a tidal water wheel. The building housed electro-acoustic musical machinery and instruments which responded to the constantly changing environment of the river. The work highlighted society's evolving relationship with our waterways, and processes of harnessing natural energy (Owl Project and Ed Carter, 2012).

[15] *Drawing Water* shows the relationship between where water falls and where it is consumed within the United States. It builds images to expose the reality that water is channeled, pumped, and siphoned to locations far from where it falls. Although the paths are imagined, Drawing Water is based on real data and it reveals a clear truth about water resources and use. The project is realized as a series of high-resolution print images as well as an interactive, animated map. Each line in Drawing Water corresponds to a daily rainfall measurement. The length of the line and its initial placement are determined by the amount of rainfall measured and where it fell. The final placement and color of each line are determined by the influence of urban water consumers. The more water a city uses, the stronger its pull on the rainfall. As rainfall is pulled farther from where it fell, it becomes desaturated, turning from blue to black in print and to white in the projected installation (Wicks, 2011).

environment. To support this assertion I look in particular to the research of Paul Dourish, a social / computer scientist and professor at the University of California, Irvine. Dourish notes that the politics of environmental sustainability must move beyond individual action to address problems of scale in political and environmental mobilization. Dourish argues that an engagement with environmental issues that separates the environment from other aspects of social life is restrictive because it may fail to recognize the conditions of its own emergence. He goes on to assert that environmental engagement is limited if it does not acknowledge questions of political ecology, environmental justice, and citizenship and governance. EV can be a site of productive engagement by adopting a scale that goes beyond the individual person and the individual environmental issue, by being directed towards a collective audience and visualizing multiple, compound data sets. As mentioned above, early EV works took the form of devices designed to read and relate granular information, and were primarily for individual users in their home and during their daily activity. This Introduction, and Chapters One and Two, are primarily interested in EV projects designed for a broad audience in public settings (including the Internet). Recent EV projects such as *Building Run* engage a large audience with feedback information, which is discussed in Chapter One. Other projects are intended for a collective audience beyond individual persons, such as Nathalie Miebach's *The Last Ride*, which interprets a variety of environmental information in abstract ways. This project will be discussed in Chapter Two.

EV artwork is compelling because it uses aesthetic means to draw attention to and promote understanding of humanity's impact on the environment. In this introduction, I broaden the interpretation of EV to include art forms other than screen-based artwork. This opens the discipline of EV to encompass data-interpretive forms including sculpture**.** I will frame EV in the

context of eco-psychology, which examines the relationship of environmental issues and mental health and well-being.

Linked to this discussion are my own concerns about ongoing acute environmental degradation, an overall sense of cultural disempowerment, and my feeling of general malaise when considering the future of the Earth's organic systems. The overarching and driving concept of my research is my experience of solastalgia. A neologism originating from the philosopher Glenn Albrecht, "solastalgia" is a combination of the Latin word *solacium* (comfort) and the Greek root *–algia* (pain). Albrecht defined the global condition as intensely localized: "the pain experienced when there is recognition that the place where one resides and that one loves is under immediate assault…a form of homesickness one gets when one is still at 'home'" (2004). The phenomenon is a documented form of psychic distress, or place pathology, resulting from negatively perceived environmental change. Causally linked to changing climates and ecosystems, the melancholic psychoterratic illness is exacerbated by a sense of powerlessness regarding ecological shifts. In addressing solastalgia, I wish to reject simplistic good / bad dualisms that tend to characterize the larger discussion of ecopsychology, whether they are generally ontological (nature versus culture) or specifically political ("green" conservationist behavior versus capitalist consumption). However strong my own feeling of solastalgia, my aim is not to be didactic or overly judgmental: I remain hopeful for a positive shift in social practice and behavior.

Terms and Principal Concepts

One facet of this dissertation research and creative project is an overarching sense of environmentalism. As a general term, it designates the attitudes that inspire behavior advocating for the preservation, restoration, and improvement of what is collectively agreed upon as the

natural environment. Ideas including the practice of environmental ethics, the pursuit of biodiversity support, and ways to achieve ecological balance figure predominantly in the broader discourse about the environment. These concerns conceptually drive EV projects. For present purposes, environmentalism is an attempt to balance relations amongst humans and the natural systems on which they depend in order to maintain sustainability, now and in the future. This eco-centric behavior depends on an individual person's awareness of the effects of human action upon the environment. These human actions include energy consumption, land-use practices, and strategies (including the lack thereof) of dealing with atmospheric pollution.

Environmentalism as a set of behaviors depends upon a culture of sustainability. Sustainability is a loaded term with a variety of meanings.[16] Sustainability is of central importance to a number of authoritative sources, including business-oriented environmental organizations, EV researchers, and national policy makers. Each offers their diverse interpretation of sustainability:

- **Econimically focused**: "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development [WCED], 1987).
- **Resource focused**: " how humans manage and maintain natural resources for future use without compromising ecological diversity" (Holmes 2006, 3).
- **Urban / community focused**: "a set of values, goals, strategies, and initiatives that communities — and the institutions and individuals within them — adopt to meet their needs without compromising the ability of future generations to meet their own needs. Increasingly cities are interpreting urban sustainability as a decision making framework that considers all benefits and costs to the economy, environment, health, and quality of life" (Parzen, 2012, 51).

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[16] Sustainable business development is a salient issue in our contemporary economy, and there is still work to do to achieve the United Nations' set goals (United Nations, 2013).

For an analysis of said report, see: Confino, 2013.

The UN High-Level Advisory Panel recently submitted a report saying that faster, broad-based change is needed (Jeremić, Vuk and Dr. Jeffrey Sachs, 2013).

- **Systems focused**: "requires comprehending linkages between cities, nature, and countryside and thinking holistically about the interconnections of water, energy, transportation, communications, and other infrastructure" (Scarlett, 2012, 52).

The economic- and resource-focused definitions articulate sustainability looking towards future development and use of resources. The first, economically focused interpretation is too ambiguous in terms of its future resource use, and fails to address pressing questions about the real needs of business to grow their profits. Sustainable business development strives to meet the triple bottom line[17] (TBL) of accountability, including social, ecological, and financial factors that contribute to public sector full cost accounting.[18] Innovative thinking about the environment and development was first introduced in 1987 through the *Brundtland Report*, but these mandates do not always result in social and environmental justice.[19] Sustainability researcher Pratima Bansal asserts that time is central to sustainability, which aims to secure intergenerational equity through intertemporal trade-offs (2014). Time is the aspect that differentiates sustainability from other similar concepts, such as corporate social responsibility (CSR).[20] Bansal supports this assertion by exemplifying how CSR may lead to environmental and societal degradation (Ibid, 72).

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[17] Sustainability scholar John Elkington coined the phrase "the triple bottom line" (TBL) in 1994 as a conceptual framework for business analysis (Elkington.1997).

[18] The TBL dimensions are also commonly called the three Ps: people, planet and profits. The TBL captures the essence of sustainability by measuring the impact of an organization's activities on the world, including both its profitability and shareholder values and its social, human and environmental capital. For an overall understanding of TBL, see Slaper and Hall, 2011.

[19] The Brundtland Report's obfuscated introduction of the term sustainable development was a result of the UNWCED's inability to properly identify and analyze the mode(s) of production that are responsible for degradation of the environment. In the absence of analyzing the principles governing market-led economic growth, the Report postulated that such growth could be reformed and expanded (UNWCED, 1987).

[20] Responsibility scholars argue that CSR represents the set of organizational activities that are good for both society and business (McWilliams and Siegel, 2001).

The second, resource-focused interpretation holds environmentalism at its core, with an implication that meeting current and future economic needs would be a requirement. Like the first articulation of sustainability, this definition is inconclusive.

Each definition has something useful and relevant to offer for the comprehension of sustainability. However, the third and fourth definitions offer the most provocative and comprehensive framework pertaining to this investigation. Unlike the preceding articulations looking towards the future, urban / community and systems focused approaches to sustainability are situated in the present, considering interconnected social space. The urban / community and systems approach are also conceptually aligned with eco-art, which holds that organisms are interdependent.

Information Visualization

Information visualization (info-vis) is about making something visible, building a foundation for thoughts and questions, explaining interrelationships and for obtaining new knowledge. I draw from the research of Warren Sack, a professor of film and digital media at University of California, Santa Cruz, who specializes in social computing, software design and studies, and media theory. Sack situates info-vis as a spatial product and a producer of space:

> The genealogy of information visualization work includes the collection of work done by artists and designers throughout centuries to make these collective bodies visible and give them the means to assemble and connect. There is a specific lineage of this work devoted to the *demos*, the creation of spaces, places and representations for the Body Politic of democracy.
>
> In other words, the aesthetics of information visualization concerns the Body Politic and the history of information visualization is the history of art and design created to gather together, reflect and represent the Body Politic. Its history includes the history of public spaces, the arts, and literatures (Sack, 2007, 14).

Sack's description of information visualization situates the practice as a tool for collective communication of knowledge both public and private. Once communicated, the knowledge empowers individuals and social entities (corporations and states, for example) to initiate behavior and / or policy changes. A sustainable world requires the participation of everyone to provide knowledge, make decisions, and change their daily routines (Myers and Macnaghten, 1998, 333).

Technological devices continually gather and compile a vast amount of information regarding any number of topics from a variety of sources. However, this data is seldom visual and the relationships between the data sets can be obscured and confusing for those outside particular fields. The information is hidden in numbers and broken up between industry reports. This knowledge fracture is remedied by info-vis. Data is actively associated and connected, in order to provide a foundation to support cognition and promote further research. Info-vis is a tool for sensemaking, for knowledge crystallization. According to Stuart Card, a pioneer in human-computer interaction, sensemaking involves the following actions: 1) Acquire information. 2) Understand the connections between the information. 3) Create something new from the data. 4) Act on this new understanding. By going through these processes, info-vis will amplify the user's cognitive powers (1983). Info-vis is a mode of communication that uses data from layered and complex systems, making visual the connections amongst seemingly disparate datasets. Info-vis can also be an art form, and it is referred to artistic info-vis. In an influential paper in 1948, scientist Warren Weaver recognized that science is shaped by "problems of organized complexity" (4). Weaver argued that future scientific endeavors needed to simultaneously deal with large, complex systems of information, composed of a considerable number of connected and interdependent variables. By influencing contemporary thinking about science and network

theory, Weaver laid the groundwork for recognizing rhizomatic properties of complex information including decentralization, emergence, mutability, nonlinearity, and diversity. The rhizomatic, networked structure of information visualization operates as a decoder of complexity in a graphical / visual way to express connections and meaning within and among data.

A number of leading media theorists and researchers offer definitions of info-vis, that when read together, offer a comprehensive understanding of the contemporary field as it relates to technology:

1. Infovis is the use of computers to interactively amplify cognition, using visual representations and metaphors for mapping abstract data (Card, et al., 1999).
2. Visualization "can be thought of as a particular subset of mapping in which a data set is mapped into an image" (Manovich, 2002, 2).
3. Info-vis is a set of tools and techniques for distinguishing the 'forest' from the 'trees,' a means for providing context from the data details (Sack, 2007).

The first definition relies on technology as a main component of visualization. Computer-driven visualizations dominate the discipline, and are components of the EV projects discussed in Chapter One. However, the two latter definitions of info-vis are more pertinent to this introduction, and allow for a wider interpretation of visualization specifically as it pertains to the discipline of EV.

Sack asserts that the practice of info-vis arose from a practical need for governance, orientation and navigation to create a visual archive and filing system. Info-vis fills a cultural need to comment on, critique, provide alternatives, and distance the group from the bureaucratic forms and procedures of modernity, especially those of information technologies, government practices, and hegemonic business tools and ideas (2007, 13).

The field of info-vis is extensive, reaching in all directions of inquiry. For the purposes of this research, I focus on the sub-discipline of EV, dealing with environmental and ecological

information, in specific, those projects visualizing energy use, weather patterns, air & water quality, and issues related to animal conservation. Info-vis is directly associated to the disciplines of Human-Computer Interaction (HCI) (Card et al., 1986; Carroll, 2013), Persuasive Technology (Kim, T. et al., 2010; Fogg, 2002), and Ubiquitous Computing (UbiComp) (Weiser and Brown, 1997).

HCI, Persuasive Technology, and UbiComp have associated concerns that are relevant to the characterization of digitally based info-vis. Persuasive technology is designed to change the attitudes or behaviors of its users through social influence without coercion. In doing so, persuasive ambient displays can bridge sustainable design and info-vis (Kim, et al., 2010, 105). However, voices of dissent argue that persuasive technology (including HCI and UbiComp) is problematic as a process that can prioritize technology as a way of improving life.
Hrönn Brynjarsdóttir, a computer scientist specializing in the politics of information, asserts that narrowly framing persuasive sustainability as a simple metric of the relationship between human behavior and sustainable actions can lead to incorrectly placing technology as an objective arbiter over more complex issues of sustainability (2012, 947). This framing leads to portraying sustainability as fixed, known, and stable, and excludes social political concerns regarding resource allocation (DiSalvo et al., 2010; Dourish, 2010; Pierce et al., 2010).

Persuasive sustainability systems can be understood as an example of modernist[21] technology design, which aims to improve life through technical means and embraces scientific perspectives as the grounds for new definitions of value. In a modernist mindset, these formal

[21] Modernist approaches are characterized by three axioms: First, techno-scientific reasoning and top-down, expert knowledge are a way to organize our lives; Second, orientation around means-end thinking, maximizing efficiency, and exerting control are ground principles optimizing daily processes; and Third, rational methods capture essentially everything that matters about a given situation (Brynjarsdóttir et al., 950).

methods of sensing can capture the essential aspects of sustainability and lead to a predicted outcome. Modernist technological design indeed has a positive outcome for persuasive sustainability: an actionable framework structures novel solutions for managing modes of resource minimization. However, modernist solutions are based on a "narrowing of vision" (Scott, 1999, 11).[22] Brynjarsdóttir et al. note that while a narrow vision enables a range of technical solutions, those solutions collapse beyond the constructed framing of the problem (951). Persuasive technology does not tackle the complex issue of sustainability as a whole and focuses on granular individual consumer behavior. Focusing on individual pattern consumption can obscure the actions of larger entities (Dourish, 2010, 3). The methods used by persuasive technology can lead to focusing too strongly on numerical analysis of individual actions, accepting expert or authoritarian decisions made by designers, and making the assumption that people will change their behavior after understanding provided information. Persuasive technology is not able to study the *meaning* of individual actions. Systemic problems include that persuasive technology focuses too much upon incremental over systemic change (again, individual user changes versus shifts of scale), and when the political dynamics as they impact individuals are understood, the persuasive solutions fall apart (Brynjarsdóttir et al, 2012; Strengers, 2011; Dourish, 2010; Pierce and Paulos, 2010; Woodruff et al, 2008). The narrow vision of persuasive sustainability is reductive, unsupportive of a synoptic view and difficult lifestyle choices that might be necessary for sustainable, green societies.

Within the discipline of info-vis two main areas of research and application emerge that are returned to time and again. First, practitioners of info-vis are engaged with aesthetics, defined

[22] Similar discussions of the possibilities and limitations of modernist design approaches are presented in (Edwards, 1996) and (Weber, 2002).

here as an appearance that is artistically beautiful or pleasing.[23] Noam Tractinsky, a researcher in the aesthetics of information technology, asserts that research in HCI reveals a bias towards the pleasing appearance of artifacts based on computing technology, rather than the effects of their displeasing counterparts. The aesthetic experience of HCI is based on audience reaction, rather than the object having an inherent aesthetic value.[24] Tractinsky also notes that the time frame for aesthetic appreciation can range from fast reactions to slow contemplations. Visual aesthetics encompasses three main areas, including the design perspective (the principles of design), the psychological perspective (a source of pleasure), and the practical perspective (design differences) (Tractinsky, 2014).

Second, practitioners analyze audience response and the ways in which info-vis may influence behavior change.[25] Brynjarsdóttir et al. ask if persuasive sustainability leads to behavior change. In an overview of the literature, they find little or no evaluation. In some cases this is because the info-vis researchers cannot evaluate because they are testing a design methodology or are discussing only preliminary results. Brynjarsdóttir et al. also find that when

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[23] The discussion of aesthetics is wide-ranging. For the purposes of this research, I limit the discussion to the context of human development. For the seminal text on the psychology of aesthetics, see: Arnheim, 2004. For the psychology of aesthetics in design for our health and survival, see: Hekkert, 2006. For a discussion of aesthetics as it relates to evolution, see: Tooby and Cosmides, 2001.

[24] Seeing an object as beautiful or aesthetically pleasing may be a more a matter of position than a matter of truth, with familiarity and authority as key factors. For a discussion of beauty and functionality within objects, and HCI specifically, see: Hassenzahl, 2012; Frohlich, 2004.

[25] A number of studies research the behavioral effects of info-vis. Research has shown that there is no single construct that predicts environmentally friendly behavior, see: Oskamp et al., 1991.

Design strategies differ for individual and collectivist cultures, see: Kimura and Nakajima, 2011.

Design strategies that support behavior change, including abstract & reflective, unobtrusive, public, aesthetic, positive, controllable, trending / historical, comprehensive, incentivizing, and competitive, see: Consolvo et al, 2009; Midden et al., 2007; Gasser et al., 2006; Bergeron, 2006; Michael and Chen 2005; McMakin et al, 2002.

For feedback behavioral strategies through design, see: Froelich et al., 2010; Fischer, 2008; Darby, 2006; Geller, 1982.

For design strategies stimulating critical reflection, see: Pierce et al., 2010; Dunne and Raby, 2001; Stern, 1993 and 1999.

behavior changes are claimed, anecdotal evidence is related but it is difficult to determine what behaviors changed or by how much (949). While some short-term evidence is reported, long-term evidence of behavior change is rare, with only one study that could be considered long-term (beyond the norm of three to four weeks in length) (Broms, et al., 2010). Rather than choosing a bottom-up, participatory or user-centered model, info-vis researchers chose a top-down method, where the targeted behavior and the measuring metric of that behavior are predetermined. A predetermined point of evaluation indicates that the info-vis is a device or program designed for consumer use.

Measuring individual consumer behavior with EV is not relevant for the purposes of this research. Instead, I evaluate the project in a larger cultural context, examining the aesthetics of governance within the spaces and representations of our contemporary culture. The practice of information visualization, and by extension, EV – is a tool for collective communication of information in order to empower individuals and social entities to initiate change.

Dynamic Data and Static Data

In the literature, info-vis is characterized as employing two distinct types of data sets: dynamic and static data. Researcher Melanie Tory, Director of the Visual Interaction Design (VisID) research group at the University of Victoria, articulates the distinction between the data sets in terms of their variables. Tory names a number of characteristics:[26]

- Scalar, vector (2D, 3D, or nD), tensor, or more complicated structure.

[26] Data types are categorized into 1-, 2-, 3-dimensional data, including linear data types encompassing textual documents, program source code, and alphabetical lists of names organized in a sequential manner; temporal and multi-dimensional data, including geographic maps, floor plans, or newspaper layouts; and tree and network data, including real-world objects such as molecules, the human body, and buildings that have potentially complex relationships with other items (Shneiderman, 1996, 337-338).

- Discrete (e.g., number of people in a city) or continuous (e.g., population density across a metropolitan area). In many cases, data is discrete but sampled from a continuous source (e.g., medical images); this data may be considered continuous since we can interpolate between sampled points to guess at the values in between.

- Nominal (values have no natural order), ordinal (values have a natural order), interval (there is a meaningful distance metric between any two values, so arithmetic can be done on them), or ratio (an interval variable with a meaningful zero). For example: (1) The set {cherry, apple, banana} has no natural order and is nominal. (2) The sets {small, medium, large} and the alphabetically ordered {apple, banana, cherry} are ordinal. (3) Temperature is commonly measured using interval scales such as Celsius and Fahrenheit. (4) The Kelvin scale for temperature is a ratio scale because it has an absolute zero (i.e. 0 K is the lowest possible temperature) (2004, 2).

Of the listed data sets, several forms may be represented visually, including data values (as described above), data structure (file hierarchies, grid formations), and meta-data. Meta-data is derived from data values or structure (it is data about data). Derived data can consist of derived values and / or derived structure. Both dynamic and static data are referred to in info-vis literature; however, static data is of less interest to contemporary digitally based visualization researchers. Even though static datasets are less prevalent, they are featured a part of the field, and are featured in EV projects discussed in Chapter Two. In my chosen examples dynamic data is visualized with a screen or with other computer-mediated technology. Static data is visualized with non-digital materials.

Dynamic info-vis is characterized by variations over time. In essence, dynamic data is state-changing (Marca and McGowan, 1982, 137). As listed above, data can be discrete but sampled from a continuous source (wind speed); wind speed data may be considered dynamic when it can be interpolated between sampled points to guess at the values (speed) in between (Tory et al., 2). For example, static, time- and place-based wind speed data becomes dynamic when it is continuously read from a large region. Martin Wattenburg's and Fernanda Viégas's *Wind Map* (2012 – present) project illustrates aspects of dynamic data: static wind speed

information is interpolated and visualized. Wind speed data is produced by weather reading devices, sampled across the continental United States, and collected from the National Digital Forecast Database (NDFD). *Wind Map's* imagery subtly shifts and changes hourly as surface data is updated. *Wind Map* estimates the wind speed between sampled points. Because of this, Wattenburg and Viégas advise against using *Wind Map* as a weather map.

Dynamics in digital info-vis are not limited to the data; dynamics can include user-interaction for navigation, continuous queries (web trawlers), and streaming information. I continue to draw upon *Wind Map* to exemplify two of the above points. First, users can navigate the *Wind Map* page by hovering their cursor. Once paused, the wind speed and North / South coordinates are displayed. The users can further interact with the map by clicking and enlarging a given point. The site responds by enhancing the web view to offer more details of wind pattern. Wattenburg and Viégas programmed *Wind Map*'s algorithm to dynamically query the NDFD for hourly wind information, so their imagery changes over the course of the day according to the wind patterns through the US.

The dynamics of info-vis can also be visual. Joseph Cottam, a post-doctoral researcher at the Center for Research in Extreme Scale Technologies, notes that the optical aspects of digital dynamic info-vis change over time by modifying two sets of variables, spatial and retinal. The spatial variables are the X, Y, and Z coordinates in a 2D space, such as a computer screen. An element changes its coordinates by moving within the area of the screen, including layering over other elements (Cottam et al., 193). Retinal variables include but are not limited to the size, value, orientation, texture, hue and shape of visual elements (Ibid, 193). *Wind Map* exemplifies dynamic visuals and is structured as a series of flow lines in the form of comet-like trails. Wind patterns are visualized using a generated texture of discrete points in response to the data input.

The texture constantly changes and is animated to illustrate flow direction and magnitude of wind movement. Dynamic visuals are unpredictable, bounded only by incoming data.

Static data can function as an unmoving, foundational structure for info-vis (Marca et al., 1982, 137). This data may be an unchanging number, for example, a water temperature at a given time. Static data is what the artist Nathalie Miebach uses to inform her work. Miebach gathers temporal weather data, both numeric and observational. This collected data is compared against historical information and is then plotted in three dimensions to create a sculpture. The weather data is discrete, and from a continuous source. Miebach's work will be discussed at length in Chapter Two. Static data may also be historical information, as with Miebach's work, in which case analysis and representation convey historical dynamics (Wolter et al., 2009). Cottam et al. assert that it is up to the audience to interpret a static info-vis by identifying the correspondences between the visual representation and the underlying data (2012).

Maps, Diagrams, and Graphs as Information Visualization

Spatial metaphors dominate info-vis research. Phrases like 'mapping information,' 'information terrain,' 'network navigation,' and ideas including the visualization of scale are regular concerns within the discipline and are prevalent in my discussion of EV. For example, info-vis researcher Rohrer states that visualizing the nonvisual requires mapping the abstract into a physical form, whether the form is a pixel or a physical object (1998). In keeping with the mapping metaphor, some info-vis works take the form of a map and their creation is informed by existing cartographic approaches (Skupin, 2000). Maps are efficient when the data being conveyed is presented as clearly as possible. For efficiency, the main data should be clearly distinguishable from the additional information displayed, such as the terrain or boundary lines of the geography. *Wind Map* is efficient – a minimal amount of geographic data is used to give

context to the dynamic imagery, including the outlines of the continental United States and a few major cities. Other EVs, like Miebach's series, *The Sandy Rides,* work in opposition to this idea of efficiency. While information is mapped into a dimensional object, the "mapping" is interpretive. Miebach's artwork is open to audience interpretation: the audience can identify the correspondences (or not) between the visual representation and how it is formed by the underlying data.

Refining and systematizing the art of mapping was conceived by cartographer Jacques Bertin, as he laid a foundational theory for information visualization with his seminal 1967 work, *Semiology of Graphics: Diagrams, Networks, Maps*. Bertin asserts that the effectiveness of any diagram is based on the degree of structural equivalence and meaning that can be reached between data and the visual variables. In the case of maps, geographic coordinates fix the most powerful variables, the two planar dimensions, as in elevation. Any information beyond geometry must be expressed by encodings using the remaining retinal variables. Bertin describes graphic representation as

> One of the basic sign-systems conceived by the human mind for the purposes of storing, understanding, and communicating essential information. As a 'language' for the eye, graphics benefits from the ubiquitous properties of visual perception (2).

Bertin lays the groundwork for information visualization by articulating graphics as a monosemic system of signs. In a monosemic system, the meaning of each sign is known and agreed upon, specified and stated through the legend or external identification.

These concepts spread to other visual disciplines, and Bertin later noted that graphic designers seek to reduce confusion, enable discussion of a collection of signs, and construct a rational moment of understanding (1984, 2). Successful graphics function by answering a chosen question through the recording, communicating, and the processing of information. When the

information is complex and multi-layered, the organization and visual representation of the components must follow in order to convey meaning without misunderstanding.

One case of visual confusion is the Dymaxion Map, patented in 1946 by Buckminster Fuller.[27] The Dymaxion Map, arguably based on Cahill's patented butterfly map of 1909, solves several problems facing other map projections, namely the distortion of the size and shape of some continents. Instead of projecting the round earth onto a flat surface, Fuller presented the globe as an unfolded cubo-octahedron, thus visualizing the Earth's landmass as an island in one large ocean, with very little distortion or splitting of the continents. While accurately displaying the size and shape of continents, the angular geometry of the icosahedral-shaped map is criticized for having a weak correlation to the globe. Other criticisms include Fuller's disregard for accuracy in ocean areas, with the map being unsuitable for navigation because of the broken parallels and bent meridians (Stockton, 2013).

Graphs can be a way to convey relationships between data sets, but they can become confusing if they are too abstract in their representation, similar to the visual confusion created by the Dymaxion Map. While a graph is a perfectly accurate means by which to represent data, it may only be meaningful to its creator. In *Visualizing Data* (2008), Ben Fry warns against using a graph because of the susceptibility to obscure information:

> There is a tendency when using graphs to become smitten with one's own data. Even though a graph of a few hundred nodes quickly becomes unreadable, it is often satisfying for the creator because the resulting figure is elegant and complex and may be subjectively beautiful, and the notion that the creator's data is "complex" fits just fine with the creator's own interpretation of it. Graphs have a tendency of making a data set look sophisticated and important, without having solved the problem of enlightening the viewer (241).

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[27] The Dymaxion map folds into an icosahedron and then morphs into a globe. See: Rywalt, 1995.

Fry is referring to work made specifically for communicating information clearly and his concern is relevant for info-vis (and particular EV projects) whose goal is direct, unequivocal dissemination of data. However, I argue that not all EV work is created for the same purpose (direct communication of data), but is made to convey an idea, provide insight, stimulate other sensory responses from the viewer, and critique culture.

Info-Vis and EV: Strategies and Functions

One main concern of info-vis is its ability to effectively communicate disparate data. In this section I establish an analytical basis for evaluating EV through a set of strategies and functions set forth by leading visualization researchers. I draw from the work of James Pierce, an interactive design researcher at the Berkeley Center for New Media. Pierce et al. (2008) offer eight communication strategies that characterize successful EVs.

1. Offers behavior cues and indicators.
2. Provides tools for analysis.
3. Creates social incentive to behave sustainably.
4. Connects behavior to material impacts of consumption.
5. Encourages playful engagement and exploration with energy.
6. Projects and cultivates sustainable lifestyle values.
7. Raises public awareness and facilitates discussion.
8. Stimulates critical reflection.

Conservation goals are supported by the first two strategies by providing useful information, in the form of contextual real-time feedback (as with live-streaming data) or ambient feedback (a pre-processed set data source). The tools for analysis differ from project to project, with some offering tools supporting pattern behaviors. Pierce et al. note that they assume that the audience has an *a priori* motivation to adopt sustainable behavior. The third and fourth strategies are

incentivizing, specifically where no financial incentives are present. These incentives may take the form of competitive games or public disclosure of sustainable activities, in order to support a connected understanding of individual and collective impact. The final four strategies are about the experiential aspects of EV that encompass playfulness, curiosity, exploration, and reflection. The user or audience may be engaged for the pleasure of the visual and/or physical experience. I interpret and expand upon the fifth strategy to signify the issue at hand, be it energy use, weather patterns, or air quality. The EV may take a form that is a symbolic gesture of awareness and a reminder for sustainable practice. An EV may also bring issues of energy consumption and environmental sustainability to the forefront of cultural knowledge, thereby prompting social action. Finally, EV may stimulate critical reflection upon the technology, energy, and materials used therein, and can be self-reflexive in addressing those concerns.

Collaborators since 2003, Wattenburg and Viégas lead Google's "Big Picture" visualization research group. Their main concerns include addressing the questions of data transparency and its social impact beyond academia, business, and government by complicating and subverting a tool that is largely used for analysis by both business and the military. As info-vis practitioners, Wattenburg and Viégas recognize "the critical role played by conversations… and social activity surrounding graphical data analysis" (2006, 810). They note that info-vis enables simultaneous viewing and polyvocal discussion within multiple contexts (802). They also note that visualization has the potential to become a mass medium (2011). Like Pierce et al., they posit guidelines for success:

1. Making the visualization relatable.
2. Share and discuss the visualization.
3. Be expressive and engaging.

Wattenburg and Viégas assert that there is no conflict between communicating well and engaging audiences. The first guideline suggests offering personalized entry points so individual users can orient and add their own context for knowledge. The second guideline asserts that it is through social experience that info-vis attracts interest, allowing for a deeper understanding of the data. The third guideline is to be expressive, using emotion through deliberate choice.

Ben Shneiderman, a computer scientist and founding director of the Human Computer Interaction Lab at the University of Maryland, College Park, offers a deceptively simple strategy for designing advanced digital graphical user interfaces. The Visual Information Seeking Mantra is: "Overview first. Zoom and filter. Details on demand" [Repeat mantra] (1996, 336). The mantra functions as a design guide and structure for his type by task taxonomy (TTT) of info-vis. Shneiderman's assumption is that viewers are seeing collections of information, with each type of information having multiple attributes. After the mantra, there are seven tasks that function as abstraction of reality:

1. Overview: Gain an overview of the entire collection.
2. Zoom: Zoom in on items of interest.
3. Filter: Filter out uninteresting items.
4. Details-on-demand: Select an item or group and get details when needed.
5. Relate: View relationships among items.
6. History: Keep a history of actions to support undo, replay, and progressive refinement.
7. Extract: Allow extraction of sub-collections and of the query parameters.

Shneiderman asserts that the strategies are useful only if their use leads to discussion and further research. Though some of Shneiderman's discussion is applicable only to digital info-vis, (strategies 6 and 7), most of the mantra and tasks can be applied to non-digital EV projects.

Building upon the above strategies as outlined by Pierce et al., Wattenburg and Viégas, and Shneiderman, are the five functions of visualization outlined by Manuel Lima. Lima is a computer interaction designer and researcher, at the forefront of networked information design development. Most importantly Lima asserts EV's future relevance as a form of communication. He states that visualizations will "prove useful for illuminating the most complex and important network of all: Earth's biosphere…These include not only the biological networks that sustain us but also the generation of the 'natural resources' that feed consumer society's global production and distribution networks" (256). Lima contextualizes his discussion of the five functions of visualization within the broad discipline of info-vis. Lima's five functions will be applied to EV.

In his 2011 publication, *Visual Complexity: Mapping Patterns of Information*, Lima builds upon Edward Tufte's foundational theory of design. Tufte is a statistician / computer scientist / design intellectual who states how an overarching concept directs visuality:

> "Ideas not only guide work, but also help defend our designs (by providing *reasons* for choices) against arbitrary taste preferences" (Tufte, 1990, 82).

Excellent info-vis is guided by aesthetics and the principles of information design. The standards of quality are "derived from visual principles that tell us how to put the right mark in the right place" (9). Tufte argues that images, words, numbers, and artistic interpretation intersect to create a whole, dependent upon the fluid interaction of composition, text, and information. Though Tufte's theories guided generations of designers towards thoughtful and expressive work, some researchers believe that Tufte's theory of color use led to too many beige-colored diagrams (Wattenburg and Viégas, 2011).

Lima contends that digitally based info-vis has an embryonic and evolving taxonomy of form.[28] This visual language is characterized by systems that use shared structures. A single data set may be visualized in several different ways depending on the way it is read and implemented by the artist / researcher. These visualizations include but are not limited to classifications like the "Arc Diagram," "Area Grouping," "Centralized Burst," "Centralized Ring," and "Organic Rhizome."[29] Other common structures include tree diagrams and graphs. They may have dynamic organization, but remain restricting in the digital realm, which is better represented by networked systems and webs of information. Networks have a rhizomatic structure and are symbols of autonomy, flexibility, diversity, multiplicity, and collaboration within socially shared virtual space. Lima states that networks are "contributing to a considerable shift in our conception of society, culture, and art, expressing a new sense of beauty" (221). While communicating data from a variety of sources, including multiple geographies and times, these emergent forms foreground a sense of interconnectedness and complexity, rhythm and movement, pattern and structure, with resemblances to natural patterns.

Info-vis is not only a decoder of complexity but also consists of five key functions. The first function is to document, which is to map a previously undocumented system and opens the door for further discoveries. The second function is to clarify, making the system comprehensible and transparent, which supports information processing and understanding. The

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[28] A number of info-vis taxonomies exist in the literature and expand annually. For taxonomy of dynamic info-vis, see: Cottam et al., 2012.
Info-vis analysis taxonomy, see Heer et al., 2012.
Info-vis animation taxonomy, see: Heer et al., 2007.
Info-vis for data-state model of visualization, see: Chi, 2000.
Taxonomies of time-varying data, see: Aigner et al., 2007; Daassi et al., 2006; Wolter et al., 2009.
Taxonomy of visualization via the models used, see: Tory et al., 2004.
Taxonomy of visualization within three-dimensional space: Keim, 2002.

[29] Other structures include code swarm visualization and flow lines, see Cottam et al., 2012.

third function is to reveal something exciting within the data set. Lima suggests that the reveal should rely on causality through disclosure of relationships while checking the central questions of the data. The fourth function is to expand, allowing the data to become a vehicle for other uses and enabling further exploration. To expand upon the data enables the information to become part of a larger work. The data can also be a means to an end or used as an underlying layer of additional visualizations. Finally, the fifth function is to abstract the data in order to explore the schema as a platform for representation. With abstraction, the visualization can depict a variety of intangible concepts that might not rely on an existing data set.

Though these strategies and functions are originally stated in the context of computer-driven info-vis, I assert that EV projects do not need to be screen-based to efficiently communicate disparate information sets. Collected together, these strategies and functions provide a means for analysis of the structure and function of EV work. Each of these points in turn will be discussed in relationship to digitally based EV projects in Chapter One, including *Building Run and Eclipse.* They will be explored in Chapter Two with projects that use multiple materials and are three-dimensional including *Cloud Car*, *Particle Falls*, *The Sandy Rides, and Mussel Choir.*

The Aesthetics of Info-Vis: Pragmatic and Artistic Visualization

Info-vis increasingly relies upon the power of aesthetics to sustain interest and communicate effectively, as discussed in a number of studies (Tractinsky, 2014; Kosara, 2007; Lau et al, 2007; Viégas and Wattenberg, 2007 and 2011). HCI researcher Marianne Petersen asserts that aesthetics is the foundation for a purposeful system of communication, and has the ability to surprise, provoke thought, and move the subject to a new insight of the world:

> "Aesthetic Interaction is not about conveying meaning and direction through uniform models; it is about triggering imagination, it is thought-provoking and encourages people to think differently about the encountered interactive systems, what they do and how they might be used differently to serve differentiated goals" (Petersen et al., 2004, 271).

For the purposes of this Introduction and the following chapters, I use the term 'aesthetics' to mean that which is visual and sensory within EV work, and discuss the role of aesthetics in effective and successful EV works.

Info-vis researchers agree that not all data is created equal, with key points being emphasized in different ways (Viégas and Wattenberg, 2011; Few, 2009.) Within the literature, there exist two types of info-vis: digital, analysis-oriented work and analog, interpretive artistic pieces. These are organized in one of two ways: pragmatic and artistic info-vis (Kosara, 2007). These pragmatic and artistic info-vis categories are not related to dynamic and static data sets – a pragmatic info-vis may be based on static data or dynamic, an artistic info-vis may be based on dynamic data, and vice-versa.

On one end of the spectrum of info-vis are pragmatic visualizations. They are created to show only the data, be purposely devoid of interpretive possibility, and use an accepted language (for example, a bar chart). Pragmatic visualization is "designed to remove any sublimity, and instead foster immediate understanding" (Viégas and Wattenberg, 2007, 190). Pragmatic visualizations result from Tufte's assertion that a large share of the ink on a graphic should show the data (1983, 96). This statement was interpreted as a directive in order to not distract the viewers with irrelevant elements. Pragmatic visualization is ultimately designed for visual efficiency and straightforward transmission of information enabling quick readability and immediate understanding. Pragmatic visualizations "have sought to minimize distortions, since these might interfere with dispassionate analysis" (Wattenberg and Viégas, 2007, 9). In this respect, info-vis was designed to maintain a functionalist perspective for a particular set of

analytic tasks (Pousman et al., 2007, 1147). Artistic info-vis opens spaces for personal stories and meaning, and has multiple correct readings of information (Pousman et al, 2007, 1151). Though indexical representation is good for informative and retrospective purposes in info-vis, iconic and metaphorical images can trigger more awareness and motivation for future behavior change through emotional attachment (Kim et al., 2010, 116).

Info-vis can be embedded into the everyday environment. This aesthetically pleasing information can change subtly, moving from the periphery to the focus of attention. Info-vis researcher Zach Pousman identifies info-vis which is ambiently embedded into the everyday environment as casual info-vis (2007). Technology and information systems can be integrated into the environment seamlessly in order to create spaces that are invested with knowledge and meaning (Aipperspach et. all, 2008.) Pousman et al. assert that casual, artistic info-vis may be useful artifacts that are helpful for providing representations of data, but without a clear task focus (2007, 1151). They recognize that eco-visualizations can function as ambient displays, relaying information that is important but not critical. Contextually adapting info-vis for different environments supports its effectiveness (Rodgers and Bartram, 2011; Bartram et al., 2010). Info-vis can relate data in abstract ways, and these modes of representation are visually rich and complex, especially when integrated to the rhythms of life. This includes home life, personal data sources, and to other areas of social engagement (Pousman et al., 2006 and 2007).

Pragmatic and artistic info-vis serve different purposes. I am most interested in and will discuss a variety of artistic EV, from those that are digital and device-mediated to those that are sculptural. They necessarily shift in style from being highly correlative to being more interpretive as each project grows more complex visually and functionally.

Sack asserts that when looking at artistic info-vis we are not to worry if they are beautiful, friendly, or easy to use:

> Instead interrogate them by asking what sorts of governance they support or reflect: Are they democratic or bureaucratic? In short, I ask that we shift our attention away from visual aesthetics and focus, instead, on an aesthetics of governance" (Sack, 2007, 8)

Sack's argument is compelling, but limiting. It is not enough to focus only on the aesthetics of governance because that does not allow for an interrelated, systems-based understanding of the ways artists are working to address ecological crisis. Instead, I will take a synoptic view and examine both visual aesthetics and the aesthetics of governance of EV. By doing so, I will consider how EV projects may reiterate the modes of industrial production and bureaucracy in order to engage, decode and critique them (Ibid, 6). By analyzing EV within our larger political and cultural contexts, I will position EV not only as a sensemaking tool for complex environmental issues, but also as a way to see the way we function within our immediate community, and beyond within a larger Body Politic.

Creative Project

The creative project is a series, *Sculpting Corn Production*, consisting of small, discrete paper sculptures. The work exemplifies the concepts and information regarding EV artwork as explored in the research investigation in a number of ways, including the strategies and functions as discussed in this Introduction. My studio work benefits from the insight of contemporary artists and info-vis researchers, including their concerns and processes within the EV genre. The research and writing have provided a strong foundation from which to develop my research and methodology. EV is a new direction for my studio work, though I have long been interested in the visualization of hidden environmental information.

The creative project presented an opportunity to engage with specific datasets in a physical and visual manner and to demonstrate the broadened definition of EV set forth in the research investigation. For instance, my chosen imagery is driven by predetermined static data sets rather than by streams of dynamic data. My creative work has used rules-based making and processes in the past, attributing a series of values, including color, form, and even physically responsive outputs to information input. Like my past work, the creative project employs rules-based making (attributing shape to data), but unlike my past work which has been playful in nature, this new body of work is serious in approach to content and form. This is a result of experimenting with familiar forms; each structure was based on existing architecture and numerical data, created multiple times, and manipulated until each element worked together as a unified structure. The imagery is dynamic, created with a sense of interpretive complexity. Though the visual elements are guided by data, the resulting imagery has undergone an uncoupling of shape from information. This work employs a multiplicity of logics and irregularity through my interpretation of the data. My EV is abstract – ultimately its logic may only be available to me. The creative project is a foundation for future work through the development of concept, the exploration of process, the interpretation / translation of data, and the deployment of information through form. Realizing successful aesthetic and visual elements of the creative project are fundamental to the overall success of the creative project, and will support future research. Creating a series of dimensional EV works has provided me with an opportunity to broaden my understanding of the process and contribute new knowledge to this emergent field.

During my research I have found a vast amount of information related directly to industrial corn production in the United States since the 1970's. The available information

includes but is not limited to: national farm legislation and economic subsidies, data sets documenting the growth of grain farming, numbers of bushels produced annually, genetically modified seed availability, chemical repellent and fertilizer usage, documentation of the widespread use of refined corn sweeteners and fillers, indexes listing the rise of American obesity, and reports of the wide-ranging environmental impact of industrial farming. These vast data sets are not organized, interconnected or visual. Most of these sets are categorized as static, historical, and geographically specific. The EV is not an exhaustive overview of the aforementioned datasets; rather, it is a sampling of a select few. I began the creative project by asking one question: "What does the average American taxpayer spend to subsidize the American corn industry?" Rather than an exact answer to that particular question, more data was revealed than expected during the course of this research, and this has allowed for a broader visual interpretation of the information. The creative project makes visual connections between select groups of information, using color, movement, scale, and pattern in gestural abstraction.

Two main aspects of my studio process were instrumental in realizing the creative project: data collection and the visual translation of that information through rules-based making. For research and data collection I used U.S. Department of Agriculture resources as a starting point. I looked for patterns and substantive links between entities, such as the rise of government subsidies supporting corn production, when it was actually farmed at a financial loss. I assigned shape, size, and numbers to the data that will then be translated into imagery. I have had to simplify my ideas and sort through data to make choices about what data was relevant and needed to be visualized. The EV is a point of engagement with the corn industry in the United States; it functions as a way for me to understand our devastated monoculture landscapes and the widespread consumption of refined corn products, and to comprehend the financial structures

that continue to support the production of a product that is expensive in almost every way. The EV also informs new processes, concept development, and ways of deployment for studio work.

Chapter Overview

Chapter One: Screen-Based Eco-Visualizations

Chapter One is a discussion of EV work whose primary mode of representation is the screen. These EV artworks demonstrate innovative design, communication, concept, and context. They are real-time and interactive, generating information and changing aesthetically via dynamic data-sources. I discuss two EV projects whose concept and media function differently while remaining examples of visualized ecological data. They address differing but connected ecological concerns, including air quality and energy use. The artists and projects analyzed are EcoArtTech (Leila Nadir and Cary Peppermint), *Eclipse*; and Keith Deverell, *Building Run*. These projects are relevant because they are interpretations of streaming, dynamic data that also allow the audience opportunity for interpretation and analysis. I chose these projects because of their varied compositional choices and the ways they engage sensing and technology.

The collaborative ecoarttech, formed by Leila Nadir and Cary Peppermint, examines how digital technologies can make ecological problems accessible. In their online EV, *Eclipse,* they harness the information sharing of the web to create user-generated glitched imagery that translates current air-quality in US national parks. In *Eclipse*, viewers can see the effects of pollution imposed upon shared images of nature. *Eclipse* seeks to engage audiences removed from the actual experience through a technological mediation.

While *Eclipse* addressed air pollution, *Building Run* engaged civic energy consumption. Installed in 2013, Keith Deverell's *Building Run* was a real-time video installation that

conceptualized five buildings as competing athletes in a daily race for greater energy efficiency. The project documented real-time energy consumption using human avatars to represent each building, each running to beat its own personal best. *Building Run* was an EV work specifically for the "Sensing Sydney" project in Sydney, Australia.

Chapter Two: Multi-Dimensional and Multi-Modal Data Eco-Visualizations

Chapter Two is a discussion of EV work whose modes of representation are media other than screen-based work, including discrete sculpture and physical installations. The artists discussed use a variety of methods and materials to visualize ecological data. These interpretive artists and projects include Andrea Polli's *Cloud Car* and *Particle Falls*, Natalie Miebach's *The Sandy Rides* series, and Natalie Jeremijenko's *Mussel Choir*. I chose these projects because they are examples of EV situated beyond those that are screen-based: they are sculpture and installation works. These are highly interpretive and artistic examples of EV. Miebach's process, forms, and final sculptures are particularly relevant to my creative project.

Polli's EV works are primarily concerned with air quality and atmospheric conditions. The first work, *Cloud Car*, is a site-specific EV employing static data that shows the direct connection between the automobile and air quality. The car is fitted with equipment that produces a cloud of mist, enveloping car and rider to make air tangible and visible. The audience was invited to sit in the car accompanied by a guide and ponder their carbon footprint. The second work, *Particle Falls*, is a large-scale projection driven by dynamic air quality data collected with a nephelometer. Resembling a waterfall, the blue light projection is disrupted with orange burst of light as air pollution is detected, giving the viewer immediate feedback.

Miebach's eco-visualization work uses static data sets collected from weather data and related information as a basis for sculpture. Her recent work translates data related to Hurricane

Sandy by employing basket weaving as a grid, plotting the hours of each day. Upon this grid data is layered and interwoven in three-dimensional space. Miebach's *The Sandy Rides* expands how scientific data may be visually translated beyond graphs and diagrams into chaotic and playful sculptures. Miebach explores visual complexity through EV works like *O Fortuna, Sandy Spins*, *The Last Ride*, and *The Ride* in order to question our cultural fascination delicate coastal ecosystems and our tendency to ignore climate change.

Jeremijenko's *Mussel Choir* is a bio-sensing EV artwork that aims to engage the public on water quality and the unseen complexities of urban ecology. Consisting of a live colony of a native species of mussels, the artwork monitors the water filtration activities of these organisms and converts this data into sound, which is available for passersby who can listen to the mussel choir in situ. *Mussel Choir* is an example of an eco-visualization that uses a dynamic data set and variety of media to communicate in real time. Conceived as a way to both clean urban waterways and support environmental awareness, *Mussel Choir* creates a one-way knowledge bridge between humans and aquatic organisms.

Chapter Three: Sculpting Corn Production

Chapter Three is a discussion of my creative project, *Sculpting Corn Production*, a series of discrete sculptures including *Spiraling Corn Production*, *High-Fructose Towers*, and *Biotech Silo*. The body of this chapter is divided into three main sections. First, I describe the creative project and the process / methodologies involved in its conception, creation, and presentation. At this time I highlight data that informed the work as collected from key USDA sources, including USDA Annual reports that provided financial data in labeled tables in millions of dollars, categorized by net enacted, estimated, and budgeted outlays in every area. In addition, USDA user-driven farming databases provided far-reaching, geographically subdivided numerical data.

Each of the discrete sculptures is made from cut paper in an evolving process of data translation into form. They begin with a straightforward representation of data from corn production since 1866, to a comparison of corn sweetener data from selected years, and finally to plotting of 15 years of data that shows widespread industrial adoption of genetically-modified corn crops.

Second, I position the work in relation to the concepts and works discussed in the previous chapters, outlining how my work exemplifies the broadened definition of EV. The research study has resulted in conclusions that affect how I consider my own creative process, and changed the way in which I approach studio work. I have looked specifically for links between the creative and scholarly processes not obvious during the process. I specifically discuss works that are important to the development of my process and studio work: of particular relevance are Miebach's static datasets and *The Sandy Rides* series.

In the concluding section, I look forward to future research and creative efforts. I discuss how the investigative study has pointed to new areas for additional research, and how new avenues and ideas are emerging for my concept development, process, and artwork. I outline future works including *Kinetic Light Instruments* and *Desert Cricket.*

Conclusion

I conclude the writing with a review of the research and creative project, and discuss the changes and future implications this work has on my process and methodology. I briefly discuss how EV is transforming into legible, interpretive forms and representations for positive ecological change. EV is shifting from being beautiful visualizations to forms that couple with viable, doable actions that can aggregate into real systems change at a larger societal level as a form of strategic design for changing the way we engage ecology in urban areas. The future of EV is transforming as its forms become more complex. The future of EV is strategic design,

transforming and shaping policy frameworks, culture, and governance in the process of their production. Future EV works require holistic frameworks, collaboration, and synthesis in prototyping ideas and are indicative of a cultural acceptance that our environment is changing and that we need to take action.

Chapter One: Screen-Based Eco-Visualizations

Introduction

Glitched, altered crowd-sourced online photographs tagged with the names of national parks and a looping video of a woman running have one thing in common: both are data-driven EV works. The screen is their primary mode of representation, and they are real-time, dynamic, and networked visualizations of live, streaming data. They rely on a computational infrastructure for their functionality, and demonstrate a range of representational forms, moving from a still image dependent upon audience interaction for the final product to the presentation of a condensed, looped video. In this Chapter I will discuss two artworks that are easily categorized within Holmes' definition of EV from 2007. Both offer a novel approach to display the real time statistics of key environmental resources for the goal of promoting ecological literacy. Therefore, eco-visualizations can be data-driven animations that display ecological information of any sort in real time. The projects are site-specific, successfully deployed in their distinct spaces: first, as an interactive online webpage; and second, as a physical installation in the courtyards of five buildings in Sydney, Australia.

These EV projects exist as screen-based artifacts, translating environmental data into both still and moving images. They visualize complex systems of environmental data and exemplify both the beginnings and current trends of EV work. In this chapter, I will discuss both the conceptual process and EV works of three artists (a collaborative group and an individual) that are relevant within the broad field of data visualization, and to EV in specific. The diversity of approaches to process and conceptual development, research, and data translation are especially relevant to EV and set the precedents for my studio process. The artists and artworks include Leila Nadir and Cary Peppermint of EcoArtTech, *Eclipse*; and Keith Deverell, *Building Run.*

EcoArtTech and Deverell explore the range of screen-based EV artwork through the use of their visual language and techniques of deployment: air pollution data is directly visualized as an artifact of energy consumption and energy use data is expressed as a context-sensitive, collective experience. Made evident are the idiosyncrasies inherent to translated, streaming data, including loss of functionality and accessibility. Furthering the discourse regarding sustainable practices and an environmentalist mindset that supports ecological preservation, they provide a framework for ongoing discussion and research while disseminating data through the lens of aesthetics. Environmental data regarding air quality, including the degradation of the atmosphere, and 24 hour per day energy use is presented to broad audiences. They introduce information artistically, transforming the data into still images and streaming video, in order to communicate values fostering a sustainable lifestyle to a broad audience.

These artists are actively addressing how we can be agents of change within our environment; a commitment exemplified by their creative investment and efforts to communicate an ethically directed response to the forces that are destroying ecosystem integrity. Their work is experimental, visualizing environmental data in ways that are challenging, expressive, abstracted, and participatory. *Eclipse* and *Building Run* are located at the intersection of science, art, engineering, and social engagement, translating streaming, real-time air pollution and energy use data. Both projects draw from powerful, networked communications worldwide to foster a sense of relative immediacy and live connection with their audience. Networked and web-based user connectivity is supported by streamed content and continuously updated data, with allows a potential connection to coincident social realities that supports environmental awareness and participation (Couldry, 355). Of particular relevance to my studio work is EcoArtTech's process of embracing conceptual dualisms and their simple approach to data sets. Both projects engage

technology as a fundamental part of human experience: the computer and digital media are used both as tools to encounter nature and to assist with the adoption of energy-conscious habits. Both projects ask the audience to embrace contradiction and assist with their mediated experience in two curated environments: a rural landscape and an urban ecosystem. These data-driven EV works prompt a sense of environmental awareness and are situated within the charged social space of political ecology.

EcoArtTech: Air Quality as Visualized by *Eclipse*

Seeing and Changing Atmospheric Conditions

The United States legislative process has historically been slow to protect the atmosphere (and individuals) from pollutants. From 1881 to the mid 1950s, there was very little legislation to control air quality.[30] When faced with concrete evidence in 1955, the United States finally recognized the dangers facing public health and welfare, agriculture, livestock, and deterioration of property on a national level.[31] The vast physical geography of the continental United States and the regional nature of the problems obscured the need for action on pollution. Geography became geopolitics as the public, industry, and lawmakers weighed in to protect their particular interests, whether it was environmental, economic, or political. As the problem air compounded,

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[30] The first clean air legislation starting in 1881 at the city level, and included Chicago and Cincinnati. During that time, people experienced nausea and it was not uncommon for businesses to suspend operations (Eisinger, 2010).

There was no regulation at the national level. Los Angeles experienced its first big smog in 1943 from cars and industrial plants, with the number of dangerous smog days numbering 200 a year (McNally, 2010).

Similarly, in 1948 a deadly smog engulfed Donora, PA, killing 20 people and leaving another 7000 to recuperate in hospitals (Williams, 2013).

[31] The Air Pollution Control Act of 1955 was passed to study the issue, providing research and technical assistance. Early studies of pollution focused on its physical, chemical, and technical traits while ignoring the social aspects of the pollution (Fleming and Knorr, 1999).

the issue necessarily became a widely agreed-upon social construct before there could be any change mandated by new laws. Environmental policy researcher Dr. José Luis Lezama notes that environmental problems have a social dimension:

> From this perspective, environmental problems depend on a process of social construction and are identified by their perception and public recognition. A problem *may* have a physical existence, but unless it is socially perceived and assumed as such, the physical facts become socially irrelevant (2001).

Air pollution is a product of human activities in the environment but it does not become a problem until people agree that it is. Air pollution and its abatement are products of social space.[32] Pollution has its own social ecology, and the conflict always take place within a natural milieu, a space of atmospheric turbulence (Barker, 2012).

Protecting Visibility in National Parks

Administered by the Environmental Protection Agency, the Clean Air Act sets a national goal of preventing any future and abating any existing impairment of visibility caused by human-caused air pollution in congressionally designated areas where visibility is an important value.[33] Visibility, as a resource in national parks, is a complex concept encompassing technical systems of measurement and psychophysical processes. Visibility is closely associated with

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[32] There are a number of researchers articulating environmental pollution, and the processes of control, as a product of social space (Véron, 2005; Bickerstaff and Walker, 2001; Irwin and Walker, 1999; Macnaghten and Jacobs, 1997; Gooch, 1996; Harrison, Burgess, and Filius, 1996; Burgess, Harrison, and Maiteny, 1991.

[33] Congress passed the Clean Air Act in 1963 in order to improve, strengthen, and accelerate programs for the prevention and abatement of air pollution. Congress passed another Clean Air Act in 1970 to improve regulation and increase enforcement authority. It proved too ambitious and needed amendments in 1977 for "non-attainment areas," or jurisdictions that were (and are) not able to meet the requirements. Acid rain and smog prompted an amendment to control air pollution in 1990. The new amendments would impact regional economies, specifically those dependent on the coal mining industry (EPA, 2013).

conditions that allow appreciation of the inherent beauty of landscape, namely the form, contrast detail, and color shifts of near and distant features.[34] Parks where visibility is an important value-added component to the natural experience include the Grand Canyon, the Great Smokies, Shenandoah, and Yosemite. For example, Yosemite is designated a Class One area, which grants the park the highest level of federal air quality protection.[35] Without the effects of pollution, a natural visual range in the West is almost 140 miles. In contrast, pollution can limit visibility to a short 33 miles. The biggest air pollution threats to parks like Yosemite are anthropogenic emissions of fine particulate matter from vehicles, industry, and pesticide use. The EPA's state haze plans also must include a long-term strategy for making reasonable progress toward meeting the national goal.[36] The EPA's *Visibility Site* displays common air pollutants, visibility trends graphs, and photographs for each of its listed parks (Figure 1). The photographs are direct comparisons of moments with pristine, unobstructed views and days where haze is the dominant element of the image, concealing and obscuring landscape features. These Class One parks and wilderness areas are the zones of dialogue for the collaborative duo EcoArtTech.

Artists Leila Nadir and Cary Peppermint began collaborating in 2005 as EcoArtTech. Nadir is an Afghan-American critic, scholar, artist, and creative writer, and Peppermint is a digital artist whose early works examined the ways in which online spaces effected our expectations of the environment. Both currently teach at the University of Rochester.

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[34] Malm discusses the technical and psychological aspects of visibility as a resource (Malm, 1999).

[35] This protection was furthered with the 1999 Regional Haze Rule that implemented strategies to improve visibility on the most impaired days, and to ensure that no degradation occurs on the clearest days (Schichtel, 2014).

[36] Under EPA's implementing regulations, the plans must show progress over the next 10 years as states are required to revise their haze plans every ten years and submit the revised plans to EPA for approval (EPA, 2012).

Although recognizing that they have a division of labor as EcoArtTech, they do not have a conscious strategy for how they work conceptually:

> Ideas emerge for us out of an ongoing, sometimes unconscious, sometimes over-analytical, conversation that meanders through the digital/physical places we inhabit, whether we are in our studio or the kitchen…We are committed to an experimentality in process that involves interaction, exchange, exposure, and research that can take advantage of the energy created by blurring the lines between self and other. Proprietary works and the myth of the "genius" artist are detrimental to emerging modes of working, especially with regard to new media art production (Kosmaoglou, 2012).

They resist categorization, allowing new definitions and conflations of the self to emerge. They are most interested in staging fluid experiences that ask difficult questions and interrupt a sense of certainty. "When assumptions fail, things fall apart, and we can't depend on what we think we know, that is when our most creative thinking takes place. These are exciting, experimental moments" (Ibid).

Their projects explore industrialized, urbanized, and digitized culture through aesthetic experiences of food, ecology, media, and memory, rendering endangered food and environmental habits visible and practicable. EcoArtTech merges old and new ideas, including biological systems, primitive technologies, meditation practices, varied theories of nature and modernity, and new media technologies into participatory, interactive situations. They conceive the environment as a wide variety of networked systems, including biological habitats, global exchanges, industrial grids, digital networks, and the democratic imagination. Their work investigates the idea of "industrial amnesia," a cultural memory disorder wrought by our contemporary routines of living. Industrial amnesia is a depreciation of knowledge, resulting from the change of products and processes which render old knowledge obsolete. Knowledge

can also decay because records and practices are lost or difficult to access.[37] This type of knowledge depreciation is an idea revisited further in the discussion.

EcoArtTech positions art as an urgent and necessary intervention operating between utility and imagination in order to remediate industrial amnesia. Their objective is not to propose specific solutions to the global environmental health crisis. Instead, processes reliant on participation are a medium for aesthetic experiences both unsettling and creatively stimulating. In doing so, they provoke their audience to ask questions left unanswered by the corporate structures of industry, science, and entertainment media. EcoArtTech work collaboratively with participants, seeing themselves as both artists and healers facilitating the healing of modern bodies and the recovery of memory for modern minds.

For example, in a recent participatory project, *OS Fermentation* (2015), EcoArtTech worked collaboratively with local communities (human, bacterial, and ecological) to revive historic food practices (Figure 2). Included in the series was a reading group about microbiology, public health, and the industrial food system; a hands-on fermentation workshop for making veggie krauts, hard cider, and wine; a fermentation tasting party, where participants enjoyed their creations in a communal setting; and a gallery installation of microbial "selfies" and chalkboard notes made by participants. *OS Fermentation* was interactive, reviving the ancient practice of fermentation as an alternative to industrial processes of food preservation, such as refrigeration and pasteurization. Participants created a jar of fermented vegetables, an unfolding microcosm to be part of a future meal to boost digestion and immunity. The installation included digital prints created by custom electronics and software that allow microbes to take their own "selfies" and add manipulation effects to their images based on the shifting pH levels, oxygen, and color

[37] There are a number of documented, institutional losses of information, including the Steinway piano company and the original film stock from the *Star Wars Trilogy* (Argote, 1999, 53).

values of the fermentation process (Figure 3 and Figure 4). Though not an EV work specifically because it is not informed by a dataset, *OS Fermentation* was a viral performance of food independence from industrialized food systems and an affective reimagination of an active relationship with diet, nutrition, and edible substances. *OS Fermentation* exemplifies how artists transform a data-driven, digital practice into one that is interactive and multi-modal at its core.

A critical part of their practice includes the implementation of technology as a tool for knowledge and creative expansion, displacing technology from its role of pacifier and entertainer. In their work, mobile technology and digital networks are revealed to be fundamental components of the way we experience our environment. EcoArtTech rejects the dualism found in contemporary environmental thought, wherein technology is the cause of the ecological crisis and therefore must be abandoned; or the opposite approach where technological progress will save the world, and trusting in corporate and scientific innovation is essential. They see another possibility:

> We see humans as essentially technical beings: human-animals literally cannot survive without technics…How do we engage technology sustainably and in a way that supports creativity and freedom? And if human beings are technical beings, relying on nature and culture simultaneously, is it even possible to distinguish between what's natural and what's not? Isn't our sustenance dependent upon not only our biological needs (clean air, water and food) but also our cultural practices, beliefs, and imagination? (Kosmaoglou, 2012).

The environment is intertwined and mediated by electronic and digital technologies. Their ongoing engagement with environmental science questions the notion that holds that the role of the arts in the interdisciplinary exchange is to visualize or communicate knowledge produced by scientists. EcoArtTech goes beyond the oversimplified relationship of visualizing data to disrupt experience.

Eclipse

The political ecology of air pollution is the driving concept for the online EV work *Eclipse. Eclipse* is an interactive EV application merging user-provided photographs of national parks and wilderness areas with weather data, creating algorithmically derived glitch imagery, ultimately presenting a visual interpretation of air quality (Figure 5). In 2008, EcoArtTech were commissioned to create *Eclipse* for Turbulence, an organization that supports new and emergent hybrid networked art forms.[38] Notably, *Eclipse* has been exhibited at El Museo Cultural de Santa Fe / Currents 2012: Santa Fe International New Media Festival, Ohio State University's Pearl Conard Gallery, University of Massachusetts–Boston's Harbor Art Gallery, the Woodstock Digital Media Festival, and Electronic Village Galleries at Penryn Town Hall (UK).[39] In addition to being exhibited within the space of galleries, *Eclipse* is online perpetually.

Building upon the dominant visual language of the EPA's *Visibility Site*, *Eclipse* appears as if published from a neutral governmental institution. The site purposefully employs early 2000's website design where content was limited to small, centered windows on the screen. The users do not have to search for anything, link to another page, or scroll through pages of content. This cohesive design strategy is maintained throughout the site to focus users' attention on the windows, informational content, and support user's awareness of their action and end result. *Eclipse* opens to a welcome page that reads very much like an opened book with a center spine. Centered in the browser window, the application's portal is a medium grey ground with white

[38] Turbulence is a project of New Radio and Performing Arts, Inc. (NRPA). Turbulence has commissioned over 200 works and exhibited and promoted artists' work through its Artists Studios, Guest Curator, and Spotlight sections. Turbulence has remained at the forefront of the field by commissioning, exhibiting, and archiving the new hybrid networked art forms that have emerged (Turbulence).

[39] Curated by Frank Ragano and Mariannah Amster, the Currents Festival explored the role of technology and the diverse applications of New Media in the arts (Currents, 2012).

text. On the left is a "Welcome" tab featuring how *Eclipse* functions. On the right is the title and instructions for operation, beginning with Step One. The first action is a drop-down menu, where the user chooses a National Park, forest, monument, or state park. After making the selection, the user clicks to Step Two, which opens the next page. Page two features educational information regarding AQI conditions, how they are measured, and their corresponding color charts for both American and Canadian rating systems. Users then proceed to Step Three to see *Eclipse's* abstraction: the final, altered image. Each step of the portal is reliant upon the user's click to move to the next step, which emphasizes personal responsibility within the environment, without being prescriptive about the experience. Though the encounter with the site is serious, the outcome – a photograph digitally "etched" with current air quality data – is playful, surprising, and open-ended.

Eclipse's application functions perform three distinct operations to document and visualize dynamic, real-time weather data. To begin, the application searches for images tagged with a park's name from the image sharing and hosting website Flickr. These images sourced by *Eclipse* represent a range of styles, subjects, and professionalism. *Eclipse* data-scrubs for particular naming tags, for example, "Yosemite" or "Yellowstone." Then *Eclipse* searches for the real-time Air Quality Index (AQI) from cities within a 65-mile radius in order to visually reveal air pollution data.[40] AQI is calculated from the five major air pollutants and particulate matter regulated by the Clean Air Act including ground-level ozone, particle pollution, carbon monoxide, sulfur dioxide, and nitrogen dioxide. Finally, *Eclipse* processes the AQI through an algorithm in order to expand upon the air pollution information, which glitches the chosen image based on the level of pollution. Higher pollution levels equate to a more distorted and unreadable

[40] Air quality data is reported from across the United States (AirNow, 2015).

image through the imposition of intermittent mirroring, banding, deletion, file cropping, color change, saturation, and contrast. The visual products of *Eclipse* are assembled through a process of interaction, reiterating the ways in which the naturally conceived landscape is marked by its interactive relationship with its human inhabitants. The result positions landscape imagery as a production of many interacting elements, pointing towards anthropogenic action as the negative force within that system.

Eclipse tapped into the ubiquitous participatory culture of the Internet, a place that is driven by passive consumption. However, *Eclipse* alters the course of passive consumption by transforming the site's users into active producers. Media theorist Tim Barker notes that *Eclipse* can be thought of as an assemblage of user-generated images residing together in an archive wherein each image, and its set of associated metadata, adds to the meaning of all the others.

> This reformulates the genre of landscape by framing it as a participatory experience, where users actively engage with the creation of iconography, engaging not merely with images but also with the cultural and ecological significance of these images, and the experiences of other geographically distant users (SAC, 2012).

Eclipse uses a technologically mediated set of practices via the screen to present the world as an interactive and immersive system, made apparent as each click eclipses the original landscape image.

A celestial eclipse is the partial or complete interception of the light of one component of a binary star by the other. To eclipse something is to obscure its light; to reduce or take its splendor, status, and reputation; and finally, to make it less outstanding or important by comparison. In *Eclipse*, the photographed landscape - which is originally the subject of the image - moves to the rear of the composition and becomes background. In doing so, the landscape transforms into the substratum. The sourced, tagged images range from the extraordinary to the banal, from mountain vistas to tree stumps to the local convenience store. Layered over the

image are digital glitches, color changes, and striations. Air and pollution emerge visually as the subject and obscure these sourced images, some of which are emblematic of the concept of nature as untouched, wild, and unspoiled. Each image is rendered flawed through interaction, creating through the process a new narrative, one that underscores human responsibility.

At the time of this writing, the functionality of the site was compromised, as the Flickr images would not load, thus no AQI conditions could be visualized in a final image. Exemplifying a depreciation of knowledge, *Eclipse* is crippled as a web application, a result of accessibility issues. However, the site was operational in the past and numerous screen grabs are available in an image search. Website functionality is a concern with Internet applications and platforms that are reliant on external sources of data. The problem could be anything from broken links, to a loss of network or host negotiation with Flickr, to a breakdown of an application program interface (API), the building blocks of Internet applications. For example, it could be making JAVA- or Flash-based calls to an API that does not exist anymore. The site is Flash-based, and it could be that my browsers are blocking and disabling Flash sites. However, *Eclipse* is being archived at the Rose Goldsen Archive of New Media Art, Cornell University, Ithaca, New York.[41]

Eclipse is a presentation of ecosystem trauma, presented in a series of disjointed images. Users triggered layered content, thus providing a condition for individual experience rich with emotional content. With *Eclipse*, information visualization has been used to give a new sense of materiality to the atmosphere, repotentialising the air as an informational entity (Barker, 2012).

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[41] Under the sponsorship of The Division of Rare and Manuscript Collections, the Rose Goldsen Archive of New Media Art serves as a research repository of new media art and resources. The curatorial vision emphasizes digital interfaces and artistic experimentation by international, independent artists (Rose Goldsen Library of New Media Art, 2015).

Air pollution is not an annoyance to be seen through. It becomes impossible to ignore within *Eclipse*, where users can immediately see AQI data as an altered image - or in the case of clean air, an unchanged and pristine view of someone's digital photograph of nature. *Eclipse* is a participatory project in a world where the discourse on environmentalism is dominated by science. EcoArtTech recognizes that science has been positioned as the icon of truth and objectivity, at the top of the hierarchy of knowledge, a discipline that has the answers to global crises. However, they challenge the position of science as the arbiter of the right answers to ecological problems. Instead, they position the audience as agents of change. *Eclipse* welcomes public participation in the ongoing project of trying to have a sustainable world, to arrive at new ways to support a healthy environment, starting with awareness and recognition of being part of the digital network:

> For us, the job of artists, hackers, theorists, and creative workers is to interrupt that drive, reduce the speed, and allocate time to rediscover our place, our bodies, and our relationships to others, nonhuman and human. EcoArtTech stages opportunities for moments of mindfulness, and for reflection about what it feels like to be a technical human-animal dwelling in the here and now (Chester, 2014).

EcoArtTech invites users to ask, participate, and interact, while rejecting the idea that they have to passively wait for answers. *Eclipse's* glitched images work to revise our assumption of parks as immaculate and untouched space. Our remodeled recognition of nature as a place negatively impacted by pollution encourages critical thought regarding our environment. *Eclipse* connects environmental data to place, contextualizing air quality data and making this knowledge visually accessible and visceral.

Keith Deverell: Visualizing Energy Use with *Building Run*

The Shifting Landscape of Energy

Renewable energy is slowly providing alternatives to fossil fuels and changing the energy landscape.[42] However minute the production of renewable energy, the shift of resources allows different perspectives for understanding energy production and consumption, providing an urgent lens through which to discuss human-environment relationships and their embedded politics.[43] Central to energy production is governmental management of the worlds' electricity providers: political institutions structure the rules of supply and demand, and are a central driving force of the ecological crisis by maintaining the industrialist, fossilist, and capitalist way of living.[44] The changes within global energy production shift the geopolitical order, unsettling social, economic, and ecological landscapes.

As energy issues become critically important to society's ecological and economic survival, they become politically contested. Contradictions are rampant, and renewable energy resources, including wind and solar, spark contentious debates. Some argue that renewable

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[42] In 2012, global electricity production totaled 21,532 billion kilowatt hours. In contrast, global renewable energy generation totaled 4,715 billion kilowatt hours. (EIA, 2015).

[43] Willow and Wylie highlight the need for ethnographic studies of the tumultuous social and physical transformations resulting from, and produced by, the unfolding frontier of energy production. They examine how intercommunity connections are vital to recognizing the shared structural conditions produced by the oil and gas industry's expansion. Of particular interest is their examination of the sequestration of information and agnotology (the deliberate production of ignorance), divide and conquer tactics, and shared experiences of risk and embodied effects (Willow and Wylie, 2014).

Political scientist Richard Heinberg notes that, "Energy is, by definition, humanity's most basic source of power, and since politics is a contest over power (albeit *social* power), it should not be surprising that energy is politically contested (Heinberg, 2014).

[44] Energy policy is created through complex social institutions (Brand, 2014; Keohane and Victor, 2013; Min, 2012; Yergin, 2012; Nadaï and van der Horst, 2010).

energy could supply 100% of demand by 2030.[45] Others challenge these theories with claims of hidden financial costs, land use problems, and grid limits (Trainer, 2012; Gilbraith et al., 2013). Analysts claim that the world will be worse off economically if we rely on renewables.[46] Another report argues the opposite (SolaVis, 2014). Ecologist Charles Hall is pessimistic regarding the promise of solar photovoltaic (PV) and surmises that it will not be able to support an industrial economy.[47] The solar industry claims otherwise.[48] The discussion of wind power has similarly embedded contradictions, with some arguing that global wind capacity has been over-estimated while others claim that it could be a primary source of near-zero emissions power.[49]

As energy conversations are being contested, they are also becoming more common. Whole landscapes and civic identities are being restructured through the process. A number of cities and regions are committing themselves to reducing energy consumption and carbon emissions, and setting strict standards for future dates. A sweeping commitment by the European Union promises to reduce emissions by 80% by 2050. However, large-scale policy changes are

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[45] Renewable energy is a contentious subject (Jacobson and Delucci, 2009).

[46] Tverberg argues that renewables may not reduce carbon monoxide emissions (2014).

[47] Prieto and Hall present an energy analysis of a large-scale, real-world deployment of photovoltaic (PV) collection systems representing 3.5 GW of installed, grid-connected solar plants in Spain (2013).

[48] Energy Independence claims that Solar power alone could provide all of the energy Americans consume (American Energy Independence, 2013).

[49] De Castro et al. use a top–down approach to evaluate the physical–geographical potential and, for the first time, to evaluate the global technological wind power potential, while acknowledging energy conservation (2011).

Marvel et al. use a climate model to estimate the amount of power that can be extracted from both surface and high-altitude winds, considering only geophysical limits. They argue that there is enough power in Earth's winds to be a primary source of near-zero-emission electric power as the global economy continues to grow through the twenty-first century, with considerations (2013).

less prevalent than regional commitments.[50] For example, Sydney, Australia, has committed to reducing carbon emissions by 70% and adopting 100% renewable energy resources for heating and cooling by 2030.[51] As a site for ongoing conversations regarding energy, the city of Sydney wants to establish itself as a civic leader with outstanding environmental performance and new 'green' industries driving economic growth. They are working to reduce their carbon emissions, and establish a network of green infrastructure to reduce energy, water and waste water demands. Part of achieving these goals includes involving the public in the process of change and transformation, to engage a broad audience in energy awareness. The City of Sidney is the site for fostering transformation and environmental awareness, and is the place for artist engagement for "Sensing Sydney," a collaboration between the arts organization Carbon Arts and the City of Sydney in 2013. For the event, invited artists brought sustainability data alive in ways that celebrated and advanced Sydney's collective efforts to address environmental challenges. *Building Run* was Sensing Sydney's public commission to promote energy awareness, using the city as a canvas for creation and story telling.

Building Run

Visualizing energy consumption was the driving concept for the EV *Building Run*. Installed in 2013, *Building Run* was a video installation that conceptualized five buildings as competing athletes in a daily race for greater energy efficiency (Figure 6). The project

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[50] The state of California has committed to emission reduction by 80% below 1990 levels by 2050 (ARF, 2014).

New York City has committed to reducing carbon emissions by 2950 (NYCMOS, 2015).

Four other U.S. cities have committed to changing their carbon footprint through a variety of means including Denton, Texas; Dubuque, Iowa; Santa Cruz, California; and Albuquerque, New Mexico (Tallman, 2013).

[51] Sustainable Sydney 2030 is a set of goals set for the city to help make it as green, global and connected as possible by 2030. The plan is transformative for the way residents live, work and play (City of Sydney, 2014).

documented real-time energy consumption using human avatars to represent each building in a competition to beat its own personal best. The artist, Keith Deverell, created *Building Run* specifically for Sensing Sydney.

Deverell is a Melbourne based artist who also has a professional background in installation design and data visualization. Deverell is interested in the gesture of the human body, using the metaphor of the horizon line as a way to locate the subject. Other topics examined include the representation of identity, the embedded politics of place, and observational and documentary forms of sound and video, with an emphasis on the destabilisation of documentary forms within the field of video art. Deverell questions the idea of an overall "truth" as expressed by corporate, scientific, and governmental systems. His work explores the possibility for multiple, coexistent narratives promoting environmental and social awareness that are emblematic of the potential for change.

Building Run was produced in part by the organization Carbon Arts, a unique organization which generates and evaluates creative models for engaging society in imagining and shaping a more sustainable future (Carbon Arts,2015). Carbon Arts is a new model for arts and ecology advocacy, forging connections and partnerships with artists, businesses, the sciences and government. Their projects foster innovation and dialogue between science, the arts, government, business sectors, and the public as a means to address contemporary environmental challenges. *Building Run* was a cross-sector collaboration, bringing arts, environmental and sustainability professionals, businesses, and the city together both within and across the participating organizations. The project itself was a work of many, including a stylist, Emina Dzananovic; installation design by Foolscap Studio; and additional programming by Jayson Haebich. Brought together for the collaboration were Investa Office, a major real estate

company; Deutsche Bank, a global financial services provider; and Buildings Alive, which provides technical information and analysis to optimize the performance of buildings.[52] Five green buildings that have taken energy efficiency measures were chosen as sites. Each supplied data through management systems every 15 minutes, including 255 Elizabeth Street, Deutsche Bank Place, BT Tower, 400 George Street, and Customs House.

Each of the five sites had a screen with a young female running avatar, whose twenty-four hour performance timespan was compressed to forty minutes, with the date and time on the display for the entirety of the video. The energy use data was compressed into a forty-minute span to reveal the previous day's data, allowing it to be played on continuous loop. *Building Run* employed a commercial engine – Buildings Alive – which provided all the streaming data. The dataset contained energy usage in 15 minute increments, translated in the EV every 15 seconds. By noting the time and the effort of the runner, Deverall intended that the viewer would be able understand the energy profile of a building throughout the day and night. Since the avatars were next to each other, viewers could compare each building. Deverell expanded the data set by comparing the various data streams, which enabled the audience to understand each building's consumption relative to other users. Finally, the information was abstracted through symbolic representation. Low energy use corresponded to a faster, more efficient race. The more energy that was consumed lead to signs of exhaustion in the runner. Deverell noted that during the course of the exhibit, each building was trying to achieve its "Personal Best," or PB.[53] "It's

[52] "Buildings Alive" provides automated feedback and technical analysis to help optimize the performance of buildings (Buildings Alive, 2015).

[53] Personal Best (PB) is determined by comparing today's energy consumption with the building's predicted performance for today based on modeling of historical data and prevailing conditions, such as the weather. Buildings Alive produces both the predicted performance (or personal best) as well as actual performance.

playing with the metaphor of personal bests more than a race against each other, so they can all win…At the end of the race if they get a personal best [for energy usage] the video is happy, it's celebratory, and if it's not [a personal best] then they're a bit more forlorn. There's a humor and a poetics to the whole work" (Crozier, 2013). At each site all five runners (screens) were adjacent, so the audience could compare their respective performance and levels of fatigue.

Visually, the project's physical manifestation was tightly controlled with polished lines, heavy, large materials, large individual footprints in each site, and matching citywide promotional materials (Figure 7). It was fabricated at the scale of soaring corporate foyers, including 50" LED screens, runways that look like the starting gates at a racetrack with accompanying handholds, a variety of printed materials and explanatory, educational signage. From the track, viewers faced an oversize black facade that housed five screens and the time clock, displaying a green LED stopwatch. Deployed in five different locations, the project faced design challenges. Tufte argues that first and foremost, the data needs to be clear. Unfortunately, the data remained ambiguous because of mode of representation for the data translation. This was partially due to lacking a monosemic system of signs: *Building Run* did not have an onsite legend for explanation, which would have assisted in the comprehension of the streaming video imagery and allowed audiences to understand when the buildings were achieving their PB and at what level they were running.

This comparison is shown on a continual basis, as in a sporting event so that we can see if the runner is on-track to receiving PB at any one time. The bar at the top shows today's performance and the bar at the bottom of each screen shows the PB. If the building is on track to achieve a PB, then the top bar will turn green other wise it will be red. In this way, one can tell at a glance which buildings are 'winning.'

As the runner completes the race, she will stop and pick up her bottle of water and mobile phone. Upon glancing at the phone she'll learn whether or not she beat her PB. At this stage she will either crouch down and look disappointed (not achieved PB), or stay standing looking sky ward and smile (achieved PB). It is entirely possible that all buildings achieve a PB on the same day (Newcombe, 2013, 24).

Building Run was a metaphor for how humans' use affects the health of a building. Deverell saw the possibility for buildings to be humanized architecture, considering their place in a corporate fitness program:

> *Building Run* is a video installation that poetically comments, through the language of sport and the healthy body, on how we as occupants affect the health of a building, in this case its energy consumption. In developing this artwork, I was interested in the idea that buildings are living and breathing organisms – much like human beings – and that a healthy body image is as relevant to buildings as it is to humans (Deutsche Bank, 2013).

Deverell's choice of a strong female athlete counteracts contemporary media, where women are more likely to be depicted in a sexually suggestive manner than males, a language which marginalizes women and reinforces male dominance in the sporting world.[54] As the runners worked to achieve their PB, their effort – and the building's energy consumption – was indicated by a "Levels" icon, styled similarly to that of one on a treadmill. The framing of the image provided another visual cue as to energy consumption. At the slower speeds we are the farthest visual distance from the runner and her entire body is captured within the frame, corresponding to little energy use. At medium speeds the camera zooms in closer. At the fastest speeds only the torso remains in the frame, corresponding to the most energy use. The runner was featured wearing a variety of outfits meant to symbolize the emotional sensibility of each building. By giving each building a discrete personality, Deverell intended to clarify the energy data. Five different roles were presented: the "Quiet Achiever," wearing matching purple and accessorizing with a water bottle; the "Sophisticated," covering up in all black; the "Tech Savvy," in a sports bra and sweatpants; the "Sunny Outlook," in a red hooded zip jacket and sports bra; and finally,

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[54] From 1990-1997, *National Collegiate Athletic Association* media guide cover photographs were analyzed, with gender differentiation in the depiction of women and men athletes. Women athletes are less likely to be portrayed as active participants in sport and more likely to be portrayed in passive and traditionally feminine poses (Buysse, and Embser-Herbert, 2004).

the "Fashionista," in a floral jacket and yoga pants.[55] Deverell claimed that these choices represented the character of each building, however, none of the workout clothing was specific enough to render them discernable as separate characters without explanatory text.

Building Run worked double-duty to reveal energy data and to express an equally complex position in the broader discussion around environmental sustainability. In using large, networked screens, the installation required electricity, which was also the object of much criticism, an issue that remains unresolved in the project. However, *Building Run* can be considered an example of strategic design; a term used by the theorist Dan Hill to describe works that operate in multiple dimensions:

> Strategic design is about applying the principles of traditional design to "big picture" systemic challenges such as healthcare, education and climate change. It redefines how problems are approached and aims to deliver more resilient solutions (Hill, 2012).

Projects employing strategic design frequently transform and shape policy frameworks, culture, and governance in the process of their production. Hill calls for developing holistic frameworks, for collaboration, and for deploying synthesis (rather than just analysis) in prototyping ideas. In this context, the artist has to engage the "dark matter," the soft structures of policy, culture, and governance that include civic organizations, culture, rules, and regulations that drive the space of the city. Dark matter is the nebulous context that can allow or disallow change.[56] Dutch architectural historian Wouter Vanstiphout articulates that visionaries engage dark matter:

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[55] The clothes are modeled on headless, armless mannequins, rather than modeled on the runner (Newcombe, 2013, 14-15).

[56] The concept of dark matter is drawn from theoretical physics. It is believed to constitute approximately 83% of the matter in the universe, yet is virtually imperceptible. It neither emits nor scatters light, or other electromagnetic radiation. It is believed to be fundamentally important in the cosmos, we simply cannot be without it, and yet there is essentially no direct evidence of its existence, and little understanding of its nature.

> If you really want to change the city, or want a real struggle, a real fight, then it would require re-engaging with things like public planning for example, or re-engaging with government, or re-engaging with large-scale institutionalised developers. I think that's where the real struggles lie, that we re-engage with these structures and these institutions, this horribly complex 'dark matter.' That's where it becomes really interesting (Hyde, 2011).

Building Run and Carbon Arts worked to establish an ongoing conversation of transformative change within the civic mindset.

Building Run enabled a productive and reflexive discussion with residents of the existing state of environmental responsibility within the contemporary smart, networked city. Three key groups comprised the audience, including the general public, the tenants of the building, and the buildings' managers. Post-project interviews revealed that the building's managers were instrumental in actualizing changes based upon data: their work directly affected the performance of the runners. Revealed to the interested public were the infrastructure systems of private buildings. Tenants actively engaged the idea of sustainability and energy conservation, desiring change, their sense of place and identity heightened through the placement within the lobby of their buildings. This began a process towards the move for an open-data society, demanding that organizational, policy, and regulatory environments change to support energy efficiency.

As an experimental EV work, *Building Run* allowed discussion of the feasibility of data-driven artwork and its multi-pronged motivation, while exploring the dominant framing narratives of technology and environmental data within an urban setting. The collaborations necessary to make *Building Run* cemented relationships necessary for fostering future energy efficiency challenges. Tenants of nearby buildings expressed the desire to become more sustainable. The power of *Building Run* lies in how the work redistributes public attention in order to shift perception and motivate change. As a powerful symbol and motivator, *Building*

Run served to contextualize the role that green buildings play, together with the communities that inhabit them, in achieving long-term sustainability goals by drawing the audience into a more intimate relationship with the surrounding urban infrastructure and environmental health indicators. While giving voice to the artist and organizations outside the corporate agendas dominating the cityscape, strategic EV works like *Building Run* work as a cultural motivator.

Conclusion

Both *Eclipse* and *Building Run* are screen-based EV works, examples of networked, dynamic data. Though their conception, process, and mode of representation are quite different, they rely upon a computational infrastructure for their functionality. *Eclipse* is a still image dependent upon audience interaction for the final product, reiterating the ways in which the naturally conceived landscape is marked by its interactive relationship with its human inhabitants. *Eclipse's* result positions landscape imagery as a production of many interacting elements. Though the encounter with the site is serious, the outcome – a photograph digitally "etched" with current air quality data – is playful, surprising, and open-ended. *Building Run* is a small series of condensed, looped videos representative of five buildings in a race towards achieving their personal best energy conservation. Building Run exemplified strategic design, a process that has the potential to stimulate civic transformation. These EV works offer new avenues for the presentation and interpretation of data, and ask us to examine the very ways we engage data and technology.

In the next chapter I will discuss EV works that exemplify the broadened definition of EV through their mode of representation, including Andrea Polli's *Cloud Car* and *Particle Falls*, Nathalie Miebach's *The Sandy Rides*, and Natalie Jeremijenko's *Mussel Choir*. These EV works go beyond the screen to offer unique ways for the presentation and interpretation of data,

demonstrating a range of three-dimensional presentation, from discrete objects and sculpture to dynamic site-specific installation. I claim that these projects which are beyond the boundaries set by EV literature to be EV in terms of both their content and function. These artists are actively addressing continuing environmental damage by exploring ways to visualize environmental data in ways that are exciting and expressive.

Chapter Two: Multi-Modal Eco-Visualizations

Introduction

Cars enveloped in a pulsing, atomized mist; pixelated "waterfalls" of light moving down a building; spiraling, miniature amusement parks constructed from toys, and singing mussels all share a common quality: each is driven by environmental data and the artist's need to address environmental and biodiversity degradation. They are all part of recent EV artworks that move beyond the screen in a variety of ways that explore other modes for representing data. While Chapter One discussed primarily screen-based EV works like *Eclipse* and *Building Run* that relied on computers and the Internet as a live source of information, Chapter Two features artworks that exemplify the broadened definition of EV. They demonstrate a range of three-dimensional presentation, from discrete objects and sculpture to dynamic site-specific installation.

As such these EV projects use a variety of visual and audio materials in order to visualize complex systems of environmental data and function as cultural critique. It is precisely these projects without screens which are beyond the boundaries set by EV literature that I claim to be EV in terms of both their content and function. In this chapter, I will discuss both the conceptual process and recent EV works of three artists that are important to the larger field of data visualization, and to EV in particular. The diversity of approaches to research, data translation, and mode of representation are especially relevant to the broader definition of EV and to my own studio process. The artists and artworks include Andrea Polli, *Cloud Car* and *Particle Falls*; Nathalie Miebach, *The Sandy Rides*; and Natalie Jeremijenko, *Mussel Choir*. These artists are redefining EV artwork by exploring the fluid language of data through three-dimensional, materialized form and a variety of media. These artists are actively addressing continuing

environmental damage, exploring ways to visualize environmental data in ways that are expressive and educational, and in the case of Jeremijenko (and to a lesser extent, Polli), reformulating social space to support environmental awareness. The EV artworks discussed in this chapter are located at the intersection of science, art, engineering, and social engagement, deciphering data pertaining to air pollution, weather events, and aquatic habitat. Of particular relevance to my studio work is Miebach's process and studio work, however, every artist and project discussed informs my work. Each featured EV work abstracts the data to depict a variety of intangible concepts that work to bridge the divide between scientific knowledge and public perception. Some of these intangible concepts revealed by these EV are of a psychological nature, including an emotional response (to poor air quality), a sense of personal intimacy and cultural disillusionment (with a weather event), and a sense of being a part of a larger system (as in an urban aquatic ecosystem). Each artist has expressed feelings similar to solastalgia, and work to heal themselves and overcome solastalgia by finding a connection with living things and life processes on this planet.

Polli, Miebach, and Jeremijenko collect information into both static and dynamic datasets in order to translate environmental data into three-dimensional and audio forms in relatable, tangible, and abstracted ways. A static dataset is the substrate for both Polli's *Cloud Car* and Miebach's *The Sandy Rides*; however, the two artists' datasets are different in that the former EV's dataset is simple, presented in ways that are straightforward and denotative, while the latter EV's is layered and complex, presenting it in ways that are chaotic and playful. Both Polli's *Particle Falls* and Jeremijenko's *Mussel Choir* employ dynamic datasets, and while I did not use a dynamic dataset in my own work, their approach to data collection, conceptual development, information translation, and interpretation for a final form informed my studio project. The final

example, Jeremijenko's *Mussel Choir*, is not only a complex eco-visualization but goes another step to offer a long-term way to improve the environment.

These three artists are helping us imagine and navigate a possible environmentally healthy future in visceral ways. They are creating meaning from constantly growing data sets, establishing an evolving and exploratory language that investigates, appropriates, and reveals the culture and ecology that both generates and responds to data streams. Their new language, with data translation at its core, recognizes that we have entered into the Anthropocene. Here, within the larger context of nature, artists are making meaning with data with eco-visualization.

In this chapter I discuss each EV work, including the content type of data sets both dynamic and static, and media both digital and non-digital; the functional issues of form; aesthetic issues, including visuality, site-specificity, and the ways in which each individual EV work offers a critique of contemporary cultural practices. I also look to the aesthetics of governance of EV, considering how contemporary EV projects may reiterate the modes of industrial production in order to engage, decode and critique them. I position EV not only as a sensemaking tool for complex environmental data, but also as a way to see how we function within our immediate community in order to make positive environmental change.

Andrea Polli: Visualizing Atmospheric Pollution with *Cloud Car* and *Particle Falls*

Particulate matter (PM) pollution can be lovely, contributing to spectacular red sunsets, the suspended particles scattering radiation both enhancing the red and removing the cooler violets and blues in the spectral palette.[57] PM pollution is also dangerous, causing environmental

[57] Particles of any kind will make the sky brighter at the expense of purity of color. Molecules and small particles like manufactured aerosols scatter light in a similar way to molecules of nitrogen and oxygen (Ballantyne, 2007).

degradation[58] and a host of health issues. PM is a mixture of extremely small particles and liquid droplets, categorized by size: inhalable coarse particles and fine particles.[59] Size is directly linked to the potential for causing a wide range of health problems,[60] with those particles that are 10 micrometers in diameter or smaller being the most detrimental to human health. Common primary particles are emitted directly from construction sites, unpaved roads, fields, smokestacks or fires. These particles are large enough to be seen by the eye, including dust, dirt, soot, and smoke. However, most of the PM pollution in the US consists of secondary particles that form in complicated reactions in the atmosphere and require an electron microscope to be detected. These fine and ultrafine particles (Figure 1), specks of waste at least 36 times finer than a grain of sand, are often riddled with toxic combinations of sulfate, nitrate and ammonium ions, hydrocarbons, and heavy metals. Small particles are the most dangerous because they pass through the nose and throat to enter the lungs, at which point they can enter the bloodstream and the neural pathways to the brain. About 147 million Americans are chronically exposed to PM pollution that exceeds EPA standards and 14 percent of the total US population lives in areas that

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The EPA reports on the long- and short-term causal relationship of PM to cardiovascular effects, respiratory effects, cancer, mutagenicity, genotoxy, and mortality (EPA, 2009).

[58] PM pollution causes widespread environmental damage because PM can be carried over long distances by wind and then settle on ground or water. This can make lakes and streams acidic, change the nutrient balance in coastal waters and large river basins, deplete the nutrients in soil, damage sensitive forests and farm crops, and affect the diversity of ecosystems (EPA, 2012a).

[59] Researchers categorize particles according to size, grouping them as coarse, fine and ultrafine. Coarse particles fall between 2.5 microns and 10 microns in diameter and are called PM10-2.5. Fine particles are 2.5 microns in diameter or smaller and are called PM2.5. Ultrafine particles are smaller than 0.1 micron in diameter and are small enough to pass through the lung tissue into the blood stream, circulating like the oxygen molecules themselves (EPA, 2009).

[60] We have known that ultrafine PM particles both cause and exacerbate respiratory problems that include asthma, infections, and cancers of the lungs. Researchers suspect that PM contributes to a diverse range of disorders, from heart disease to obesity, and now to degenerative brain diseases (Reuben, 2015).

suffer from short-term particle pollution (Figure 2).[61] Any time the acrid smell of engine exhaust is present, the immediate environment is very polluted. Ambient (outdoor air pollution) in both cities and rural areas was estimated to cause 3.7 million premature deaths worldwide in 2012.[62] 88 percent of those premature deaths occurred in low- and middle-income countries, and the greatest number in the Western Pacific and South-East Asia regions.[63] However appalling these statistics and grossly obvious the resulting health effects of airborne PM, people ignore air pollution. Smoggy atmospheric conditions have become a mundane backdrop to a lifestyle dependent upon fossil fuels. Culturally, we are suffering from an occluded vision of smog.

The artist Andrea Polli addresses PM pollution and the related phenomenon of not seeing the haze with *Cloud Car* and *Particle Falls*, two site-specific EV works based on interpreted environmental air quality data. Polli is an international environmental pioneer who merges technological innovation and scientific inquiry with artistic expression. Interdisciplinary collaboration is at the heart of her practice,[64] and she has worked with the NASA/Goddard

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[61] The American Lung Association reports on the State of the Air in 2014. Though the US air quality is better overall from a decade ago, air quality worsened from 2010-2012 (State of the Air, 2014).

A long-term study of six U.S. cities 1974 to 2009 suggests that cleaning up particle pollution had almost immediate health benefits. They estimated that the U.S. could prevent approximately 34,000 premature deaths a year if the nation could lower annual levels of particle pollution by 1 $\mu g/m^3$ (Lepeule et. al., 2012).

[62] If we take steps to keep the air clean as mandated through the Clean Air Act, we will prevent at least 230,000 deaths and save $2 trillion annually by 2020 (State of the Air, 2014).

[63] The Environmental Protection Index offers a global "Interactive Air Pollution Map" that shows countries suffering the worst air pollution. Data is revealed by city, satellite image, and dirtiest power plants. It color-codes high-resolution air pollution data (specifically, fine particulate matter or PM2.5) from ground level (data reported by the World Health Organization) and from the atmosphere (satellite-derived estimates calculated by researchers at Dalhousie University). Regions shaded in black are exposed to very unhealthy or hazardous levels of particulate matter, and dark red to red represents unhealthy amounts, using classifications from the EPA's Air Quality Index thresholds. The areas with safe air quality are colored yellow to orange. Locations of the world's dirtiest power plants, according to Carbon Monitoring for Action (CARMA), are also included (EPI, 2014).

[64] An important long-time collaborator is her husband, Chuck Varga. Past projects involved (GWAR – 1985-1997) and fabricator for Blue Man Group, The Lion King, Where the Wild Things Are, Into the Woods, Sweeney Todd, and Cirque Du Soleil. Currently Varga works as a scenic artist for Broadway productions such as The Wedding Singer, Pajama Game, and for Disneyworld's Cars (Pixar).

Institute Climate Research Group in New York City, the National Center for Atmospheric Research and AirNow to realize major projects that translate data sets with visual elements and the materiality of sound. Polli holds a doctorate in practice-led research from the University of Plymouth in the UK, focusing on participatory media and social engagement in order to engage the public with conceptual concerns. Polli is currently Professor of Art & Ecology with appointments in the College of Fine Arts and the School of Engineering at the University of New Mexico. She directs the Social Media Workgroup (SMW), a lab at the University's Center for Advanced Research Computing.[65]

The Social Media Workgroup is closely tied with Polli's creative practice. The SMW investigates the social and ecological impacts of media technology through practice-based research. Central to their work is the investigation of the phenomenology of a computer-mediated experience, specifically if said experience can be as aesthetically and emotionally powerful as a walk in the woods. They look to both manufactured and natural environments as information spaces, places where data is constantly generated and interfaced with ubiquitous computing platforms. At the heart of this is the investigation of the kinds of mobile and locative media that can work to reveal environmental information and to help users approach real-world understanding of the presented data. The SMW sees their role as one of translating the work of scientists and engineers into a visual language that is meaningful to the public. One of SMW's projects, *Skylight*, is a user-interactive LED lightshow on the façade of the Albuquerque Anderson-Abruzzo Balloon Museum. The light patterns are responsive to visitors' text messaging about the alternative energy potentials of solar and wind. Their focus with this project

[65] UNM faculty, undergraduate and graduate students, and outside experts work in interdisciplinary collaborative teams to design and develop a wide variety of media tools, assets and events (Social Media Workgroup, 2015).

and others (*Cloud Car* and *Particle Falls*) is in the design and production of encounters and events, coupled with an ongoing analysis of social media as it contributes to larger cultural practices and meaning making.

Conceptually, Polli defines the environment as "information space," a place where data is continually generated. Polli's EV work uses data extracted from the environment as material substrate: in *Cloud Car* as a static data set, and in *Particle Falls* as a dynamic, real-time data set. Polli articulates that dynamic datasets revealed in real time can be problematic because of the way people experience artwork: "No one can stand in front of a piece for 10 years to listen to how, for example, climate in the arctic has changed, even though in climate terms that's a really short period of time" (Knebusch, 2008). Long-term weather and air pollution data require a mode of representation that compresses both the timeline and information translation to enable understanding, however, *Cloud Car* and *Particle Falls* use limited datasets that do not require time-based representation. They are examples of ambient EV, embedded into an everyday urban environment within a public space. They evoke abstract natural phenomena, associating the phenomena with alarms about the fragile environmental equilibrium through the translation of air quality data into dynamic visuals. In this way, Polli works to make climate science accessible and to communicate the urgency of the matter. She does this to counteract generalized human apathy:

> When you're hearing things about climate change all the time, you just get tired of it and you can't keep responding. I think that's the thing about people making interesting artwork; it keeps some of these ideas fresh and offers new solutions and new ideas. It helps people have access to the data and start to understand it. I think it touches [people on] an emotional level. These artworks that I'm doing, and other people are doing, interpreting data — compared to looking at a spreadsheet or bar chart, it's a lot more emotional. What we're dealing with, with climate change, is so big that whatever people come to the table with, you need to bring those [skills]. Artists can have an impact, and designers, and journalists (Thompson, 2012).

Polli makes invisible data palpable using everyday materials and technology as an aid in participation: "I wouldn't say that I'm really explaining anything as much as I'm promoting a kind of emotional reaction," (Yoerger, 2013). Polli's work helps people who already care about some of these issues to understand them better through tools that make it them more visible, accessible and interesting. In order to achieve visibility, accessibility, and interest, Polli's works rely on "sonification," a process that translates raw data (about everything from sulfur dioxide, carbon monoxide, and ozone pollution to lightning, wave, and wind trends) into compelling and audible forms.[66]

Polli believes that language needs to evolve in order to communicate and interpret extraordinarily large, complex data sets. Polli asserts that the language for communicating invisible data must evolve:

> Part of that evolution must include the work of artists. How is the artistic process of transforming data different from the process of transforming physical material? Like a photograph, a data set is a representation, but unlike a photograph, this representation can be entered, explored and transformed. Artists have the opportunity to create works that have an impact through touching the emotions of the audience, which can affect environmental understanding and behavior (516 Arts).

With sonification, emotional content and feeling can be communicated with sound, stimulating mindfulness and a comprehension of the forces at work behind the data. The translation of data into sound can also be an aesthetic choice to materialize data as patterns and percussive compositions. Polli's past work, *Sonic Antarctica* (2008), combined tones, field recordings and interviews with the weather station personnel of the South Pole. The work began

[66] Sonification is the use of non-speech audio to convey information or perceptualize data. Auditory perception has advantages in temporal, spatial, amplitude, and frequency resolution that open possibilities as an alternative or complement to visualization techniques. For a complete understanding, see Herman et. al., 2001.

Polli offers explanation of her sonification, *Atmospherics/Weather Works*, which was an interdisciplinary project that sonified storm data and other meteorological events, producing a highly detailed and physically accurate model of weather systems used for research and forecasting (Polli, 2004).

with a helicopter ride, slowly descending into a world of glaciers and sub-zero readings; recordings of freezing southern winds; the sounds of local fauna such as penguins; and the discussion of researchers out in the field, who reveal how they feel the political heat for revealing the inconvenient truth of global warming. Though neither *Cloud Car* nor *Particle Falls* employ sonification as a means of data communication, the concept is relevant to the discussion of Polli's process and aesthetic choices because she is working to capture the nuances of the data as well as cultivate an emotional response from the viewer, albeit now with visual means. Polli discusses the experience of nature in spiritual terms, inseparable from her scientific knowledge of atmospheric phenomena. Polli's experience of the data is intimate and is directly linked to both science and technology: "In terms of my relationship to climate, again knowing more about how the chemical composition of air can have such a serious effect on climate has made me much more sensitive to my personal footprint" (Knebusch, 2008). Though the focus of her work is ecological, Polli notes that the concept of 'sustainability' may be contradictory to technologically driven artwork in two distinct ways. First, electronic media is directly dependent on the grid, and second, the substrate technology is manufactured in ways that are decidedly not green.

Polli conveys her close connection to the atmosphere and makes the effects of anthropogenic climate change obvious through her work. In the following sections I discuss two relevant EV works that exemplify her sensitivity to air quality and her drive to make knowledge publically accessible, approachable, and understandable. Both *Cloud Car* and *Particle Falls* visualize atmospheric conditions in order to evoke an emotional response from the audience. They show two very different approaches to EV through data interpretation and visualization,

from *Cloud Car* that interprets a static dataset with an interactive, three-dimensional form to *Particle Falls* that interprets a dynamic dataset as a projection via technical and digital means.

Cloud Car

Polli's *Cloud Car* is a site-specific EV installation, creating a space of contemplation and exchange by showing the connection between the automobile, life and air quality. *Cloud Car* looks like a broken-down car by the side of the road spewing malodorous smoke. The sculpture is a metaphor for vehicular and oil dependence, emblematic of the time we spend passively polluting inside cars, while being less aware of what is going on outside of them. Polli subverts the power of the automobile by using it as a powerful symbol for the practices of entrenched, routine environmental degradation. The global political economy of the car is reinforced through its production, its role in capital accumulation, and its promotion over other transportation alternatives.[67] Cars contribute to the consumption of fossil fuels, social isolation and disconnection connected with urban sprawl, health degradation, air and noise pollution, and rapid urban decay.

Cloud Car is an ongoing project since 2008, most notably in New York City; Turin, Italy; and Belfast, Ireland.[68] It was first installed in New York, debuting with a Ford Taurus Wagon, a fitting vehicle for the US (Figure 3). *Cloud Car* is a smart project - versions of the work in other countries appropriate their common vehicles. For example, in Turin, Italy, Polli chose the Fiat

[67] Through an analysis of the global political economy of the car, research shows that widespread social practices which systematically produce global environmental change are simultaneously embedded in the reproduction of global power structures. Hegemonic structures create environmental crisis (Paterson, 2002).

[68] Polli exhibited *Cloud Car* at the New York Hall of Science in conjunction with the "Ear to the Earth Festival" in October 2008. *Cloud Car* was developed in residence at Eyebeam Art + Technology Center and supported by the New York Hall of Science (Eyebeam, 2008).
Cloud Car was exhibited in Polli's solo show, "Breathless," in Turin, Italy in 2011 (PAV, 2011).
The installation was also exhibited for the ISEA Symposium in Belfast, Ireland in 2009 (ISEA, 2009).

126, a car widely used throughout the country (Figure 4). The car is fitted with a variety of equipment in order to produce a cloud of mist to envelope car and rider, making air tangible and visible. The equipment is evident: hoses wrapping the hood, roof, and around the car; pressure valves rated to 1000 psi; atomizer nozzles to make a fine mist; two high-pressure pumps located off the vehicle; smoke machines, motion sensors; lighting spotlights and a timer relay (Figure 5). The car is engineered to be human-scaled spectacle, day and night. During the day the car spews clouds of vapor, which envelope spectators in condensed theatrical emissions exhaust. At night, text is projected into the mist. Reading "the future," "no water," "plenty of CO2," and "no fuel," the car extends its local reach and message (Figure 6 and 7). Ambient data from a pre-preprocessed data source is a hallmark of Polli's work, communicating a familiar (even if undesirable) narrative and collective shared experience. The art critic Maya Kóvskaya articulates how Polli's ambient data is so powerful:

> This simple but effective move is to elide the difference between the viewer and the faceless statistical victim of air pollution, and to collapse the boundary between them, which is the very boundary that allows people to treat such problems as outside of themselves and thus "not my problem" (2010).

Didactic in nature, *Cloud Car* invites visitors to ponder their own car's carbon footprint and interpret the abstraction as they are engulfed in mist. Polli's work translates data into dynamic and accessible form, connecting people immediately and intimately to their environment and helping them to understand their impact upon it.

Cloud Car does not function as a visualization of numerical, tabulated data, as a straight visualization, or a direct mapping because there isn't a clear way to discern a specific data set within the generated haze. However, *Cloud Car* is made to convey an idea, stimulate other sensory responses from the viewer, and critique our culture of consumption. Accompanying

Cloud Car was a fact sheet to further understanding of the project and help the audience make intellectual connections. Polli stated:

> One thing I thought was effective about [the car] was that people would come up to the car and we would hand them a fact sheet that would say, 'If you have to drive, here are some things you can do that will reduce your emissions.' The point of these projects is ultimately to raise awareness and understanding of the issue. If we just tried to hand people that information without having some kind of fun spectacle to perk their interest, they might reject it or feel insulted by it or just not want to look at it or read it (Yoerger, 2013).

Cloud Car as an EV is a viscerally relatable materialization of an everyday occurrence that is mundane enough to render itself invisible. The EV functions as a critique of culture, reiterating a form emblematic of industrial production in order to critique said form. *Cloud Car* is engaging because it represents a familiar phenomenon, stimulating critical reflection through discussion. Using the familiar forms of popular vehicles and atomized mist, Polli abstracts the data in order to depict a variety of tangible concepts - air pollution, smog, and vehicle emissions - in ways that are ultimately approachable and relatable for a wide audience. An actual data set is unnecessary for comprehension of the issue. One does not need to go far to find exhaustive smog data or understand how cars are a major contributor to tropospheric ozone.[69]

[69] The Environmental Protection Agency provides different types of air quality data through numerous systems. These data can be separated into two categories.

Air quality data includes the amount of pollution and other substances present in the atmosphere. These data are measured by monitors throughout the nation.

Emissions data includes the amount of pollutants and other substances being emitted from facilities, vehicles, and other activities that release pollution into the atmosphere (EPA, 2014).

Particle Falls

Particle Falls is a large-scale, technically sophisticated, real-time dynamic data EV work that visualizes local air-quality data in the form of a projected waterfall (Figure 8).[70] Like *Cloud Car*, *Particle Falls* has exhibited in a number of venues since first debuting in San Jose, California, as part of the 2010 ZERO1 Biennial.[71] Notably, in 2014, *Particle Falls* was featured in Pittsburgh, Pennsylvia as part of the "Breathe Project;" in Detroit, Michigan for the "Dlectricity" exhibition; and at Utah State University in Logan, Utah, as part of ARTsySTEM.[72] A site-specific EV, the work consists of a projection upon a tall building's wall. A background of blue LED light is animated to appear as if it was a waterfall. This light constantly "falls," providing a background for a visible disruption in what could be an unspoiled "waterway" – spots of bright, fiery color that emerge and crackle depending on the amount of sensed PM pollution. A nearby air monitor detects the presence of fine particulate matter, and as the air clears, fewer bright spots appear over the falls. Polli works to make what is invisible – PM pollution – into something visible, and to encourage awareness about air pollution: "As an artist,

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[70] *Particle Falls* was a collaborative project with partners working in multiple disciplines. Collaborators include meteorologist Tim Dye, artist Chuck Varga, student Ryan Romero and others in The Social Media Workgroup. MetOne instruments provided particulate monitoring equipment and calibration. Eric Geusz and Jared Rendon-Trompak donated programming and other technical assistance (Polli, 2011).

[71] *Particle Falls* was one of five commissioned works supported by the San Jose, California Art and Technology Network. Conceptually driven by the idea to "Build Your Own World," each work looked to the future; one that isn't just about what is next, but one that is about creating a foundation to ensure that what is next matters (Zero1, 2011).

[72] The Pittsburgh, Pennsylvania installation was at the Benedum Center façade in the 700 block of Penn Avenue as part of the "Breathe Project," a coalition of residents, businesses, and government that are working together to clean up the air (Breathe Project, 2014).

The Detroit, Michigan installation of *Particle Falls* was part of *Dlectricity*, an annual exhibition of sound and light (Dlectricity, 2014).

THE INSTALLATION AT UTAH STATE UNIVERSITY IN LOGAN, UTAH WAS PART OF ARTsySTEM, an interdisciplinary project aimed at incorporating art and design methodologies toward scientific data collection, analysis, interpretation and design (USU, 2014).

I felt the best way to promote this dialogue was to take…something negative and present it as a thing of beauty" (Diana, 2013). *Particle Falls* visualizes microscopic particles as they are exhausted nearby and whatever amount has accumulated in localized wind currents. Visible smog that plagued urban centers in decades past has been mitigated, but these tiny, invisible particulates go unnoticed without detection.

An instrument called a nephelometer monitors and samples the local air to generate the data for *Particle Falls* (Figure 9).[73] The nephelometer used in this EV combines two different technological methods, including light scattering and gravimetric filtering. Light scattering operates by pulsing a beam of light through a sample of air. The particulates in the air scatter the beam of light, which is collected and concentrated onto a photo diode in the E-Sampler. That light is then converted into an electric signal, which is proportional to the concentration of particulates in the air. That electric signal is converted to usable data and sent to the projector via a computer software program, which displays concentrations of particulates in bursts of bright color. Increasing frequency of the crackling dots of color indicates a greater concentration of particles. *Particle Falls* updates with new particulate data every 15 seconds. Also used in scientific analysis is the E-Sampler's gravimetric filter system. After measurement via light scatter the sample is drawn onto a filter. The filter can be taken for lab analysis as a second

[73] A nephelometer is an instrument for measuring concentration of suspended particulates in a liquid or gas colloid. A nephelometer measures suspended particulates by employing a light beam (source beam) and a light detector set to one side (often 90°) of the source beam. Particle density is then a function of the light reflected into the detector from the particles. Nephelometers are calibrated to a known particulate and use environmental factors (k-factors) to compensate lighter or darker colored dusts accordingly.

A recent study in northern China researched the optical properties of anthropogenic PM, which showed dominant contribution during the sampling period, accompanied by occasional dust events. Moreover, the major contributors to aerosol optical properties are attributed to the mixture of black carbon (BC) and brown carbon (BrC) (Zhu et. al., 2015).

method of measurement of air particles.[74] The *Particle Falls* nephelometer measures particles in the gas sample that are smaller than 2.5 micrometers in diameter.

At the heart of *Particle Falls*' operation is a computer program. This custom program was designed to convert the nephelometer readings into patterns of light. Meaning was assigned by color: blue signaled clean air, and yellow signaled polluted air. The installation visualized the differences in air quality by disrupting the peaceful blue imagery of the waterfall. When the air is extremely polluted, *Particle Falls* resembles a fireball as the number of bursts increases and ebbs in proportion to the shifts in particulate matter floating in the surrounding air (Figure 10). Because of the proximity of the nephelometer to the street, an idling bus increases the frequency of the visual disruption. Various types of vehicles triggered the EV, giving the audience an immediate visual understanding of the real differences between clean burning emissions and heavy polluters. Audience members could also trigger a response from *Particle Falls* if they smoked near the sensor. Polli noted that they "were able to see…how much more particulate is created by diesel vehicles and idling" (Meier, 2015). The distinct differences vehicle emissions as visualized by *Particle Falls* were an opportunity for the audience to consider the ways in which we contribute to pollution. *Particle Falls* supports an immediate understanding of atmospheric conditions through real-time, dynamic visualization. The EV is a tool for learning about air quality by connecting behavior to the material impacts of consumption, encouraging playful engagement and exploration with energy, facilitating discussion, and critical reflection on the state of the air.

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[74] For the Pittsburgh installation of *Particle Falls*, scientists obtained the data from the nephelometer for further study at The Center for Atmospheric Particle Studies at Carnegie Mellon University in Pittsburgh, Pennsylvania.

Nathalie Miebach: Taking the Long View with *The Sandy Rides*

The signs of climate change are obvious, experienced everywhere: global spikes in temperature are marked by increasingly powerful storms that bring tidal surges, violent precipitation, devastating floods, widespread drought, calamitous winds, and deadly heat waves. Recent US events include a prolonged drought in California; super cell storms in Texas raining softball-sized hailstones, disastrous flash flooding in Kentucky; and record temperature fluctuations across the continental US (Figure 11). Powerful typhoons Nangka and Chan-Hom forced 1.5 million to evacuate in Japan and China; extended heat waves are brutalizing India and Pakistan; unprecedented floods swept through Chile's Atacama desert; and in March, four simultaneous tropical cyclones surged in the southern hemisphere.[75] These episodes are part of a new normal for weather, a pattern of extremes across the globe, shaped in part by human-induced climate change. Weather is what we immediately encounter, what is going on outside right now: at the time of writing this there were violent thunderstorms. Climate is the pattern of that weather, measured and recorded over decades. Understanding the nuances of these changing patterns requires sifting through masses of information over time in order to analyze the data of individual storms.[76] However normalized, storms and their aftermath remain enigmatic and complex phenomena, a disturbed state of an environment and atmosphere. Storm, originating from the Proto-Germanic *sturmaz*, means "noise, tumult, and disturbance."

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[75] The occurrence of four simultaneous cyclones has only happened twice before, in 1998 and 1893. For an understanding of the weather patterns that lead to cyclones, see Erdman, 2015.

[76] Weather events are becoming more extreme because they are developing in a different climate. For an overview of global changing weather patterns, see: Cutting et. al., 2015.

Extreme weather is a product of climate change, with mega-storms becoming more common, the new normal (Carrey, 2011).

As storms increase in intensity, floods are more common. Tornados are more frequent and intense (UCS, 2011).

The complexity of the "noise" is formed from layers of data, which is comprised of air temperature variations, wind direction shifts and difference in speed, precipitation levels, tides and currents, humidity, marine temperature, atmospheric pressure, dates and duration of the event. The density of this weather data and related information is the material of choice for artist Nathalie Miebach, who filters the "noise" visually. Miebach also draws upon other data, including location and geologic formations, moon cycles, historic and geologic temporal comparisons, the habits of biological organisms, and her own personal accounts and experience of the event, the latter often not considered data as it is experiential and not numerical. By drawing upon personal experience, Miebach challenges what is considered data. The data sets can be characterized as static; all data used to create the sculptures have been pre-recorded. Miebach's hybrid creative practice borrows from the methodologies of both art and science to visualize complexity, and is not an objective indicator of data. A featured TED Global Fellow in 2011 for information visualization, Miebach is considered a preeminent EV practitioner and is at the forefront of the data visualization conversation, specifically regarding meaning-making using data. Her CV is extensive: since 1995 she has received a number of high-profile accolades, notably a residency at the Fine Arts Work Center in Provincetown in 2007 - 2008. During this time Miebach first made her weather-recording device and began logging daily data, which she then translated into sculpture. This process laid the foundation for her future work. She continues to exhibit globally and is a prolific maker, and she has recently begun to collaborate with musicians and composers.

The daily practice of scientific data collection is an important aspect of Miebach's creative practice and a testament to her patience. Though the data collection can take months for one sculpture, Miebach says, "In order to truly understand weather, you have to understand the

environment as well. And an environment is not an app; it will not reveal itself to you quickly" (Lovelace, 2014). Miebach records a given environment with sensitivity to context and details, be it specific storm or an area like the gulf of Maine. She builds data collecting devices to record numerical data, chronicles personal observations beyond the numerical, and appropriates information from weather stations and buoys. She compares her findings to historical databases and records. Using this wide variety of data, she translates her findings into whimsical structural accounts of the event that are chaotic, complex and rich. Miebach's work is artistic, sculptural EV, employing a three-dimensional mode of representation.

Rejecting traditional and ubiquitous (normative) information-mapping methods like graphs and diagrams, which are limited means of data expression, Miebach uses an aesthetic three-dimensional language of form, object and sculpture as an entry point into data analysis and meaning making using numerical information. The sculptures are one way that Miebach emotionally connects to our evolving environment, one possible way to continue the discussion regarding climate change. Miebach describes her work as "a narrative approach to the climate crisis, to appreciate how super-storms are connected to the social fabric, to economic reality, to jobs. We're not going to get it with one more graph. We need metaphors, storytelling" (Miebach quoted in Harwood, 2015). These sculptures are a way to understand the disorganized complexity of storms and related weather events. Here science and art converge for a multi-dimensional comprehension of our world through Miebach's individual subjective experience. It is as if each sculpture is an entreaty for an understanding of the universe, each woven reed a way to solve global warming, each plotted object a way to question the relationships inherent to the data.

Originally both inspired by astronomical spaces and frustrated by her inability to conceive of their dimensional configuration, she turned to basket weaving as a way to reconcile representation with her own cognitive experience of the data set. Miebach regards the structural possibilities of the basket as a contemporary tool for visualization, a form that can be manipulated to represent any map, matrix, or web. Revealed within this unusual process of transformation are the ways in which Miebach processes information, constructs understanding, reveals connections, and makes meaning with materials and tactile experience. Structures both organic and manufactured are organizational devices for the plotting of data, which is mapped intrinsically and extrinsically in her forms.

Elements from the data drive the substructure, a three-dimensional grid held together by the tension of the weave. Embedded in the weave is a time matrix, a data scaffolding that is a timeline, often a 24 hour period that distorts and shapes the structure. Though guided by her hand, the reed material bends with tension, curves that are transliterated numerical information. Miebach intentionally allows the material to drive the underlying form of the sculpture. The physical form emerges through this system, upon which she layers more data. Familiar structures are incorporated upon the surface as if points on a chart, a symbolic annotation for definitive information. Though the data is plotted in a slow and logical way, Miebach works to engulf the audience in the density of the environment she studies, surrounding them in the complexity of the biological, chemical, and physical interaction of the science data. The sculptures are a slow reveal, allowing telling clues for weather events. At times, Miebach works in opposition to a monosemic system of signs; however, viewers can decode each individual work by consulting an accompanying legend (if provided). Decoding is unnecessary, because the sculptural forms are compelling without the need for data interpretation.

A core concern of her work is to challenge the conditioned and accepted visual vocabulary of science by expanding the traditional parameters of data visualization. Miebach subverts the restrictive boundaries of the scientific discipline by allowing her choices to be informed by the context of play. Play is employed both as a mode of creation and a way of engaging content. The sculptures can be encountered without a specific, predetermined outcome and are open to interpretation. Fun on the first encounter, the use of colorful, recognizable toys as plotting elements belie their seriousness, accuracy, and numerical logic. Acting as a physical lure from the perspective of play and drawing in the viewer, Miebach's EV work conveys a sense of peril regarding our immediate environment, and critiques our choices regarding our land-use. Miebach's work shifts the boundaries of scientific acceptability to enter into the emotional distress and tumult of storms.

The Sandy Rides

In October 2012, Hurricane Sandy, a late-season post-tropical cyclone, damaged hundreds of thousands of homes, forced tens of thousands of survivors into shelters and caused billions of dollars in damage to vital infrastructure systems including power transmission, transportation and water and sewage treatment facilities.[77] The storm shut down the east coast of the US. Hurricane Sandy was the largest Atlantic hurricane on record, with winds spanning a diameter of 1,100 miles (Figure 12). The super-storm moved up from its first landfall in the Caribbean all the way to Canada (Figure 13). Sandy's strength and angle of approach combined to produce a record storm surge of water into New York City. The surge level at Battery Park

[77] Hurricane Sandy came ashore in northern New Jersey Oct. 29, 2012, and as the powerful storm made its way along the East Coast it brought damage to NASA's Wallops Flight Facility in Wallops Island, Va. For a comprehensive analysis of Hurricane Sandy, see: NASA, 2013.

topped 13.88 feet at 9:24 p.m. Monday, surpassing the 10.02 feet record water level set by Hurricane Donna in 1960. New York Harbor's surf also reached a record level when a buoy measured a 32.5-foot wave. That wave was 6.5 feet taller than a 25-foot wave churned up by Hurricane Irene in 2011. A major contributor to Hurricane Sandy's strength was abnormally warm sea surface temperatures off the East Coast of the United States—more than 3 °C (5 °F) above normal, to which global warming had contributed 0.6 °C (1 °F). As the temperature of the atmosphere increases, the capacity to hold water increases, leading to stronger storms and higher rainfall amounts. Hurricane Sandy was the basis of all the data for Miebach's recent series of sculptures, *The Sandy Rides.*

For Miebach, the most disturbing images were of the ruined amusement park in Seaside Heights, New Jersey. She was further shocked to hear that planners were going to rebuild the park, adding a ride named "Sandy" that would mimic the experience of a hurricane (SAIA, 2013). Gone were rollercoasters and a ferris wheel, structures that served no other purpose but to delight and distract. The Star Jet roller coaster was washed away from its pier mooring and submerged offshore (Figure 14). The eerie, desolate and wrecked area of the Coney Island amusement rides were ominous and emblematic images of our own inability to confront evolving environmental conditions. The images were distressing not only because the park was destroyed, but also because there were plans to rebuild. Meibach saw the folly of rebuilding on exposed coastal property as an absurd disavowal of climate change, continuing the cycle of destruction as if Hurricane Sandy was the exception. Miebach's personal experience and emotion informed the data collection from the storm, gathered from weather databases and ocean buoys. She added further layers of meaning theater sets as resource and a narrative filter, and employing these different entities to tell stories.

There are nine sculptures comprising the series, *The Sandy Rides.* Though each is a distinct object, they share a common data set from Hurricane Sandy. The series features repeated motifs, including amusement park rides, carnival text, and overt references to water as a destructive element. Rather than discuss the whole series, I have chosen to discuss two of the sculptures, *The Last Ride* and *O Fortuna, Sandy Spins,* in detail. The former is one of the earliest in the series, and is visually minimal without an overt reference to water in its base structure; and the latter is more complex structurally, with a moving, double sided element. I also introduce a third work (*The Ride*) as it exemplifies a future direction for Miebach's work.

O Fortuna, Sandy Spins

Hurricane Sandy took a spin on two different amusement rides, and in the process destroyed them both. A metaphor for what is uncontrollable, *O Fortuna, Sandy Spins* (2013) is a narrative visualization of collected weather data from October 29, 2012, on Coney Island and Seaside Heights.[78] The discrete pedestal sculpture measures 21" x 16" x 14" (Figure 15). Reminiscent of an architectural toy, the forms imply movement as a Ferris wheel precariously balances upon a winding, rickety rollercoaster. It reads like a slapdash contraption, unmoored from land and floating on a bamboo raft. Below the raft, blue rope is coiled like the churning of the ocean surface, separating the object from the grounding pedestal. Bound around the base at regular intervals are orange life rings, as if they would support the rickety structure through stormy seas and thwart its inevitable demise. Throughout the sculpture, Miebach's handwritten notations are evident, indicating moments of interest and zones of large change. Placed upon the front face is the glittering text "Wheel of Fortune."

[78] Miebach identifies her choices and object associations in a short video posted by the Crystal Bridges Museum, 2014.

Who is at the helm, driving us to the future and determining our fate? Ancient humans concluded that this someone must be a woman – Fate, or Fortuna – and if anything, she is impulsive, possibly diabolical, and occasionally benevolent. We are at the mercy of the arbitrary spins of her wheel. Though the concept of the wheel of fortune has evolved over time to become a religious symbol, it was used to teach against the appeals of the temporal, warning against hoping for an earthly fortune but instead putting all hope in Heaven. Here, we are putting hope in Nature, and it is proving not to be a benevolent force.

From the surface of the raft, reeds wind upward in a twisted spin, ascending the climb of the coaster upon a vertical frame, tracing the development of the hurricane as it made contact. Plotted in regular intervals along the tracks are hourly markings (marked with beads). A single yellow strand follows the same path, marking the movements of the sunrise during that fateful day. Another strand denotes the sunset. Overlaid upon this structure are related data, including extreme tidal movements (marked as black verticals, they are placed within the structure) and various other statistics – some denoted, some not – so much that it transforms into a cacophony of overlaid marks, lashed bamboo, and upward movement. Human-imposed crafts comically project outward as speared carnival rides, formed as woven blue paper vessels circling the central system. Their overlarge rotors imply the destructive force of cavitation.

As the storm's momentum grows, we move upward to the Ferris wheel, which doubles as a face of a clock. Time is labeled on black watch faces, following the same logic as an analog timepiece. Reeds radiate from the center point, tinted green and sharpened to impale wayward dinghies. It ticks away the minutes of the storm, measuring wind speed (dark blue blocks), wind gust (light blue blocks) and barometric pressure (green flags). On the reverse face is a dynamic, articulated wheel of fortune operating as a proxy for our gaming addiction, our ongoing gamble

with the weather. We could play roulette with our relaxed lifestyle and expensive communities of leisure while asking the question, "If the weather is to change, how do we negotiate living by the ocean?"

The Last Ride

In a similar vein to *O Fortuna, Sandy Spins*, *The Last Ride* (2012) offers a glimpse into the post-apocalyptic landscape experience left in the wake of Hurricane Sandy. *The Last Ride* is a pedestal sculpture, measuring 38" x 31" x 26," using reed, wood, and paper to visualize weather and ocean data from October 29 -30, 2012 (Figure 16). The sculpture is precariously supported upon horizontal azure floating rings that are imbued with a double life: first, as planted feet (on land) and second, as buoyant rafts (on water). A curved ribbon of blue woven reed mimics the flow of ocean currents, creating the supportive sub-structure for the vertical poles. However, the mere threat of a riptide will displace the flimsy skeletal formation since *The Last Ride* appears to already be folding in upon itself in a denial of its unsound geometry. Red cross beams fail to intersect, vertical towers impossibly list, and broken tracks abruptly end, a metaphor for falling off the end of the earth. *The Last Ride* is a surrogate doom for the fantasy of living on the ocean's edge.

Rollercoasters are meant to create an illusion of danger, prompting a swift rush of fear and adrenaline, all manipulated through architecture. The underlying principle of all roller coasters is the law of conservation of energy, which describes how energy can neither be lost nor created; energy is only transferred from one form to another. However, Miebach's sculpture is a physics nightmare, an engineering specter, calling forth the first wooden rollercoasters. The implied energy has been ripped from it during the storm. Lashed atop the precipitous towers is a double line, replicating the winding path of the flowing ocean current. This path is strong,

defining the upper edge of the sculpture while doubling as a freeform coaster to nowhere. However, this is not the route of the coaster but that of the sunrise and sunset, plotted hourly starting at 8 am on the 29th and going to 2 am on the 30th. A secondary trajectory, running through the center, is further complicated with steep rises and subsequent falls, a denotation of the fluctuating temperature during the storm. Included in this sculpture are wave height, wind speed, wind gust, and cloud cover. The mass of linear posts, diagonal lashings, beaded endpoints, handwritten marks, and proliferation of color all work to mask the underlying data, the logic of it all. Decoding the specifics of the data is impossible and unnecessary.

Red flags wave above the coaster, marking the tallest points of the sculpture. Just below are a series of TinkerToy wooden spools, their connections creating complex curvilinear forms that replicate the energy of wind currents and speed during the course of the storm. Spokes radiate from the center of the spools and are dripping delicate white flags reminiscent of dripping water and the formation of icicles. Some convey direction, relating back to the movement of the flags. In a narrative move, Miebach includes a sectional woven paper dragon that hovers just above the uppermost track as if taking a turn on *The Last Ride*.

Dragons are a recurring motif throughout Miebach's work. Dragons have long been revered in mythology, representative of the primal forces of nature, religion and the universe. They are believed to possess some form of supernatural power (for instance, flying), and are associated with water. Miebach structured this narrative around the final ride for the Star Jet Rollercoaster. In *The Last Ride*, the dragon is a metaphor for the powerful, destructive nature of Hurricane Sandy, a sea serpent taking a last spin on the rollercoaster before leaving the ride's broken corpse in a watery grave. Visually, the dragon is the only part of the visualization shifting

from the linear line quality of the whole composition – the creature's mass is oppressive. Though the dragon appears to be floating above the architecture it seems to weigh the structure down.

Staying true to the aesthetic of play, the dragon resembles a popular children's toy called the Chinese Finger Trap. By including a form representative of a situation that could be overcome by accepting circumstances rather than fighting against them, Miebach suggests that we could change our behavior. The behavior shift is complicated by our relationship of desire to live in fascination with coastal landscapes, our disavowal of climate change, and our wager that things will stay the same. *The Last Ride* allows for the projection of the self into the sculpture to take a wild ride on this engineering nightmare, and for a glimpse into how our architecture will continue to be crushed under the pressure of weather.

The Ride

The Ride (2015) employs a different process from the others sculptures in *The Sandy Rides*. Though based on the same weather data from Hurricane Sandy, *The Ride* is both a sculpture and a sound composition, a duo for percussion and cello. Unlike the other sculptures from *The Sandy Rides,* developed directly from collected weather data, Miebach constructed the underlying form for this work from a score written by Christian Gentry. The two artists were paired for the 2015 Cambridge Science Festival to create a new composition inspired by ecological art, which would be performed by the Dinosaur Annex Music Ensemble on April 26, 2015, a group committed to presenting contemporary chamber music. Unlike Miebach's previous work, which was based directly on weather data, the sculpture, *The Ride* was based on Gentry's original score, *Ride_*.

Gentry is a composer and an Assistant Professor of Music at Framingham State University. He developed *Ride_* by collecting primary source material from amusement parks

directly, as they have unique sound-worlds created by the orbits of carousels and roller coasters. Tapping into an investigation into the theater of the absurd, Gentry was informed by a space in which manmade entertainment and diversion met tragedy and destruction. Gentry describes the *Ride_* composition:

> The end result is an oddly proportioned, oddly sparse at times, mixed with some moments of more dense counterpoint. Yet, overall, it is the most "direct" music I think I have written. There is little time for development, only statements that essentialize my intuitive impulses (Gentry, 2015).

*Ride_* is organized into three sections: i. Flight "freely, lifting off, with breathing room;" ii. Wait "Dirge, slow, breath-like, still;" (Fall "fast, nimble"); and iii. Deluge "steady pulse, mechanical."

Miebach responded to his score in turn by creating *The Ride*, a discrete pedestal sculpture measuring 32" x 22" x 22" (Figure 17). Guided by the sound composition, the work is made from fiber rush, paper, yarn, wood, and foam. Both the destroyed Jet Star Rollercoaster at Seaside Heights and Jane's Carousel in Brooklyn were theatrical source material. Included in the imagery is an unnerving image of the tall ship, *Bounty*, sinking towards her watery grave in the wake of the Hurricane (Figure 18).[79] The sculpture begins at the base with blue rope, curved and looped to resemble the ocean's choppy surface. Suspended in the water is a small black rowboat, a tiny island sure to sink. The boat is precariously balancing a complex anatomy that includes a tall mast ship frozen in a moment of failure, jutting out sideways; a miniature, simplified Ferris wheel, repurposed as a waterwheel; part of a roller coaster in an inverted twist that ends midair; and a skeletal, horseless carousel caught in mid-spin. Above it all flies a grey, simplified dragon.

This discrete sculpture is reflexive: rather than going directly to the numerical data, Miebach filters her work through Gentry's opus, and then looks to data, which is plotted upon

[79] Fourteen people were rescued from he *Bounty*, but the captain and one of the crew perished with the ship. For an in-depth report as to why the leaking craft was out in the first place, see: Miles, 2013.

the score's framework. This is a divergent approach from her previous work, as heard[80] with the score "Navigating into a New Night" (2009, ink, data on notation paper, 10 pages, 8.5 x 11 in) and its accompanying sculpture, *Musical Buoy in Search Towards a New Shore* (2009, wood, data, reed, 32 x 32 x 32 in) (Figure 19). With "Navigating Into a New Night," Miebach wrote the score directly from weather data as a blueprint for *Musical Buoy in Search Towards a New Shore.* Curving blue lines indicate cloud cover, wind direction is noted by teal marks, and other weather variables including humidity, temperature, and barometric pressure are indicated by the colors orange, red, and green. Finally, tempo is represented by pink shading, open for interpretation by musicians.[81] Musical notation became another way to artistically represent weather data. Miebach is quick to point out that she is not a trained musician, and acknowledges that human comprehension of an event can be enhanced with sound. Numerical data was not capturing everything that was physically experienced – the data was missing emotional nuances. In order to express the fullness of the moment and the human perception of weather, she began translating musical data into numerical scores that have a double use as weather almanacs and plans for sculptural objects, functioning as a sort of sculptural shorthand.

Miebach applies the same logic to the musical score as the sculptures – the data and its interrelationships are revealed sonically, without being manipulated to arrive at a particular

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[80] Elaine Rombola plays "Navigating Into a New Night," see: Rombola, 2010.
Rombola articulates her experience and understanding of Miebach's musical scores:

> These scores contain an immense amount of information, more even, in a way, than a standard score made by a trained composer. Coming to them as a pianist with experience with graphic notation of the type pioneered by John Cage and other experimental composers, I felt very comfortable interacting with them and finding ways to turn them into fully realized performances. Nathalie communicates her personal experiences during the period when the data is collected, creating the opportunity for exploring the cyclical relationship between one's life and mood and the weather. Her openness to the musician's free exploration of the material presented in the scores makes it possible for every performance of the score to be totally different, depending on the musician's personal approach to it (Ibid, 2010).

[81] Marina Koren offers insight into Miebach's process as pertaining to sound and sculpture (Koren, 2013).

sound. Musicians have some freedom of interpretation, but are asked to preserve what is essential, ensuring an artistic sonification of meteorological data. By entering into the sculptural process by way of a musical score, Miebach is working to convey a nuanced emotionality that she is concerned was previously absent. She believes that musicians might be able to reveal new, unseen patterns in the data and bring a heightened sensitivity to the process. The translated weather scores are constructed with only a small fraction of storm data: a total of three variables, including temperature, wind, and barometric pressure. The extremes of the data – high values from the wind and low values from barometric pressure – can demand an eight-octave range. Few instruments command such a range, so Miebach suggests that musicians can interpret the score without altering core information. What emerges from this is an understanding of Miebach's past adherence to a "straight" data read, a sort of inflexible control on a specific way of interpreting data.

This process is upended with *The Ride*, which is a new direction for Miebach's work, because she did not write the score. Inherently reflexive and employing Gentry's narrative interpretation of amusement parks as the substrate, *The Ride* is yet another methodology for Miebach. Some familiar elements remain: weather data is plotted upon the surface and overlaying itself, theatrical narrative devices like amusement park architecture continue to defy gravity, and the visualized arc of the hurricane / dragon persevere. It, too, is a call to reevaluate our position on the edge of the water.

The series *The Sandy Rides* demonstrates Miebach's chronicling and data visualizing impulse, not as an objective record of every event, but as a thoughtful and studied approach to revealing the complexities of human existence. The series also calls to mind an idea of the fluidity of data – how new understanding can emerge through the visualization and sonification

of information. *The Sandy Rides* bring to mind the dilapidated, structurally unsound carnivals, the memories of children shouting, and the hot, sticky cotton-candy days of summer. They could easily be interpreted as an escapist journey to the coast, a colorful, playful, fun-filled experience. However, I see contradictory forces and something much darker and ominous, even though Miebach's material language is governed by the concept of play and children's toys. I see fear, exacted by how our collective behavior, and hopelessness and despair in the sensitive translations of weather data, of wrecked communities, of changed lives. Miebach's obsession with the storm is evident as she re-explores the data and imagery in multiple compact sculptures, almost overwrought and chaotic with information. They are ruined architecture, left in the wake of a super-storm, characteristic of what is the new normal for evolving weather patterns. *The Sandy Rides* are a call to change our habits and reevaluate our disavowal of climate change.

Natalie Jeremijenko: xDesign for the Future

The most memorable, striking aspects of Hurricane Sandy were the ephemeral effects of the high winds, pelting rain, and devastating waves that displaced thousands after they tore through cities and coastal communities. But Sandy also revealed a key vulnerability within our critical infrastructure as several wastewater treatment plants were knocked offline in New Jersey. Raw and partially treated sewage that carried high levels of bacteria, viruses, and pollutants flowed into rivers, bays, canals, city streets, and were thus inflicted upon the delicate biology of the coast.[82] Satellites tracked the path of fouled water as it spilled out of rivers (Figure 20). The

[82] An interactive graphic, "11 Billion Gallons of Sandy Sewage Overflow," clearly communicates the type of overflow, the cause, and state totals caused by the hurricane. 11 billion gallons is equal to New York's Central Park stacked 41 feet high with sewage, or more than 50 times the BP Deepwater Horizon oil spill. The vast majority of that sewage flowed into the waters of New York City and northern New Jersey in the days and weeks during and after the storm. See: Kenward et. al., 2013.

pollution appeared as a murky, tan color as it flowed toward the Atlantic Ocean, contrasting with clean, blue ocean water. 94 percent of the spilled sewage, over 10 billion gallons, was the result of some form of damage caused by coastal flooding. Cleanup is ongoing, prompting new ways of thinking about urban biodiversity and alternative, long-term methods of resource management.

One such method of resource management is using bivalve mollusks to clean the waterways. Mussels were once a natural part of temperate marine and estuarine ecosystems but have largely disappeared because of threats including channelization, impoundment, pollution, and invasive species that have lead to global decline and, in some cases, extinction. For example, the Dwarf wedgemussel (*Alasmidonta heterodon*) is federally endangered, and New York State lists a total of seven species of mussels as endangered.[83] Using bivalves like mussels to clean waterways has been a consideration of conservationists and scientists for decades. Scientists are increasingly exploring mussel colonies as potential water filterers, because they quickly and densely grow in three dimensions on large, floating rafts. They can also withstand weather events and a range of toxins (though they may no longer be edible).[84] These exciting human and non-human collaborations for habitat restoration are brought to public awareness with Natalie Jeremijenko's *Mussel Choir.*

Jeremijenko is a cultural producer who questions everything, one who works at the edge of multiple disciplinary practices that include engineering, bioengineering, neuroscience, design,

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[83] Pollution has become an increasingly prevalent problem for all freshwater organisms across North America. Point source pollution includes that from industrial effluent pipes, wastewater release, and chemical spills. Non-point source pollution includes sediment accumulation, nutrient overloading, acid precipitation, and heavy metal increases. Mussel response to these pollutants varies. Responses to toxicants can include a decrease in metabolism and respiration, tissue deterioration, reduction in growth rate, and death (AMNH, 2015).

[84] Paul Greenberg discusses how scientists evaluate mussel function, resiliency, and living conditions, a choice bivalve for cleaning waterways (Greenberg, 2013).

and art, claiming all as important. She resists being categorized as an artist; however, she acknowledges that there are advantages to playing that role:

> Particularly in a techno-scientific context, no one trusts an artist, no one believes an artist. Artists have no authority, artists don't get paid. So when it comes to complicated technical, political, social or environmental issues, the artist then stands in for the everyman. Not having to set expectations about expertise I think is the greatest advantage of saying "artist" (Substratum, 2011).

Jeremijenko coined the term xDesign to symbolize her practice. "X" is a charged term: it can be a marker, as in "X" marks the spot; it is equated with extreme sports or an ex-partner; and it is also a variable. xDesign is part of a disruptive model of exploring how technology can provide the opportunity for social, technical and environmental change. She is an optimist, creating places of hopeful opportunity, where the artificial barriers between the urban and the natural are removed. Jeremijenko makes public art that aims to change the way people engage with science, and the natural systems within their urban environment. Jeremijenko articulates how her practice functions like a laboratory embedded within the environment:

> Art is as much about making change happen as it is about making the things themselves. We all need to be experimenting with what works to produce a healthy, desirable future…the challenge for the 21st century is how to make urban spaces livable, desirable, productive, healthy. The best tools we have—ones that are ubiquitous, inexpensive, and demonstrated to work – are natural systems (Pompilio, 2013).

Jeremijenko is Associate Professor of Art and is associated with the Computer Science Department and Environmental Studies program at New York University, where she began the Environmental Health Clinic (EHC).

The EHC is one of the main components of Jeremijenko's practice for socio-ecological systems design, which operates within the standard institutional framework of the University.[85] Technology is at the core of the clinic's shared goal towards improving environmental health, and since technology is always evolving, it provides new opportunities for investigating and manifesting change. The EHC operates like a medical clinic, with "impatients."[86] Rather than concurring with the patronizing idea that citizens are merely politically neutral spectators in a consumer-driven culture, Jeremijenko works with impatients to activate and give individuals a way to participate within their environment. These (re)mediated environments generate information in turn. In Jeremijenko's words:

> The more radical way to redesign socioecological systems is to understand that we are designing within complex systems, and we have very specific opportunities that we can use and exploit that require participation, not fascist bullying, and engaging the imagination. I know it works to engage people's imagination" (Evans, 2011).

Fundamentally, the clinic is a place for collaboration and establishing communication between communities (human and non-human). By working in tandem with nature for a healthy ecosystem, rather than suggesting simple fixes for systemic problems, Jeremijenko's critique is aimed at the institutions and groups of individuals making policy to determine the fate of our

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[85] The Environmental Health Clinic at NYU is a clinic and lab that approaches health from an understanding of its dependence on external local environments rather than on the internal biology and genetic predispositions of an individual (EHC, 2015).

[86] Jeremijenko articulates that people who visit the clinic are called: "Not patients, but impatients, because they're too impatient to wait for legislative change to address local and environmental health issues." The EHC is a clinic like a health clinic at any other university, except people come to the clinic with environmental health concerns. Impatients leave the clinic with prescriptions for things they can do to improve environmental health, as opposed to coming to a clinic with medical concerns and walking out with prescriptions for pharmaceuticals.

society. By drawing on established practice of Institutional Critique,[87] the EHC extends a critique of art institutions to a critique of medical and governmental institutions, demonstrating that environmental health is connected to human health. Aspects of existing medical models are appropriated, like the prescription, to reimagine alternate practices and networks. Jeremijenko states that this critique "reaches far beyond the collections of museums in which artists question the absences in this cultural record. All legacy institutions are up for grabs for reimagining" (Hutter, 2014). A driving concept of EHC is to redress the crisis of agency in non-human biological organisms, such as trees, in the project *TREExOFFICE* (Figure 21).[88] They question the relevance of corporate personhood in a time when non-human biological organisms suffer from a lack of agency. The EHC explores how individuals engage this dilemma for themselves, by translating abstract information into tangible experience and providing novel models of interaction in physical and social spaces. The interaction models examine the interaction as mediated by technology. Jeremijenko does not assume that there is an existing 'community,' however; providing shared resources and experiences facilitates community building.

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[87] One of the movement's key aims was the exposure and ironization of the structures and logic of museums and art galleries. Key artists include Andrea Fraser, Renée Green, Fred Wilson, Daniel Buren, Hans Haacke, Louise Lawler, Michael Asher, and Marcel Broodthaers. See: Fraser et. al., 2006.

"One increasingly finds institutional critique accorded the unquestioning respect often granted artistic phenomena that have achieved a certain historical status. That recognition, however, quickly becomes an occasion to dismiss the critical claims associated with it, as resentment of its perceived exclusivity and high-handedness rushes to the surface. How can artists who have become art-historical institutions themselves claim to critique the institution of art?" (Fraser, 2005).

"Institutional critique…along with activist work…remain, for me, at this time, the most convincing strategies for an art with claims to the political" (Meyer, 1993).

[88] Installed through December 15, 2015, TREExOFFICE is a temporary installation transforming contemporary work practices into a performance and lifestyle experiment. Driving conceptual issues include: Tree-as-landlord, Rights of Nature, mutualistic systems design, business models for non-humans, ecstasy of the commons, texting with a non-human, and contributing to tree, pollinator, and local environmental health (BBC News, 2015; Tate Harmer, 2015).

Jeremijenko's numerous projects span more than two decades. While I find all of them engaging and relevant, I am particularly drawn to *Mussel Choir* because of its humor, its potential to stimulate discourse, and the potential benefits it can provide to its local environment. For the purposes of this discussion I will discuss the version as installed in Melbourne as historical basis with an eye towards situating the future installation in New York City. Though the New York City installation is incomplete as of this writing, there has been extensive preparation for its infrastructure, in ways that are both physical and social. I believe that *Mussel Choir* is emblematic of a new American cultural trend towards choices that encourage sustainable behavior from a large scale, one that promotes top-down societal change. In this way, Jeremijenko goes beyond incremental individual participation.

Mussel Choir

Mussel Choir is a bio-sensing EV artwork that aims to engage the public on water quality and the unseen complexities of urban ecology. Consisting of a live colony of a native species of mussels, the artwork monitors the water filtration activities of these organisms and converts this data into sound, which is available for passersby who can listen to the mussel choir in situ. The first installation of *Mussel Choir* began at the 2012 Venice Architecture Biennial (Figure 22), in a group exhibition called "Spontaneous Interventions." The project is a result of collaboration amongst many, the main contributors including architect Mark Shepard from the Buffalo School of Architecture and Planning and architect David Benjamin from The Living Architecture Lab at Columbia University Graduate School of Architecture, Planning and Preservation.[89] Since then, the project has been produced globally, including in Melbourne, Australia, with Carbon Arts, and

[89] The Living was just purchased by AutoDesk in a bold move by a company ready to embrace 21st Century strategies of community and accessibility design (Maher, 2014).

it is scheduled for installation in New York City in 2015 (Figure 23). In a major change of scale and location, *Mussel Choir* was recently exhibited as a discrete sculpture in the exhibition "This is What Sculpture Looks Like" in the Postmasters gallery during the summer of 2014.[90] Jeremijenko's work frequently shifts in both scale and location, as exemplified with another xClinic project, *Agbags*.[91] Formally installed *en masse* upon the façade of the Postmasters Gallery as a vertical urban farm, each bag is a growing platform created out of Tyvek and filled with soil, nutrients, edibles, and a time-lapse camera. Bags were available for the public to purchase to develop their own food systems. Jeremijenko conceived of *Agbags* as a clinical trial, a tool for testing and distributing scalable urban agriculture. Each of the white *Agbags* were printed with a rotated red "X," symbolic of the medical red cross and a recurring motif in her work, standing in as the "X" and as a twist on health.

The red "X" was again present on the version of *Mussel Choir* as it was installed in Postmasters Gallery in 2014. Jeremijenko described the discrete work as a pocket ecosystem where the mussels rehearsed. The red "X" hovered over a clear, fused acrylic tank that sat on the floor and was filled with water. Within the main tank were a series of mussels, each within their own lit and vacuum-pressured plastic perch, "singing." Jeremijenko described these spaces as "a sort of luxury high rise apartment, for mussels. The view elevates the mussels to eye contact, or

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[90] "There are too many painting shows. There aren't enough sculpture shows. We are fixing that. Sixteen artists. Sculpture has suffered negation in the discourse and the marketplace…Modernism and postmodernism aggrandized the painting, the mark, the brush, the gesture, rendering sculpture's critical presence invisible, its space a void. In the Internet age, painting and photography slide in and out of JPEGs while sculpture is left behind IRL, its simulacra always giving the digital game away. By now we can't deny it: the critical theories we have erected have proved impotent when confronting the fertile field of sculpture as it is practiced today. Artists are making sculptures with all the overlooked verbs on Richard Serra's list (*). Sculpture exists in and defines not just physical space, but psychic space, conceptual space, political space. And not just space, but our presence in it, our relationship to it, our movement through it, our responsibility for it. Sculpture is physical, at once a thing, the space around it, and an image, a full-spectrum experience imprinted on the brain and the body of the viewer (Postmasters, 2014).

[91] For a full explanation of *Agbags*, including their form and constituent materials, see: EHC, 2014.

rather bivalve to bilabia, breaching the insistent mirror-flat surfaces of our bodies of water and giving voice to new possibilities. Wild observatories may lead to wild observations, wild claims and more wildness in the urban context" (2014). Though the structure of the observatory defeats the idea of wildness, the mode of presentation does bring together the human and non-human nose-to-shell, allowing for direct examination and understanding of Jeremijenko's application of technology, and it lays the groundwork for the future version of *Mussel Choir.*

In 2012, New York City's Economic Development Corporation (NYCEDC) approved the reconstruction of a deteriorated storm sewer outfall pipe at the foot of Pier 35.[92] A series of 30 extremely heavy concrete blocks, weighing between 11 and 59 tons each, were installed on top of the outfall. In an unprecedented move NYCEDC allowed city planners to do something new, beyond the requirements of state and federal regulatory agencies: introduce a sculptural object, with grasses on one end and a small footbridge. The submerged concrete is intended to attract mussel colonies on top of the outfall.[93] Exposed at low tide and fully submerged at high tide, the outcropping is ready for mussels to move in. Enter Jeremijenko's innovative and novel *Mussel Choir*, a technical-biological installation that sonifies silent mollusks as they go about doing what they do: filtering water. The subtitle to *Mussel Choir* is explanatory: "Natural Intelligence for Water Quality Sensing in Urban Habitats." The installation lives underwater, mostly hidden from view until the tide recedes to reveal the subaquatic real estate and its interconnected technology. In the version of *Mussel Choir* that was installed in Melbourne, grouped mussel

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[92] The mission of NYCEDC is to realize New York City as the global model for inclusive innovation and economic growth, fueled by the diversity of its people and businesses, by strengthening the City's competitive position and facilitating investments that grow quality jobs and cultivate dynamic, resilient, livable communities throughout the five boroughs (NYCEDC, 2015).

[93] Similar efforts are underway at Hunts Point Rivers and the Bronx Kill (LaSalle, 2010; and Loria, 2015).

strands were connected with pink sensor wiring and multi-stranded heavy red rope to a red circuit box in the tides (Figure 24).

Mussel Choir is literally a grouping of mollusks and wiring components that activate when the mussels gape to filter water. Their movement triggers a responsive set of sounds. The mussel shells are attached to a hall effect sensor[94] and a rare earth magnet.[95] As the mussel shell opens and closes in response to local water conditions, data is extrapolated from movement and converted into sound patterns. Audio mappings included sound pitch to water depth, timbre to pollution levels, and tempo to the shell's opening and closing. Arrays of these mussel-sensors are incorporated into the mussel colony, and a computer program driven by the collected data generates the choir's sound.

Mussels are natural water purifiers. One mussel can filter approximately 6 liters of water per hour, removing particulates and pollution. The larger the colony size, the larger the environmental benefits. Mussels pump water through gills, simultaneously supplying oxygen and filtering particles of food, which are then transported to the mussel's mouth and stomach. Each mussel is unique and has its own CHIGA (changes in gape angle per second). Since the mussel life span can run the course of several decades, even up to a century, *Mussel Choir* can illustrate the adaptation of organisms to evolving anthropogenic conditions. Using standard mussel-farming techniques in Melbourne, Jeremijenko's team established a scalable mussel population of 5,000 individuals, 20 of which were instrumented. The mussel colony was established on a

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[94] A Hall effect sensor is a transducer that varies its output voltage in response to a magnetic field. Hall effect sensors are used for proximity switching, positioning, speed detection, and current sensing applications. In its simplest form, the sensor operates as an analog transducer, directly returning a voltage (Ramsden, 2006).

[95] Rare-earth magnets are strong permanent magnets made from alloys of rare earth elements. They produce significantly stronger magnetic fields than other types such as ferrite or alnico magnets. However, a new material has been manufactured with nano-particles has the potential to revolutionize the manufacturing, transportation and clean-energy industries (Collette, 2012).

rope system, a low-cost process commonly employed in mussel farming. Mussels prefer living in the littoral zone (Figure 25) from suspended ropes. Vertical rope systems were created to function as littoral zones. By doing so, Jeremijenko ensured that part of the mussel colony will be viewable from the surface.

The intersection of the digital and biological is known as "Moistmedia," a term coined by artist/ theorist Roy Ascott in 2000 to conceptualize the joining of virtuality and biology in the transformation of a new, fluid reality. Recognizing that intelligence is everywhere, Ascott says that Moistmedia will be the future substrate of art and form new awareness:

> This burgeoning awareness is technoetic: techne and gnosis combined into a new knowledge of the world, a connective mind that is spawning new realities and new definitions of life and human identity. This mind will in turn seek new forms of embodiment and of articulation (2000, 2).

This new technoetic embodiment is exemplified with Jeremijenko's *Mussel Choir* as an agent of environmental and social change. The mussel's elusive biological mechanism is a phenomenon, relegated to the submerged world and unencountered on land. Jeremijenko actualizes the organisms so that their presence is sonified and made measurable for the terrestrially bound.

Though new and relatively untested, biological organisms can be used as sensors. Biological organisms are integrative of a variety of variables, simply translating them into a legible data stream. In a simple world, that legible data stream might appear as mussels singing, therefore indicating that the water quality is good and the mussels are doing well (at least for those who are on sensors).

An inspection of Jeremijenko's data assignments indicate layered over-complexity and can obscure information: for example, water quality is indicated by a blue or red LED; the presence of fish illuminates an underwater path; human interest through text messages results in a variety of blinking lights; air quality has another set of blue and red LEDs; the presence of

people triggers a blue LED; activity of birds prompts both sound and light; and finally, the mussel choir sings, at dusk and in individual regions (Figure 26). A data set that incorporates water pH, dissolved oxygen, turgidity, and the meaning of those combinations is discipline-specific knowledge – a difficult to understand dataset for the layperson. Jeremijenko clearly articulates the biological organism (whether mussel or butterfly) as a point of human interest and engagement. In this case, the biological organism indicates a healthy ecosystem:

> This butterfly is critically dependent on the sage grass that only grows in particular brackish water and I knew that if the animal volunteers to be there, then I've done a good job…This is legible for everyone… It's the independence of that butterfly, it's autonomy, it's agency to say, "I'll hang out here" that really validates what I'm trying to do (Substratum, 2011).

The biological organism (the mussel) can function as one component of a complex system that indicate water health, which include dissolved oxygen, water temperature, pH, escherichia coli, specific conductance, nitrates, transparency, and visual tests.[96] The data collected from the mussels will be specific record of their CHIGA frequency and how they have colonized. The mussel colonies will contribute to the stream of environmental data as collected from selected ecosystems where they have historically existed and are being re-introduced. Like other biological organisms, mussel colonies behave in response to environmental pollutants and can be an indicator of ecosystem health.[97] For decades, mussels have been studied around the world as bioindicators and biomonitors, as they are sensitive to anthropogenic contaminants like trace metal pollution and PCBs; landscape alterations including sedimentation from impoundment and

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[96] These measurements provide a snapshot of water conditions as a basis for further analysis. The measurements can be applied to any body of water (LCRA, 2014).
For further reading regarding microbial water quality, see: Ashbolt, 2001.

[97] A key indicator of environmental health and biodiversity are amphibian species. Research suggests that we cannot rely on data from only one species as a bioindicator, but that a suite of bioindicators is required. See: Sewell and Griffiths, 2009.

marine dredging; and boat traffic (Grabarkiewicz and Davis, 2008). Future data could be collected from mussel colonies, checking for colony establishment and reproduction. Establishing new mussel colonies in urban areas is one step towards supporting the future of urban biodiversity as a global movement.[98]

Mussel Choir translates data through sonification, using a rules-based methodology of wherein specific sounds are attributed to the local ecosystem. For example, the songs map parameters such as water depth to sound pitch, presence of pollutants to sound timbre, and the rate of the opening and closing of mussel shells to sound tempo. Jeremijenko notes,

> The aim is to clearly represent the qualities of water, rather than to represent water quality as it has been codified for regulatory purposes. There are two main choral modes: real time "mussel tone" and the data review or mussel performance mode. (Carbon Arts, 2013).

The sounds of the real time "mussel tone" are controlled through changes in the mussel gape. As the mussels open and close during water filtration, the gape angle triggers an arpeggio around a chord. Overlaid on this chord is the Shepard tone effect, controlled by the tides: as the tide is incoming, the tones appear to ascend; as tide retreats the tones appear to descend.[99] The chords use both functional and modal harmony to map the turbidity of the water, a critical parameter that expresses the degree to which light is scattered and absorbed by particles suspended in the water column, directly effecting the underwater food network. During the mussel performance mode, *Mussel Choir* sings "Daisy Bell," alluding to recent computational history with the first

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[98] Fostering biodiversity in urban and suburban areas is one way to support a rapidly diminishing ecosystem, and work towards establishing "green cities." See: Conniff, 2014.

[99] The *Shepard tone* is named after the cognitive scientist Roger Shepard. The *Shepard tone* is a sound consisting of a superposition of sine waves separated by octaves. When played with the base pitch of the tone moving upward or downward, it is referred to as the Shepard scale. This creates the auditory illusion of a tone that continually ascends or descends in pitch, yet which ultimately seems to get no higher or lower. See: Shepard, 1964. For a sonic example of a Shepard Tone, see: Icydrift, 2012.

invented speech synthesis experiment in 1961. At that time, Bell Labs demonstrated the sound of computerized speech patterns with a powerful (at that time) IBM 704 computer. The machine sang "Daisy Bell:"

> Daisy, Daisy, Give me your answer, do.
>
> I'm half crazy all for the love of you.

Previous machine-speech interfaces employed "Daisy Bell" as a defining structure. In Stanley Kubrick's 1968 "2001: A Space Odyssey," the computer HAL 9000 sang "Daisy Bell" when it regressed; the Homebrew Computer Club created a machine-speech interface using a radio and an Altair 8800 in 1975 that sang the refrain;[100] and on the IPhone 4S when Siri is asked to sing, she repeats "Daisy Bell." Finally, Aaron Koblin and Daniel Massey encouraged 2000 people to contribute their voices to the song via Amazon's Mechanical Turk[101] (Gallardo, 2013). Though *Mussel Choir* is an intelligent singing enterprise simultaneously looking back to reference history and reaching forward into the future of NI, there seems to be too much referential reliance on the "Daisy Bell" lineage. It remains unclear why Jeremijenko is choosing to memorialize "Daisy Bell" using mollusks, and I question this particular sonic choice as vocal representation. The overt reference to the history of speech synthesis distracts from the beauty and complexity inherent in *Mussel Choir.* The mussel performance mode functions as a triggered recording and sound playback rather than vocal synthesis. There are other possible ways to capture the sound of

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[100] The Homebrew Computer Club is the birthplace of the entire personal computer revolution. See Wozniack, 1984.

[101] *Bicycle Built For 2,000* was synthesized with a distributed system of human voices from all over the world. This was made possible with the MTurk platform where the artists invited workers to listen to a short sound clip, and to then record themselves imitating what they heard. People from 71 countries responded and each was paid $0.06 USD for his/her work. Bicycle Built for 2,000 is a comment on only on today's forms of precarious immaterial labour but also on our inability to detach ourselves from the media reality and the continuous preoccupation with it (EMST, 2009).

the mussels by using the AC impulse captured by the already employed hall sensor. Once amplified, the raw output could be ambient, unrecognizable, and beautiful in its abstraction. *Mussel Choir* is not embedded in the history of computer synthesized voice programming; rather, it is a mapping of sounds to controlling parameters. The reference to historical voice synthesis seems and heavy handed because the anthropormorphization of mussels by mapping of human vocals (or the computerized version of them) prompts thoughts of Disney movies where every animal becomes humanized and likeable. I argue that for *Mussel Choir*, this calculated move is unnecessary because we already see them positively as collaborators, protagonists, neighbors, and allies.

Mussel Choir is a multifaceted installation that provides the opportunity to develop a deeper ecological understanding of a shared urban habitat. Through this knowledge and appreciation, the mussel colony will encourage curiosity and public commitment to ecological knowledge. Real estate at the water's edge is a charged space normally associated with leisure activities and distraction, but *Mussel Choir* inverts this expectation through the exploration of data on immediate local estuarine water quality through visceral experience. Urban aquatic phenomena become intimate and relatable, demonstrating how we can make the intersection of land, air, water and urban systems more productive and viable. In an economy buttressed by the entertainment industry, *Mussel Choir* becomes the focus, a new community service-oriented commodity, and a water-cleaning spectacle for the future of green cities.

Conclusion

Each of these works, *Cloud Car* and *Particle Falls*, *The Sandy Rides*, and *Mussel Choir*, exemplifies the broadened definition of EV through their mode of representation. Ranging from Polli's repurposed car and digital waterfall that make smog visible, to Miebach's discrete

sculptures playfully materializing storms, to Jeremijenko's electronic singing mussel colonies, these EV works go beyond the screen to offer unique ways for the presentation and interpretation of data, and the conception of a healthy, sustainable, diverse planet. Through creative translation, these artists make comprehensible the factors impacting our environment by examining the very way we look at data. They question how we see environmental data by employing a variety of visual and auditory elements help us to see and hear while simultaneously investigating how those same elements might prevent clarity and insight. Of particular relevance to my studio practice is Miebach's series, *The Sandy Rides*, which employs complex datasets of weather events and related phenomena and translates this information into complex, visually playful sculptures made with common materials and parts of childrens' toys.

Polli, Miebach, and Jeremijenko are concerned with our global ecosystem as a whole, though their work related directly to air pollution, climate change (storm patterns), and urban ecological systems. Their incorporation of a variety of modes of representation that visualize environmental information are indicative of our changing perception of the human impact upon the environment and ecology. These projects provide a solid foundation that informed my conceptual development, data collection, material choices, and mode of representation for my creative work, *Sculpting Corn Production.* Like them, I am concerned with the global ecosystem and feel distress when considering climate change, environmental degradation, and the loss of biodiversity. I chose to work with factory-farmed corn as an entry point to the broad discussion of the environment. In the next chapter I will discuss the historical precedents of the corn industry and how it informed my creative project. I will link my creative project to the EV work discussed here, and to a lesser extent, in Chapter One. I expect my research and creative project to be a foundation for my future studio work and research.

Chapter Three: Sculpting Corn Production

Introduction: A Patriotic Grain

Agriculture holds an esteemed place within the American identity, conjuring images of amber fields of grain, a small family farm, and an idealized "authentic" America. Corn is a major part of that powerful imagery but it did not begin to shape our collective national consciousness with success when it was first encountered. The first white settlers agreed with the herbalist John Gerard in 1597 when he described corn, a staple of the Native American diet, as a "heathan graine" (McWilliams, 2005, 8).[102] Originally seen as fit only for animal feed, corn was slowly assimilated into the dominant colonial diet. Though historically American cooking was distinguished by creole cuisine, taste was reconfigured as part of the process of cultural adaptation and domination of North America. Corn was rapidly accepted into the colonial diet. By the middle of the 17th Century, the newly settled English were consuming corn as a staple by incorporating it into a variety of food products, like quick breads, whipped cornmeal pudding, and brewed beer. Highly political, corn as a main food source became an essential part of the cohesive Colonial American identity and underscored the connection to their land.[103]

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[102] John Gerard's 1597 *Herball, or Generall Historie of Plantes* was popular, and strived for greater accuracy in publication. Discoveries of previously unknown plants brought over from the Americas familiarized botanists with the concept of geographical variation and distribution. In Gerard's herbal, locations of plants were added with the help of a network of correspondents in England to detail where plants had been found. Although Renaissance herbalists were critical of medieval practices, they inherited the tradition of plant portraiture from their predecessors. The tradition was much improved by this new wave of herbalists who used illustrations drawn from actual plants, rather than stock images privileging mythological or emblematic considerations, which were useless for identification purposes. See: Gerard, 1597.

[103] For an historically contextualized discussion of food and its connection to the creation of a national identity, see: McWilliams, 2005; Smith. 2007.

Today corn remains a mainstay of an idealized America, with overlapping identities ranging from the profitable and powerful industrial mega-giant producing ethanol fuel and factory goods; to the hardworking pastoral agrarian overseeing miles of waving grain; to the benevolent provider as a global food producer and supplier. It's a numbers game: the United States' corn harvest accounts for approximately 40% of the world's overall corn production, projected at a total value of $76.62 billion annually and growing. Corn is processed into over 3,500 forms, including plastics, fuel ethanol, alcohol for beverages, animal feed silage, pet food, sugars and cereal starches for human consumption, oil, penicillin, and glue. Contemporary farmers grow five times more corn than they did in the 1930s and on 20% less land. Historically, farmers could harvest an average of 100 bushels of corn by hand in a nine-hour day. Now mechanized combines harvest 900 bushels of corn per hour, equal to 100 bushels in less than seven minutes. The 2014 harvest was valued at $51.89 billion. No matter which way this information is encountered, there is a lot of money embedded in this valuable crop, and the sheer scale of production and distribution is totally overwhelming. The data from the production and distribution is available from primary sources including the United States Department of Agriculture (USDA). The USDA data is aggregate statistical and economic information, presented without analysis and little to no explanation, and with even fewer visually supporting diagrams. The specificity of detail, abundance of information, and lack of supporting visual documentation is where I found a foothold to begin my creative endeavor.

I entered this confusing (and seemingly boundless) field several years ago when living deep amidst cornfields in central Ohio at Kenyon College, as an artist in residence. The social isolation and sheer loveliness of the place were striking, but there was a resonant chord of disquiet amongst the stalks. At the same time I also became aware of a persistent allergic

reaction that was finally attributed to my processed-corn consumption. Fueled by concern, I could not stop thinking about the miles and miles of cornfields, the endless farming and rotation, how corn was in almost every processed food product in the supermarket, and how it is the substrate of countless products and fuels. Corn was unavoidable and literally surrounded me. I also began to have a sense that all the corn production was not good for the environment, a feeling justified by the research of the effects of monoculture farming. My place-based distress, the experience of solastalgia, was connected to feelings of powerlessness around the environmental injustice of corn production. Albrecht asserts that solastalgia

> Has universal relevance in any context where there is the direct experience of transformation or destruction of the physical environment (home) by forces that undermine a personal and community sense of identity and control… the experience of solastalgia is now possible for people who strongly empathize with the idea that the earth is their home and that witnessing events destroying endemic place identity (cultural and biological diversity) at any place on earth are personally distressing to them (2005, 49).

In response to my distress I investigated how corn came to be a dominant material in food and consumer goods, and was preliminarily stymied by the vast amount of interrelated information from various sources. Very little of this data was visualized except in graphical forms, in self-congratulatory, celebratory documents like the annual "World of Corn" published by the National Corn Growers Association (NCGA).[104] After locating the appropriate data banks and researching data relating to corn production, I began visualizing this data three-dimensionally, constructing physicalized forms.

The body of this chapter is divided into three main sections. First, I describe the creative project - consisting of three discrete small sculptures - and the process involved in their conception, creation, and presentation. In this first section I highlight the specific data informing

[104] "World of Corn" is available annually from 2000. See: NCGA, 2015.

the sculptures. Second, I position the sculptures in relation to the concepts and works discussed in the previous chapters. The creative project results in conclusions that affect how I consider my own creative process, and I discuss specifically the links between the creative and scholarly processes not obvious during the process. In the concluding section, I look forward to future research and creative efforts. I anticipate that the investigative study will point to further areas for additional research, and that the creative project will lead to new avenues and ideas for concepts and artworks.

Creative Project: *Sculpting Corn Production*

Data Collection

I began the research on my topic with a simple question, assuming that I would find discrete economic data that would culminate in a clear answer. As I began this dissertation research, I encountered abundant literature discussing corn as a subsidized commodity, wherein farmers benefitted from Loan Deficiency Payments, Counter Cyclical Payments, and other governmentally financed support systems. Intrigued by the large sums indicated in the reports, I started with a seemingly simple question that led to further insights. My question began in this form: What does an individual taxpayer spend on US corn subsidies annually? Though interesting, my original question was under-developed due to a lack of knowledge of the structure of actually reported USDA crop data. I assumed that I would locate the data on individual crop subsidies and place said data in relationship to census population data. With that critical information in hand, I could then derive a number using straightforward mathematical equations. Though this approach did not lead to the answer that I had originally hoped for, it did help me find all the data that ultimately resulted in the creative project. During this period of

research, the collected data was transformed from how it was listed as a tabulated set of numbers into something much more rich and tangible, the stuff of my sculptures. When encountering this data I considered Ben Fry's suggestion from *Visualizing Data*:

> ...the most important part of understanding data is identifying the question that you want to answer. Rather than thinking about the data that was collected, think about how it will be used and work backward to what was collected. You collect data because you want to show something about it. If you don't really want to know why you are collecting it, you're just hoarding it (2008, 4).

My early data collection methodology consisted of researching relevant articles and primary sources associated with the corn production industry. This gave me a broad overview of the field, and it contextualized the main issues surrounding industrial corn production and processing. These areas of interest include the impact of ethanol subsidies on global corn production[105], the contribution of processed corn to nutrition and nationwide obesity levels,[106] data on USDA nutrition programs since 1969,[107] the evolution of corn including genome-wide changes during the breeding of maize,[108] the comprehensive genetic analysis of corn for new varieties,[109] the visual mapping of the corn genome by the National Science Foundation,[110] and

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[105] Analysts encounter complexity when discussing the impact of ethanol production on corn prices. For a thorough discussion of the issue, see: Babcock and Fabiosa, 2011; and Valles, 2014.

[106] Nationwide obesity levels have been steadily rising since the 1970's, at about the same time corn sweeteners became a staple of the American diet. See: Hawkes et. al., 2015; Fryar et al., 2014; and Fryar et. al., 2012.

[107] The USDA's Food and Nutrition Service offers datasheets on their historical nutrition spending. Governmental spending for food assistance programs was trending upward until 2014, when program funding was cut. See: "Snap Benefits Summary," 2015.

[108] The success of modern maize breeding has been demonstrated by remarkable increases in productivity over the last four decades. Research shows that modern breeding has introduced highly dynamic genetic changes into the maize genome. Genetic changes during breeding happen rapidly, see: Jiao et. al., 2012.

[109] Future strains of corn may resist pests and disease, see: Hufford et. al., 2012.

[110] This new genome sequence reports the sequence of genes in maize and provides a detailed physical map of the maize genome. This map identifies the order in which genes are located along each of maize's 10 chromosomes and the physical distances between those genes, see: National Science Foundation, 2009.

environmental degradation due to chemical usage.[111] The environmental degradation information was particularly troubling, and it heightened my sense of solastalgia when considering the thousands of acres of cropland, rivers, and adjacent environment affected by monoculture farming.

Along with relevant articles documenting the history and complexity of Farm Bills,[112] I found in-depth analysis of governmental subsidy spending for the last decade from the Environmental Working Group (EWG),[113] an overview of fiscal policies[114] and visual data indemnity maps from the USDA's Risk Management Agency (RMA),[115] relevant reports and trend analysis from Amber Waves[116] and the USDA's Economic Research Service (ERS), and

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[111] Scientists and global policy makers cite the link between agricultural practices and environmental degradation, see: UNCTAD, 2010 and Kleinschmit, 2009.

Grid-Arendal, in association with the United Nations Environment Program, released a comprehensive analysis of the environmental food crisis, see: Nellema et. al., 2009.

The Environmental Working Group (EWG) released a report in 2011 documenting soil erosion due to farming, see: Cox et el., 2011.

[112] *The Washington Post* ran a series of in-depth articles documenting how the government overspent by $15 billion in redundant spending on subsidies. See: Morgan et. al., 2006.

On taxpayer supported corn and soy subsidies, and the lack of subsidies for healthier alternatives, see: Haspel, 2014.

For an explanation of the eight different kinds of farm subsidies, including farm insurance, see: Edwards, 2009.

The United States federal government had no role in farming. It is now intertwined in all aspects of farming, from planting to harvesting to selling crops. For a history of American farm subsidies, see: Folsom, 2006.

[113] The EWG has a listing of top subsidy recipients from 1995-2012, by state, and visually represents corn subsidies. See: EWG, 2012.

[114] Indemnities are payment made by a government insurance product. For yield insurance, indemnity payments occur when yield is below a yield guarantee. For revenue insurance, indemnity payments occur when revenue is below a revenue guarantee. Multiple peril crop insurance will also pay indemnities in other cases such as prevented plantings. For an overview of the different available crop insurance policies, see: USDA RMA, 2015.

[115] Data Indemnity Map, from 6/29/15, documenting crop indemnity by county on a visual map, see USDA RMA, 2015a.

[116] *Amber Waves* is a USDA ERS publication dedicated to the broad understanding of food, farming, natural resources, and rural America. Amber Waves, 2015.

the USDA ERS Farm Program Atlas[117] and Farm Data Documentation maps.[118] These early resources buttressed my broad understanding of the political, fiscal, environmental, and health issues connected with governmental farm spending programs. With this background, I was able to comprehend and begin analysis of numerical content. Most importantly I found historical data banks regarding all aspects of corn production compiled from 1866, from the USDA ERS Summary of Business Reports and Data,[119] the USDA Feed Grains Yearbook Tables,[120] USDA Agricultural Projections to 2024,[121] USDA ERS Feed Grains Database,[122] the USDA ERS granular data relating to corn in both Commodity Costs and Returns database,[123] and the National Agricultural Statistics Service (NASS) commodity database.[124] Other critical information sources include the National Corn Growers Association (NCGA) annual reports and

[117] All Farm Program Atlas data is organized in a spreadsheet by payment program and available by state and county, see: USDA ERS, 2015b.

[118] For an interactive map documenting Direct and Countercyclical Program since 2009, see: USDA ERS, 2012.

[119] A variety of reports are pre-generated by crop, see: USDA ERS, 2015c.

[120] The June 2015 *Feed Outlook* report contains projections for the 2015/16 U.S. and global feed markets based on the most current *World Agricultural Supply and Demand Estimates*. See: Capehart et. al., 2015.

[121] Released in February 2015, the Report provides long run projections for the farm sector for the next 10 years. These annual projections cover agricultural commodities, agricultural trade, and aggregate indicators of the sector, such as farm income. See: Westcott and Hansen, 2015.

[122] The Feed Grains Database is an interactive application. Information includes but is not limited to the following: Supply: beginning stocks, production, and imports; Demand: utilization for food, seed, and industrial uses, feed and residual, exports, and ending stocks; Prices: farm and market prices; Quantities feed: concentrates, oilseed meals, and animal- and grain-protein feeds; Feed-price ratios for livestock, poultry, and milk. See: Capehart, 2015.

[123] Cost and return estimates are reported for the United States and major production regions for corn, soybeans, wheat, cotton, grain sorghum, rice, peanuts, oats, barley, milk, hogs, and cow-calf. The history of commodity cost and return estimates for the U.S. and regions is divided into three categories: Current, Recent, and Historical estimates. See: McBride, 2015.

[124] The USDA's National Agricultural Statistics Service (NASS) conducts hundreds of surveys every year and prepares reports covering virtually every aspect of U.S. agriculture. Production and supplies of food and fiber, prices paid and received by farmers, farm labor and wages, farm finances, chemical use, and changes in the demographics of U.S. producers are only a few examples. See: USDA NASS, 2015.

the USDA Budget Summary and Annual Performance Plans.[125] These select databases, in conjunction with US Census population information, provided almost all the needed data from closed-set databases for the creative project.

Once the data was sourced and assembled, I began analysis and response to the hundreds of pages of data representing numerically based insight into American corn agribusiness. This amount of data was overwhelming and unknowable in its totality, density, and disparity. In the USDA Annual reports, financial data is provided in labeled tables in millions of dollars, including total listed net enacted, estimated, and budgeted outlays in every area. In user-driven farming databases, the USDA provided numerical data that was far-reaching and subdivided geographically by state and county: the number of acres planted and harvested; the number of bushels produced by acre; overall crop insurance plans for corn, hybrid corn, and sweet corn in liabilities, premium, and subsidy; U.S. corn production costs and returns per planted acre, excluding government payments; and the corn feed ratios for a variety of farm animals. Some data was nationwide by year or growing season in the millions of bushels and / or acres: prices received by farmers; the number of acres planted and harvested; the yield per harvested acre; overall production; beginning and ending stocks; food, seed, alcohol, and industrial use; overall imports and exports; feed and residual use, by species of domestic animal; domestic use and total disappearance; alcohol for fuel, beverage, and manufacturing use; starch, cereal, and other product use; CCC-owned inventory (stocks and oversupply) - also subdivided by monthly stock price; high-fructose corn syrup, glucose, and dextrose use; and world corn production,

[125] By far the most comprehensive and easy to read database for government spending is the 2016 Fiscal Budget. New and online, it is released in a spirit of transparency. Each year, the United States' Office of Management and Budget (OMB) releases the Budget Message of the President, information on the President's priorities and initiatives, and key data to support the proposed budget, see: White House Budget, 2015.

consumption, imports, and exports. Other data came in the form of percentages: overall USDA budget outlays, subdivided by nutrition assistance, conservation and forestry, and farm and commodity programs; the use of genetically modified seed and its subdivision by type; organic corn acreage; the components of yellow dent corn; production needed for future use in 2020; and the rise in Biotech corn adopted by farmers.

In this raw form the data was meaningless, necessitating a series of rules to create meaning and provide a visual language. I established that the first step in analysis was to simplify and parse the information by choosing to represent nationwide data rather than that which was divided by state and county. Locating data that was less geographically granular eliminated extraneous, obfuscating information. From that point I organized the data into smaller, manageable sets wherein interconnections emerged and discrepancies within the data became clear. For example, the data for *High-Fructose Towers* revealed that corn sweetener use spiked, as did corn planting. The data also shows another major change: that corn sweetener use did not plateau after the spike, but continued to fall. Because of the data discrepancies, I was able to extract both interest and meaning from the data to begin making form.

Once these steps were completed, the information became a tangible substrate to be represented visually and manifested as form. However, even when simplified, the data sets remained unmanageable as a jumble of statistics, an overlapping tangle of evidence within which no clear picture emerged. Even though the data was reduced, clarity was elusive.

The creative project is the first time that I have started with a dataset as the driver for concept, narrative, and form. Since working with numerical data was new to me, I started with very small groupings of data and made a series of rules specific to each sculpture, which influenced each in both structure and scale. There were some excellent failures along the way,

specifically whenever I strayed from allowing the data to directly dictate form, as in the slant of a line, or the number of needed sections. However, it was the failures that promoted creative growth and furthered visual exploration, in scale, line quality, layout, layering, color use, and overall form. Since 50% of the creative project was previously an unknown area of studio exploration, I chose familiar materials (paper) and processes (digital drawing, laser cutting, and precision scoring / folding) to make the sculptures.

My material of choice is an archival, acid-free translucent 110 lb coated paper that refracts and disperses light, which allows for excellent high-contrast photographic documentation. Through experimentation, I ascertained that this paper absorbs ink, does not tear easily, glues relatively well without much buckling, is forgiving with handling errors, and is made with enough natural fibers and a thin coating permitting work with the laser cutter. Since this paper is heavy and thick, it also holds creases, curves, and supports itself if stood on end, even when 90% of the material is removed.

Data was the main consideration for form, and influenced every successful drawing. Each was constrained to a 16” by 12” compositional space due to the size of the laser cutter bed. I consider this to be a tiny amount of material real estate to work within and it certainly forced me to creatively engineer objects larger than 16” in any dimension. Preliminary sketches were made with pencil and ink on paper, but all of the layout designs were made in Adobe Illustrator, a vector drawing program. Each pattern design was based on data, which were driven by a sculpture specific, rule-based system. The design logic was maintained for each sculpture and necessarily changed with the individual datasets, as I worked to experiment within each design. For example, the vertical spiraling grid of the first sculpture needed to plot 150 years of data over three horizontal pages. The grid also needed to represent an explosive population growth of 300

million persons but not exceed an upright height of 12". For this grid, I chose a strong ⅛" wide line weight was chosen for both the horizontal and vertical lines, with ½" squares. The angle of growth was based on population growth. The entire length of the completed cut object is 15.25" tall x 45" wide, which was then manipulated into an 8" wide spiral and glued with connective pieces.

One of my main goals was to work on a smaller scale (18" height x 10" width or less) since most of my previous work consists of large-scale installations and objects. Adapting my processes to this rule of scale was critical because I see the creative project as laying the foundation for future work, and thus, as a series of experimental three-dimensional "sketches" toward larger sculptures. All my past work began as paper and / or cardboard models, which is the way in which I conceive of installations and sculptures. Paper became the final presentation material for these three data sculptures. Therefore, processing the paper accurately with precision was essential to success. The forms I chose to represent data are tiny, detailed, and impossible for me to cut by hand. The laser cutter translated vector drawings based on line quality and silhouette into manageable objects. Each drawing was tested and cut for scale checks and accuracy. Some shapes seemed large and clunky, requiring total redesign after they were cut in paper. Other line weights were infinitesimal, and the laser cutter burned the paper away, rendering them unusable. Some designs just did not cut well due to technical machine complications. Other designs were not chosen at this time because of personal choice. Successful paper forms were then manipulated post-process and glued with PVA to hold a shape. The miniature shapes required small tools for manipulation: curved bent-nose jewelry pliers and toothpicks were employed for positioning, clamping, and glue application.

The silhouettes are familiar, common industrial forms that are strong compositional elements in my past work that hold both personal and cultural significance. Architecturally inspired towers, fences, grids, silos, concentric ovals, and linear reticles are all structures and geometry present in my other work. These constructions are emblematic of industrialized culture, are omnipresent within suburban and rural landscapes, and are part of a shared collective American agrarian consciousness that positions us within our fields of production. Silos, towers, and other agrarian architecture represent the rampant overuse and abuse of our shared farmland. While these structures seem celebratory and benign, they represent a culture of unsustainable land use dependent upon limited (and polluting) fossil- and carbon-based fuels.

In the creative project, each sculpture is assigned meaning in order to embody data. I consider these fabrications symbolic, holding data-driven content while being both abstracted and aesthetic. In other words, these three sculptures are physicalized eco-visualizations but their meaning and represented data are purposely removed from a clear reading by the viewer.

Each of the sculptures is a discrete exercise identifying a new process for my work, serving as one way for me to examine how to work with data as substrate, and subsequently how to translate the information into form with meaning. The overarching purpose of my research was to deeply investigate the corn-production industry in order to further my own understanding of our food production in the U.S. I did not start this project from a position of judgment, nor do I wish to castigate individuals for their personal food choices. Looking at our food production holistically I see that few choices are as cut and dried as one could hope.[126] However, I do think

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[126] Perhaps one of the only ways to avoid the pitfalls of our food production system is to grow our own food. See: Kingsolver, 2007.

Ensuring that every individual has affordable access to sufficient and nutritious food is a profoundly important and consensual moral imperative. However, while there is no debate about the moral imperative to feed the world, there are contested visions of what it means to feed the world ethically. Feeding the world ethically could

that we as consumers can make better choices in terms of food consumption for ourselves and for the health of our global ecosystem. I reached this conclusion as one dataset led to another, starting with Corn Production, whose years began with the first recorded corn harvest in 1866. The rapid growth of corn as a staple crop is part of what compelled me to explore the excessive harvests and corn grain surplus since the 1970s. This information led to the second sculpture, *High-Fructose Towers*. This sculpture compares data from three select years wherein there was a discrepancy in the corn sweetener data, either in production or consumption. Each of the three years sampled by this dataset featured a high numerical value that did not plateau, but in comparison went sharply down. The relatively limited dataset of the second sculpture functioned as impetus to visualize a larger set, informed again by the corn grain surplus. The excessive harvest is directly linked to genetically modified corn as supported by the use of pesticides, herbicides, and fertilizers. This information drove the dataset for *Biotech Silo*, an examination of the rapid adoption of genetically modified grain and the change within the farming industry across the U.S. Linked conceptually; the sculptures are discrete exercises with form.

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mean ensuring universal access to what is needed nutritionally for human survival and mitigating hunger; it could be securing a sufficient quantity and quality for a high quality of life; it could extend to include the welfare and rights of agricultural workers and farmers, the environment, and the well-being of nonhuman animals; and it could mean protecting choice in the marketplace or on respecting cultural and national traditions and ways of life. The challenge for ethically acceptable global food security is to find a path forward, where tangible progress on ethical issues and disagreements in global food policy and practice is possible even in the absence of consensus about relevant values and permissible means. See: Faden, 2013.

Past Project: Subrural

In 2010 I was at Kenyon College in Gambier, Ohio, as the Mesaros Artist in Residence. During that time I read Michael Pollan's *The Omnivore's Dilemma* (2006), a thorough discussion of the dysfunction of the entire American industrial food complex.[127] Pollan details how corn is at the base of the national food chain, explaining how its growth, processing, and sale constitute a titanic industry which is focused on increasing profits rather than health and well-being. Pollan's work was personally influential; I began to see the cornfields surrounding me in a new light. Rather than recognizing them as an element of natural beauty or even neutral backdrop to agrarian landscape features, the giant fields became symbolic of the ongoing ecological industrial disaster. I began to feel forlorn and powerless amidst the miles of corn monoculture. This new insight informed a body of work that is directly related to my creative project. Created in collaboration with Kenyon College Professor Karen Snouffer[128] and Matthew McCormack, *Subrural* was an installation work exploring the increasing homogeneity and continuing dichotomies of urban and rural environments. This work was narrative in intent, a visual reimagining of an increasingly industrialized rural landscape. The work sought to address the cultural anxiety experienced at the intersections of these familiar but unpredictable places and ecologies. Though not directly visualizing cornfields, *Subrural* was a visual narrative informed by the complex systems of large-scale agribusiness and its pervasive and negative impact upon the environment and landscape.

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[127] Though I don't subscribe to the idea that Pollan is an expert on all things food-related, his writings were key inspirations for my research.

[128] Karen Snouffer is an artist whose work concentrates on installation and multi-media, exploring themes of identity, history and place. See: Snouffer, 2015.

Subrural marked the beginning of the exploration of repeated visual elements informed by the rural agrarian landscape, including abstracted invasive flora and fauna and the similarly invasive architecture of the electrical grid. Using translucent polycarbonate plastic sheet, fiberglass window screen, paint, and thread, we created a series of printed, enlarged cicada wings which were layered into large swaths throughout the installation. The same materials were used to create contorted, undulating vines informed by species like Japanese honeysuckle, a plant which thrives in disturbed habitats, such as roadsides, trails, fencerows, abandoned fields, and forest edges. Disturbances such as logging, road building, floods, and windstorms create an opportunity for this vine to invade native plant communities. Cicadas also figured within the work as a visual response to the Brood II emergence during 2013.[129] Oversize power towers, plasma cut from metal, were wired with blinking red lights. Crisscrossing electrical wires functioned as large gestural patterns, subdividing the space and terminating in a field of windmills. The windmills stood as a vestige of hope for a new consciousness surrounding landscapes of energy.

Ultimately, *Subrural* was a meditation on the desire for control, shifting boundaries, and the environment. Rather than a specific protest or a call to action, *Subrural* was a series of observations about the changing rural landscape, based on personal experience and the overarching narrative informed by *The Omnivore's Dilemma*. Contemporary societies string wires and roads together, connecting and implicating us all in an ever-burning thirst for energy and development. Likewise, our actions are invasive upon the landscape and climate, not unlike the plants and insects we seek to manage and control.

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[129] Periodic cicadas are unique in their combination of long, prime-numbered life cycles (13 or 17 years), precisely timed mass emergences, and active choruses. See: Magicicada Mapping Project, 2015.

Design Rationale: Spiraling Corn Production

Spiraling Corn Production is the first and most straightforward data representation of the three sculptures, stemming from a desire to visualize the rampant upward spiral of both US corn production and population (Figure 1 and 2). I materialized this sculpture as if it was vertically extruding data from a flat page, as if from a two-dimensional graph. In the finished piece, the spiral moves counterclockwise around an invisible center point, with the vertical walls moving upward from a height of 1" at the beginning outside edge to 15" high at the inner ring. The vertical walls of the spiral represent the United States' population growth as documented for the years 1866 through 2014, and projected to 2016, marked in increments of 15 million per every vertical row. Population representation begins at approximately 36 million persons and ends at 318 million persons. Plotted at the top line upon this graph is the data for Annual Corn, Harvested Acres, in Millions, marked with red spacers and florescent yellow diamonds. Years are indicated on the bottom edge of the spiral. Population values are indicated in the innermost spiral and on the very outer rim, and fluctuations account for the uneven top, as the growth of both population and agricultural production is visualized on a steady incline. The horizontal length of the spiral is guided by the number of years for which data is gathered, from 1866 to 2014, and projected data to 2016, with the most recent years positioned centrally in the spiral. The relationship of production to population growth is maintained logically within the work. *Spiraling Corn Production* represents exactly 150 years of data, plotted every two years.

Since this was the first sculpture created, I was cautious with the amount of information visualized in order to avoid optical confusion. I limited the information to every two years of census population data and the millions of acres of harvested corn. When first analyzing the data for *Spiraling Corn Production*, I remembered Hick's Law: the time required to make a decision

increases as the number of variables increases (Hick, 1952). I was struggling with how to handle data and form. Accordingly, I tried to simplify the data set in order to make design decisions. To further my understanding of the data, I took it one step further by creating a clear relationship by adjusting the Production of Bushels for population growth in order to understand the actual growth of the corn crop. However, once it came to plotting this data dimensionally, I made the choice not to include the "Adjusted for Population" part of the dataset. The sculpture was already complete in its simplicity.

Spiraling Corn Production: Reading the Data and Preliminary Conclusions

A preliminary analysis of the adjusted-for-population bushel production dataset shows irregularities in production over the years. A number of years stand out for remarkably low yield, including 1934, where production dropped from over 16 bushels of corn per person to just over 9. Small harvests raise questions: was there a drought or some other natural disaster that adversely impacted the harvest? Did farmers purposely grow less corn because of decreased prices? Publications from 1934 indicate that an intense drought in the Midwest combined with the arbitrary curtailment of acreage from the Agricultural Adjustment Act of 1933 drastically impacted farming yields (Chicago Tribune, 1934). The year 1983 showed a similar drop in the harvest, and research reveals that a wet, rainy spring season resulted in significant planting delays and impacted pollination (Thomison and Geyer, 2013). The data used for *Spiraling Corn Production* conclusively show that the ratio of bushels per person more than doubled from 20 bushels per person in 1866 to 43 per person in 2013. Seeing inconsistencies with the data while creating the sculpture helped me make meaning and understand the explosive rate of monoculture corn production. I achieved my goals with *Spiraling Corn Production* but wanted to

have a more inventive, interpretive, and comparative approach with the next data series and accompanying sculpture.

Design Rationale: High-Fructose Towers

High-Fructose Towers represent a very small slice of data from three non-consecutive years (Figure 3). Rather than representing a series of annualized datasets, the sculpture shows a comparative relationship amongst US population, corn sweetener production and individual consumption of said sweetener. I originally conceived of this design as if it were a pop-up, constrained to one sheet of paper. After visual analysis, I altered the sculpture by transferring the elements from the single sheet to a crisscrossed cut ground. Three towers stand vertically from the flat surface, with separate forms moving up the tower architecture like vines. Each of the impossibly high towers are stabilized with guy lines that cross over one another. The shifts within this piece are subtle but noticeable, from the varying heights of each tower, to the number of concentric rings moving upward, and finally to the amount of amassed corn seeds in front of each tower. The towers buckle and twist because of their architectural structure, a visual response to the broken structure of the US food economy.

The swaying architecture, curving organic forms, and narrow line weights of *High-Fructose Towers* were in direct response to the compositional elements of *Spiraling Corn Production.* I appreciated the visual weight of the curved spiraling grid, but wanted to work with considerably more delicate and smaller-scale objects. Another design change included positioning all drawn elements within the edges of one 16” x 12” sheet of paper. Beginning with the towers, I assigned each triangular cutout a numeric value of 1 million in population. Each discrete tower represents the total population of the United States for that given year, and rises accordingly in height to account for changes. For example, in 1980, there was a total population

of 227 million; in 1999, the population grew to 272 million; and by 2012, the population increased to 314 million individuals. The third and final tower is appropriately taller than the first two. Positioned slightly in front of each tower, amassed individual corn seeds represent the planted acres of corn in millions. These seeds are characterized by a noticeable lack of order, more like shrubbery and not like organized, straight rows. Because of this organic composition they reject a simple visual comparison that could be reached by counting. Lifting out from each mass of corn seeds are concentric radiating rings, each ring equaling two pounds of corn sweetener consumed by an individual annually.

High-Fructose Towers: Reading the Data and Preliminary Conclusions

I approached this dataset differently than that for *Spiraling Corn Production* in that I looked for obvious discrepancies within the data. My search was limited by the availability of data for corn sugar usage, which is available from 1966 to the present. Within a total of forty-nine years three were distinctive: 1980, 1999, and 2012 are marked because at least one portion of the discrete data was unusually high within each information grouping. For example, in 1980, the number of planted acres was a total of 84 million, a growth of 27% since 1966. Succeeding years resulted in fewer planted acres until 2012. In 1999, individual consumption of corn sweeteners reached a record high by more than doubling, as if individuals were laboring to try to consume all the excessive corn that was harvested by adding more than 49 pounds of the stuff to their diet. In 2012, 97.3 million acres of corn were planted, but corn sweetener consumption had tapered off by more than 20 pounds per person to 61 pounds per person.

On a quick first read, the number of planted acres in 1980 indicate a major growth in corn production. According to research, the expansion of corn cropland is due to expanded use of genetically modified hybrid corn seed, chemical fertilizers like nitrogen, ammonia anhydride,

and potassium, and chemical insecticides and herbicides.[130] The collected data also shows that corn sweetener consumption has been on a decline since its record high in 1999, when Americans were eating almost 85 pounds each. This finding of declining corn sugar consumption is corroborated in a number of publications discussing how the American population is consuming considerably less corn sugar.[131] As for the high number of acres planted with corn in 2012, unusually warm weather across the Midwestern states in early March and April allowed for an early start to the planting season (Irwin and Good, 2012).

Design Rationale: Biotech Silo

Biotech Silo plots fifteen consecutive years of data pertaining to genetically modified corn production (Figure 4). The sculpture is in the form of a raised agricultural grain storage silo, an element ubiquitous with large-scale agribusiness farming. I decided to build the silo in response to my own shock at the pervasive use of genetically modified seeds. Data drove the sculptural form (Figure 16). The sculpture was also made in consideration and response to both *Spiraling Corn Production* and *High-Fructose Towers*. The silo was my first choice of object because I wanted to make an immediately recognizable form, structurally sound and self-supporting like the spiral and conspicuously delicate like the towers. This final sculpture also allowed for a considerable amount of architectural complexity and multiple sheets of paper to achieve a stratified interior and exterior cylinder. I was interested in returning to annualized, comparative data representation in order to best show the massive adoption of genetically engineered corn seed since 2000.

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[130] Arturo Warman offers critical insight into the industrialized corn farming complex, see Warman, 2003.

[131] A number of articles corroborate the numerical data. See: Bjerga, 2013; Sosland, 2014; Welsh et. al., 2011.

Annual data is visualized clockwise around the silo and vertically up the walls in two overlapping layers, which overlays harvested acreage with the percentage of biotech acreage. The interior cylinder plots the data for harvested acreage. The data is represented as thin curvilinear rows, growing upward and separated by year. Each vertical column indicates the number of harvested acres, in millions from 2000 - 2015. For example, in 2013 87.45 million acres of corn were harvested and in 2014, 83.13 million acres were harvested. The overall percentage of biotech hybrids is marked numerically upon the overlaid exterior grid, which also functions as an indicator for millions of acres. The vertical and horizontal grid lines are 1/16" in width and ⅜" x ⅞" increments. Each vertical increment denotes 50 million acres of corn harvest, moving vertically from bottom (at zero acres) to top (at 90 million acres). Numerical percentages associated with data Biotech corn planting is plotted upon the exterior cylinder.

Biotech Silo: Reading the Data and Preliminary Conclusions

The data clearly shows that the overall planted acreage of genetically engineered corn rose dramatically since 2000, when only 26% of the corn harvest was GMO. By 2013, biotech corn hybrids were planted in more than 93% of overall US acreage, with the highest number of acres harvested in the data set, topping out at 87.451 million acres of corn harvested. The data also shows that corn prices, displayed in dollars per bushel, reached an all-time high in 2012, with corn reaching a top price of $6.89.

The rise of GMO crops indicates an overall rise in the use of chemical herbicides and insecticides. Data indicates that while herbicide use on corn dropped for a short time by 42 million pounds (15 percent) between 1998 and 2001, weeds had already developed resistance to glyphosate because of the overall use of herbicide. Because of the resistance, total herbicide use then increased by 81.2 million pounds (26%) between 2001 and 2010 and is adversely impacting

the environment.[132] In an early moment of hope, preliminary reports find that farmers are choosing to plant more GMO-free crops in response to consumer demand.[133] Related research shows that the amount of biotech acreage may plateau, as farmers are receiving higher prices for organically grown non-GMO corn and are returning to organic corn production (Foreman, 2010). Hopefully, this trend will continue so that we will see a drop in the use of genetically modified seeds. Overall corn prices in 2012 were high because of a nationwide drought which negatively impacted supply (Yousef, 2012). The harvest in 2015 is predicted to be low because of high rainfall, which will contribute to higher corn grain prices, which will temporarily obscure the actual difference in value between GMO and organic crops.

Relevance in the Field

A variety of modes of visualizing environmental information are indicative of our changing perception of our human impact upon the environment. The field of EV ranges from layered site-specific public art installations to interpretive sculptures to drawings to screen-based works. This complexity can result from multivariate datasets, but equally as well from abstract conceptual processes and material choices. All EV artworks use environmental information as raw material to fuel sculptural, video-based, and static two-dimensional forms that can question cultural practices. EV can be an interpretative communication of massive amounts of data and teach us something about our environment, as exemplified with *Wind Map*. EV can also communicate a smaller sampling of data and give us insight into an artist's process, as

[132] For a thorough discussion of GMO environmental impact, see Food and Water Watch. 2013; USGS, 2014; Swanson, 2013; Gish et. al., 2011.

[133] The tide of GMO is beginning to change course, see: Bunge, 2012.

demonstrated with Natalie Miebach's *Tides and Poles* series. The EV artists and projects discussed were foundational for my research and creative project. I engaged their precedents with research-guided decisions. The variety of different approaches shaped the ways in which I approach data as a material and a driving conceptual framework. *Sculpting Corn Production* furthers the field of EV because it goes beyond a two-dimensional, screen-based work to materialize in three-dimensions environmental data that is related to corn production. The use of cut and manipulated paper as a sculptural form is a mode of representation new to EV; the dataset of corn production is also a new contribution, differing from more popular discussions of energy use, atmospheric conditions, changing weather patterns, and life-cycles of non-human organisms. However, projects regarding food production, distribution, consumption, and alternative methods of preparation are becoming more prevalent as we connect our food requirements with climate change.

Certainly there are a number of quality visualization resources connected to corn production and interrelated areas of interest, but none are three-dimensional EVs. Extensive two-dimensional graphs and charts document corn production, relaying farm and economic information simply in layouts that are all business (Figure 5).[134] The material contents of corn are denoted as well in graphical form, in the elementary "Components of Yellow Dent Corn (Figure 6)[135] and in the discursive "Kernel Characteristics" (Figure 7).[136] Charles Hornbaker et al.

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[134] These graphs are produced by the authors of the annual brochure and online data system, *World of Corn.* The "US Select Crop Value" graph is a comparison amongst oats, barley, sorghum, wheat, soybeans, and corn for 2013, and projections of total production in 2014. See: NCGA, 2015.

[135] Ibid. Yellow dent corn is 62% starch, 19.2% protein and fiber, 15% moisture, and 3.8% oil. Most of the corn grown in the United States dent corn or a closely related variety derived from it. Dent corn is used in food manufacturing as the base ingredient for cornmeal flour, corn chips, tortillas and taco shells. Starch derived from this high-starch content variety is turned into plastics, as well as fructose which is used as a sweetener in many processed foods and soft drinks. See: Ibid, 2015a.

created a video visualization in 2014 documenting US crop harvesting data (Figure 8) (2014). Christian Frankenberg et al. have visualized the first accurate retrievals of chlorophyll fluorescence from space as an indicator of photosynthetic activity (Figure 9) (2013). Michael Pecirno created a single subject map regarding corn acreage in the US (Figure 10) (2014). Flapjack Media visualized changes in the US corn industry (Figure 11) (2013). Cheney and Ellis visualized corn production in the movie, *King Corn* (2009). In a different vein, scientists are studying GMO corn and have textually visualized the dynamic genetic changes in the maize genome (Figure 12) (Jiao, 2012). Guo Xinyu et al. have constructed a geometric modeling and visualization of corn (2006). Researchers have successfully sequenced the maize genome for breeding purposes, and have visualized the ten chromosomes of its genome, showing its complicated structure and revealing related segments (Figure 13) (NSF, 2009). In the larger scope of food production, artists like EcoArtTech are working to reestablish a participatory and imaginative food system, and exhibitions like *Foodshed: Agriculture and Art In Action* (2015) are highlighting agricultural practices and artist activism.[137]

In 2012 I attended a keynote presentation by Nathalie Miebach at the Betascape conference in Baltimore, where she discussed the fluidity of data as a medium. Miebach believes that data is a continuously changing material with its own current. Her articulation of these key aspects of data helped me to reframe my whole approach to the substance of information, enabling my understanding of that which was germane within the numbers. In this process I learned how to see in the information what was relevant, which in turn supported my

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[136] For a primer on corn starch digestibility, see: Mahana, 2015.

[137] *Foodshed: Agriculture and Art in Action* (2015) was an exhibition of upstate/downstate NY artists who work with food and agriculture. Curated by Amy Lipton, the exhibition featured sustainable agriculture, entrepreneurship, and artists' use of food as subject matter or medium. See: Lipton, 2014.

comprehension of the narrative embedded within the data.[138] Alphabetized, ordered, tabulated, numerical data was not a familiar substrate, however, and during the time of collection and analysis I learned new ways of working. My first response was to gather masses of information, but even with so many raw materials to work with, I encountered a steep learning curve with these three sculptures. Everything seemed important, all data was pertinent and interrelated. In *Massive Change*, author and designer Bruce Mau expressed, "When everything is connected to everything else, for better or worse, everything matters" (2004, 129). After I learned how the data could be parsed I was then able to implement a system of analysis that helped me process it into form.

Some data was gathered that was not visualized, not because it was not pertinent, but because I chose to keep the data sets abridged. This choice was both clarified and inspired by *Wind Map* because of the work's aesthetic simplicity and immediate ability to communicate information. Certain interconnected data was excluded, including annual data from the USDA's Supplemental Nutrition Assistance Programs since 1969; historical obesity levels for adults and children in the US for the same period; water, land, and air pollution data since 2000; soil erosion information for the same period; annual financial data related to the crop since 1866; fuel and energy use per acre for crop row production; annual USDA budgets since 2000, and projected costs for alternative tillage systems. During the course of the research and numerical comparisons, I found that many of the government-released statements (financial and otherwise) did not match when cross-referenced. The discrepancies did not interfere with my analysis,

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[138] In their essay "Relevance Theory," social and cognitive scientists Dan Sperber and Deirdre Wilson discuss that verbal and non-verbal expression and recognition of intentions are essential features of human communication. They argue that "relevance is a potential property not only of utterances and other observable phenomena, but of thoughts, memories and conclusions of inferences. In relevance-theoretic terms, any external stimulus or internal representation which provides an input to cognitive processes may be relevant to an individual at some time." See: Wilson and Sperber. 2004.

however, the data inconsistency did prove one thing: governmental reports may contain incorrect data. My decision to abridge the dataset differed from Miebach's process, where data was layered upon itself until it became visually chaotic. I chose to keep my dataset simple and minimize the layers of data within each sculpture.

One of the unexpected results of this research is the enabling of my multivariate analysis of crop data. Though this is not visualized per se in the creative project, ties among networks have been illuminated that expose causality in patterns and relationships. In *Beautiful Evidence*, Tufte articulates that the complex and interesting worlds that we try to understand are essentially multivariate. This is vital because:

> The analysis of cause and effect, initially bivariate, quickly becomes multivariate through such necessary elaborations as the conditions under which the causal relations holds, interactions effects, multiple causes, multiple effects, causal sequences, sources of bias, spurious correlations, sources of measurement error, competing variables, and whether the alleged cause is merely a proxy of a market variable (2006, 129).

Close, ongoing reading of these manifold datasets enriched my interpretation of corn production.

The research also led me to understand the breadth of the EV field. Though there are as many forms of EV as topics that are visualized, there have not as yet been any EV projects on corn production. Furthermore, there are only a few sculptural EV projects. *Sculpting Corn Production* is a point of engagement with the corn production industry in the United States, it functions as a way for me to understand our devastated monoculture landscapes and the widespread consumption of refined corn products, and to comprehend the financial structures that continue to support the production of a product that is expensive in almost every way. The EV also informs new processes, concept development, and ways of deployment for studio work. The creative project is a platform for my future work as an artist and scholar.

Future Research and Creative Works

Not a day has passed without considering the data I collected and how it may be extrapolated further into new discrete paper sculptures. *Sculpting Corn Production* was the first time that I interpreted numerical data into sculptural form and is a benchmark point of transition for my studio process. I am excited about this direction for my studio process and will continue to develop food-related sculptural EV and related didactic materials for the specific purpose of exhibition. I am more comfortable now with corn production datasets, and have a series of new, more complex datasets. These datasets will incorporate related areas of interest including land erosion and pollution, petroleum and energy demands / use, and obesity. The future sculptures informed by these datasets will have a more fluid, interpretive approach to form. While their form will not be completely decoupled from the data, the structures will be less rigid and architectural. These sculptures will continue to be delicate, layered paper forms and a personal examination of the corn-production industry. I also plan on developing a series of related didactic materials consisting of text for a deeper understanding of the data and the sculptural interpretation. After these new EV sculptures and their accompanying didactics are completed, I will work to exhibit *Sculpting Corn Production* in a gallery setting.

Because of this foundational data-intensive research, my creative works are diverging to new areas of research and production. Data interpretation will play a key role in these developments and has evolved into a series of new projects concerned with power consumption, the generation and transduction of energy, and the infrastructure of energy landscapes. The future of my research and creative process are informed by EV work and research.

Through the research and the creative project I learned how to collect data, understand and translate information into form, look for relevancy and meaning within the data. *Sculpting*

Corn Production is foundational, and moves beyond the type of information, the process of visualizing data, and the mode of representation. One of the most important takeaways from the combined research and creative project is my adoption of a research methodology, which has changed the ways in which I work. From numerical data collection, to understanding the prior research in a chosen area, to the deployment of concepts into physical form, I am working toward being thorough and sensitive with the chosen project, as discussed in the following two sections. The other important change in my practice is the change in the type of questions I ask, informed by Jeremijenko's artistic process of questioning:

> All I do is ask questions: "How can I use this to do this?" or "How can we improve water quality?" Asking good questions is a fundamental skill and I would argue that it's the way to cut through a lot of disciplinary divides. Intellectuals I admire have just asked generally interesting questions. It's something you develop over years and years and years and I'm hoping to move towards mastery of this skill to ask questions clearly and simply (Substratum, 2013).

I will continue to ask more sensitive, informed, and interesting questions in my future work, and I, too, see the development of asking good questions as a lifelong goal. Asking good questions supports data fluency and moves beyond data visualization and into action.

EV supports comprehension and ecological awareness. Jeremijenko articulates how her artistic practice transformed from visualization into legible, interpretive forms and representations. These forms are varied, wherein data can be used for positive ecological change:

> I'm not really interested in data literacy or even the politics of data anymore. I'm interested in fluency: being able to use the data to really act and change the world and to know that – even within this context of irreducibly complex socio-ecological systems – there's always incomplete information…It's not just about beautiful visualizations, it's about how that couples into producing viable, doable actions that can aggregate into real systems change (Substratum, 2011).

For my future studio work and research, I am interested in transformative work that includes both beautiful visualizations and doable actions for environmental support. While I understand Jeremijenko's conceptual move from beauty, I am interested in artwork that will reach a broad

audience on an aesthetic level. I also look to the methodologies of strategic design for changing the way we engage ecology in urban areas.

Collaborative Practice

My studio practice has evolved since beginning my studies at Virginia Commonwealth University in 2007. One significant change is that my practice has expanded to become collaborative - a change that began in 2008 when I started working with others to realize projects. After completing the MATX coursework, I participated in a series of artist residencies across the country. It was during this time in 2009 that I met my longtime collaborator, Matthew McCormack during a residency where we were making public sculpture with reclaimed materials. We recognized mutual interests in energy, technology, and our environment. Together we investigate the connections between ecology, industry, science and identity. Since 2009 we have been working together in all aspects of concept and production in regards to studio research and creative works, with the exception of my dissertation research and creative project. However, the following discussion of *Kinetic Light Instruments* and *Desert Crickets* are projects conceived and produced in collaboration with McCormack.

Ongoing Project: Kinetic Light Instruments

Kinetic Light Instruments is interdisciplinary and unites the fields of artistic and technical research, arranged performance, public installation, and social interaction. These instruments include a series of drums, and more recently, rattles. Related to EV through the use of sensors and related technology, the drums respond to energy input via a transducer. They light up when played without the use of batteries or any external power. These sensitive kinetic light instruments merge technology with the material of light and sound, adding the dimension of light

to physical movement and percussive acoustics. The instruments are user-powered. When they are played - banged, hit, tapped, shaken, and turned over - the vibrations create electricity. The generated energy powers ultra bright LEDs, which light up with every movement. To this end, we are researching materials and devices that transform vibrational energy into electrical power. The drums use speaker transducers, and the rattle instruments use piezo-electric technology in tandem with custom wiring harnesses to create energy.

The overarching goal is twofold. The research includes developing permanent and semi-permanent sculptural installations of *Kinetic Light Instruments* and future kinetic light objects. These objects are currently for public interaction and performance, and will be for future environmental installation. They are at their core about renewable and generative energy sources. The drums are percussion instruments that are designed to withstand the elements and intense human interaction while displaying unique and sensitive light patterns intimately connected to human movement. In our findings, we have learned that in order to achieve maximum luminosity and best aural resonance with any drumhead, the interior of the drum needs to be shaped / tuned properly to the resonant frequencies of the transducer and the shell. The kinetic rattles project commenced as a result of our preliminary research into the drums. The *Kinetic Light Rattles* are complex forms, requiring an understanding of piezo mechanics, interior structural solutions as they relate to industrial manufacturing and to human motion, and the mechanics of light diffusion. Our first rattles were 6’ long performance art objects created specifically for dancers. Extreme use in Step Afrika!’s rehearsal and performances revealed key weaknesses in our design. We rebuilt the rattles, taking into account several of the observations. Since then, smaller interpretations of this instrument have been developed. This is due, in part, to end-user demand for hand-held performance objects constructed on a small scale.

Kinetic Light Instruments significantly further the fields of percussive, interactive light sculpture because the light and sound are human-generated, making the correlation between movement and sound visible. *Kinetic Light Instruments* are also one of the first user-powered electromechanical kinesthetic instruments that can be packaged for the public and have the potential to be created in more dynamic physical forms for public performance. Other contemporary exertion instrument projects use light and sound in concert with piezo-electric technology in unusual ways but are unnecessarily complex (Qi, 2011). Piezo-electric implementation is also applied specifically for stringed instruments (Matthews, M. 1989; Fishman, L. 1993; Takabayashi, Y., 2008). There is a long history of the correlation with synesthesia and between light, sound, and optics (Hertz, P. 1999; Olivier, D. 2010; Manning, P. 2012; Garro, D. 2012). *Kinetic Light Instruments* are informed by the 20th century synesthetes, such as Wassily Kandinsky and Alexander Scriabin, who sought to create an imagined "visual music," an ideal synthesis of music and visual art, with human-generated power.

Our research combines known formulas in piezo-electric energy harvesting, without any storage. The understanding of piezo-electric generation is well documented (Mitcheson, P., T. Green, E. Yeatman, and A. Holmes, 2004; Anton, S. and H. Sodano, 2007; Hanlon, M. 2008; Garvey, J. 2010; Piezo Systems, 2013). Our use of LEDs and analog circuitry also relate to emerging technology. Our instruments feature the brightest and lowest power LEDs and the most efficient diode rectifiers currently available on the consumer market. Our design work is increasingly done in CAD, specifically in SolidWorks, and we have learned from recent

conversations with industrial manufacturers that we need to develop these instruments with circuit boards and pick-and-place industry technology.[139]

In 2014 we were commissioned to build a series of kinetic light drums and step platforms for Step Afrika!'s *Green is the New Black* performance in Washington, D.C., and Houston, Texas. We designed, tested, and built the first energy harvesting platforms specifically for contemporary step dancing. Fully designed in Solidworks CAD, the platforms featured acoustically tuned cavities and horn guides that strongly coupled the movement from the birch plywood dance surface to the Eminence transducers. Our prototype was chosen over several established generative floor solution providers because of cost and performance. The harvested energy powered a series of onstage luminaries.

The collaboration with Step Afrika! is extremely fruitful and has led to two collaborative research explorations. The first is with Dr. Jaret Riddick from the U.S. Army Research Laboratory at the Aberdeen Proving Ground. Together we will be authoring a white paper for publication regarding energy generation technology and its impact on the arts and culture in the U.S., and its potential overseas. The second is with Dr. Christopher D. Meyer with the Sensors & Electron Devices Directorate at the U.S. Army Research Laboratory in Adelphi, who is offering technical engineering support for a series of connected transducers, resulting in increased energy generation.

The research and production for *Kinetic Light Instruments*, and specifically the step dancing platforms, are foundational for a future EV project, tentatively titled *Rain Pool*. At this

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[139] SMT (surface mount technology) component placement systems, commonly called pick-and-place machines or P&Ps, are robotic machines which are used to place surface-mount devices (SMDs) onto a printed circuit board (PCB). They are used for high speed, high precision placing of broad range of electronic components, like capacitors, resistors, integrated circuits onto the PCBs which are in turn used in computers, consumer electronics as well as industrial, medical, automotive, military and telecommunications equipment. See: Jacobsen-Weaver and Eisenberg, 2015.

stage, *Rain Pool* is purely a conceptual environmental project, but we are developing the knowledge, tools, and equipment with *Kinetic Light Instruments* to enable the creation of the sculptures. *Rain Pool* is a series of responsive light sculptures that will transmit information about fluctuating rainfall, including the frequency and scale of the raindrops. The interior mechanism may rely upon an accelerometer to detect the subtle input of the rainfall, use LED lights for illumination, and require an external power source, such as a solar panel and energy storage system. Each sculpture will be a touch-sensitive waterless "pool" installed outdoors. The forms will take shape as smooth white puddles. Embedded in the landscape, these pools will react by illuminating when rained upon, brightly glowing as the rainfall increases and fading as the frequency decreases. As an installation, the work will consist of three or more glowing "pools" that visually transmit immediate rainfall information with softly glowing light. They may also function as remotely sensing databanks, collecting data on localized areas of rainfall that could be employed for evaluative purposes.

Future EV Project: Desert Cricket

One new EV project is the *Desert Cricket,* a series of objects that visually transmit environmental data inspired by the random blinking of fireflies and the melodious chirping of crickets. The *Desert Cricket* is a series of environmentally powered and visually responsive sculptures that will transmit information about changing atmospheric temperature through the transformation of energy into light for installation in an outdoor environment. Inspired by the flickering of fireflies and the singing of crickets in the evening, the project combines a firefly's light production with a cricket's chirping. The *Desert Cricket* will blink and fade an LED in correlation to the temperature in order to mimic the behavioral chirping of actual crickets. As the atmospheric temperature rises, the LED light will blink faster or have a longer fade between off-

times. As an environmental installation, the work will consist of hundreds of flickering devices within the desert landscape, an electro - technological proxy for the phenomenology of two different biological organisms.

Fireflies and crickets have a series of biological traits defining their behavior. The bioluminescence of fireflies, or Lampyridae**,** is well documented,[140] a phenomenon controlled by the release of oxygen within the organism. What humans see as randomized blinking is actually luminescence triggered for a number of reasons, including larval glow indicating the presence of a defensive steroid and the unique flash patterns identifying species and members of the opposite sex. The cricket is a living thermometer made evident by its calling song. Its chirping comes in a variety of styles announcing a mating call, a triumphal song after mating, and an aggressive song to repel other nearby males. The speed and frequency of the cricket chirp is termed Dolbear's Law, which is the relationship of temperature and rate of chirping (Dolbear, 87).

Though not all visual aspects have been outlined, the *Desert Cricket* is a sculpture that will visualize environmental data by blinking a LED projected with a Fresnel lens. A Peltier device or a solar panel will provide power. I will research heat syncs, thermal transfer equations, power storage issues, and microprocessor control for the sculpture. With thoughtful design, a Peltier device would yield enough output to power a device through the night. The temperature relationship to the pulsing light may be related to thermal characteristics of charge storage components instead of a separate resistive thermometer. Other research questions include the following technical concerns: Can thermoelectric generators be used to power discrete LED devices in remote installations? Will microcontrollers or analog circuitry more efficiently control

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[140] For a simple overview documenting firefly bioluminescence, see: Branham, 2005.
For an in-depth review of bioluminescence, see: Branchini et. al., 2015; Branchini, 2013; Seliger and McElroy, 1960.

the device? I will need to calculate the potential energy gains for 12 hours of power, including comparing the energy needed with the energy generation possible from a thermoelectric material. One decision also includes going with either thermal or solar power. The final form of the object will be based on material availability, budget, and concept. Finally the last thing to consider is what other environmental information could be visualized with this sculptural form.

I hypothesize that the *Desert Cricket* will be a beautiful, functional object and contribute to knowledge generation in the field of EV. The sculpture will contribute new knowledge in distributed energy production and remote sensing, and could function as an environmental data collector for evaluative purposes. In this way, it could be installed in other locations, recording and transmitting data for a dynamic visualization website, extending the life and reach of each individual object. The *Desert Cricket* could also be designed for household use and a successful environmental installation *en masse*.

Conclusion

My creative project, *Sculpting Corn Production*, exemplifies the broadened definition of EV through its mode of representation. *Sculpting Corn Production* was in part a personal exploration of the corn industry because of my feelings of environmental distress from the negative impacts of monoculture farming. The series includes three discrete sculptures and separate datasets using information from the USDA from 1866 to the present, including farming Business Reports; Feed Grains Yearbooks Summary of Business, Yearbook Tables, and Feed Grains Database; Agricultural Projections to 2024; and granular data relating to corn in costs and returns. Data was collected regarding the main issues surrounding industrial corn production and processing contextualized the numerical information, including the impact of ethanol subsidies on global corn production, the contribution of processed corn to nutrition and nationwide obesity

levels, data on USDA nutrition programs, environmental degradation due to chemical usage, and the evolution of corn including genome-wide changes during the breeding of maize.

Spiraling Corn Production visualizes 150 years of data of corn production in relationship to population growth. A preliminary analysis of the adjusted-for-population bushel production dataset shows irregularities in production over the years, and that the ratio of bushels per person more than doubled from 20 bushels per person in 1866 to 43 per person in 2013. *High-Fructose Towers* used a comparative approach with the next data series and accompanying sculpture, visualizing corn sugar usage data from 1966 to the present. Within a total of forty-nine years three were distinctive, including 1980, 1999, and 2012. Corn sweetener consumption has been on a decline since its record high in 1999, when Americans were eating almost 85 pounds each. *Biotech Silo* plots fifteen consecutive years of data pertaining to genetically modified corn production, and was a return to annualized, comparative data representation to show the massive adoption of genetically engineered corn seed since 2000. By 2013, biotech corn hybrids were planted in more than 93% of overall US acreage, the year after the price per bushel reached an all-time high. The rise of GMO crops indicate an overall rise in the use of chemical herbicides and insecticides, but preliminary reports find that farmers are choosing to plant more GMO-free crops in response to consumer demand.

Sculpting Corn Production furthers the field of EV because it goes beyond a two-dimensional, screen-based work to materialize in three-dimensions environmental data that is related to corn production. The use of cut and manipulated paper as a sculptural form is a mode of representation new to EV; the dataset of corn production is also a new contribution, differing from more popular discussions of energy use, atmospheric conditions, changing weather patterns, and life-cycles of non-human organisms.

The research and creative project informs new processes, concept development, ways of deployment for studio work, and most importantly, the adoption of a research methodology. Through this process I understand the importance of personal expression in data-interpretive EV in order to create beautiful and transformative works. The creative project is a platform for my future work as an artist and scholar, informing my studio process which is diverging to new areas of research and production. These future works will be data interpretations and visualizations, a series of new projects concerned with environmental visualization, power consumption, the generation and transduction of energy, and the infrastructure of energy landscapes.

Conclusion

This dissertation, *Expanding Eco-Visualization: Sculpting Corn Production*, connects my pursuits in contemporary art, data visualization, and ecology. My research primarily investigated eco-visualization artwork which is a relatively new field dominated by concerns related to ecological crises. Eco-visualization (EV) is a subset of information visualization that concerns itself with visualizing data regarding the environment. EV was originally defined in 2006 as a way to display the real time consumption statistics of key environmental resources for the goal of promoting ecological literacy. Later EV definitions suggested that EV could be site-specific, controlled by a computer or associated electronic technology. I assert that the final form of eco-visualization artworks are not necessarily dependent on technology, and that in fact, the small amount of literature on the subject is too limiting in its definition. EV artworks can differ in terms of media used, in that they can be sculptural, video-based, or static two-dimensional forms that communicate this environmental information. They are creative interpretations of information that visually reveal statistical data and the effects of political and socio-spatial systems upon the environment. EVs are political acts, situated in a particularly charged climate of rising awareness and human accountability, acknowledging that changing ecologies are not phenomena safe from human exploitation and intervention. EVs can work collectively to change attitudes toward the environment for a positive shared future.

EV operates within the larger context of environmentalism, an attempt to balance relations amongst humans and the natural systems on which they depend in order to maintain sustainability, now and in the future. Figuring predominantly in the broader discourse about the environment is the practice of environmental ethics, the pursuit of biodiversity support, and ways to achieve ecological balance. This eco-centric behavior depends on an individual person's

awareness of the effects of human action, including energy consumption, land-use practices, and strategies (including the lack thereof) for dealing with atmospheric pollution. My personal experience of solastalgia carried through and informed my process during the research and creative project. This phenomenon is a documented form of psychic distress resulting from negatively perceived environmental change. However, EV art can work to heal psychoterratic illness. Albrecht contends that

> The defeat of solastalgia and non-sustainability will require that all of our emotional, intellectual and practical efforts be redirected towards healing the rift that has occurred between ecosystem and human health...the full transdisciplinary idea of health involves the healing of solastalgia via cultural responses to degradation of the environment in the form of drama, art, dance and song at all scales of living from the bioregional to the global (59).

However strong my own feeling of solastalgia, I remain hopeful for a positive shift in social practice and behavior through the creative strategies of cultural engagement.

I offer a broadened definition of EV, through an overview of important areas of overlap and difference in eco-visualization: structural issues, including the content type of data sets both dynamic and static; and media both digital and non-digital; functional issues, including approaches to form; and aesthetic issues, including visuality, site-specificity, and the ways in which eco-visualization may offer a critique of contemporary cultural practices. Within this context, two categories of EV emerge: one that is predominantly screen-based, and another that employs a variety of modes of representation to visualize environmental information. The second category is indicative of our changing perception of the human impact upon the environment and ecology. Screen-based works are discussed in Chapter One, and works beyond the screen in Chapter Two. The complexity of EV work can result from multiple, simultaneous datasets and abstract conceptual processes.

The first category of EV work includes dynamic projects that rely on the screen. I discuss EcoArtTech's *Eclipse* and Deverell's *Building Run*. These projects are relevant because they are interpretations of streaming, dynamic data that also allow the audience opportunity for interpretation and analysis through technological mediation. I chose these projects because of their varied compositional choices and the ways they engage sensing and technology. *Eclipse* is an online EV that harnesses the information sharing of the web. By translating current air-quality in US national parks, the web application allows viewers to see the effects of pollution imposed upon shared images of nature. *Eclipse* seeks to engage audiences removed from the actual experience through technological mediation. *Building Run* was a real-time video installation that conceptualized five buildings as competing athletes in a daily race for greater energy efficiency. The project documented real-time energy consumption using human avatars to represent each building, each running to beat its own personal best.

The second category of EV work includes projects that do not rely on the screen but use a variety of materials and processes for the final presentation. I discuss Polli's *Cloud Car* and *Particle Falls*; Miebach's series, *The Sandy Rides*; and Natalie Jeremijenko's *Mussel Choir. Cloud Car* is a site-specific EV employing static data that shows the direct connection between the automobile and air quality. The car is fitted with equipment that produces a cloud of mist, enveloping car and rider to make air tangible and visible. The second work, *Particle Falls*, is a large-scale projection driven by dynamic air quality data collected with a nephelometer. Resembling a waterfall, the blue light projection is disrupted with orange burst of light as air pollution is detected, giving the viewer immediate feedback. *The Sandy Rides* translates data related to Hurricane Sandy by employing basket weaving as a grid, upon which data is layered and interwoven in three-dimensional space. Miebach's *The Sandy Rides* expands how scientific

data may be visually translated beyond graphs and diagrams into chaotic and playful sculptures. Visual complexity is explored through EV works like *O Fortuna, Sandy Spins*, *The Last Ride*, and *The Ride* in order to question our cultural fascination with delicate coastal ecosystems and our tendency to ignore climate change. *Mussel Choir* is a bio-sensing EV artwork that aims to engage the public on water quality and the unseen complexities of urban ecology. Consisting of a live colony of a native species of mussels, the artwork monitors the water filtration activities of these organisms and converts this data into sound, which is available for passersby who can listen to the mussel choir in situ. *Mussel Choir* is an example of an eco-visualization that uses a dynamic data set and variety of media to communicate in real time, creating a bridge between humans and aquatic organisms.

The future of EV is transforming as its forms become more complex. Screen-based EV works remain prevalent, and are being deployed in ways that have the potential to stimulate change. They signal the future of EV as strategic design, transforming and shaping policy frameworks, culture, and governance in the process of their production. Future EV works require holistic frameworks, collaboration, and synthesis in prototyping ideas. The systems of policy, culture, and governance will have to work together to create both visualizations and actions to improve the environment and change our collective approach to resources on land, in water, and in the air. Future large-scale EV works like *Global Fishing Watch* are possible as corporations collaborate to collect global data.[141] Governments, federal agencies, and other global entities are also creating EV, exemplified by the White House's *Climate Data Initiative* web application that

[141] Global Fishing Watch analyzes massive amounts of satellite data to create a global view of commercial fishing. The public version will give citizens a free, global online platform to visualize, track and share information about fishing activity worldwide. The EV exposes illegal practices, and shows what is at stake for the ocean. The combination of cloud computing and massive data is enabling new tools to visualize, understand and potentially reverse harmful practices. See: Global Fishing Watch, 2014.

will visualize climate change.[142] Large-scale EV projects like *Global Fishing Watch* and *Climate Data Initiative* are indicative of a cultural acceptance that our environment is changing and the widespread acknowledgement that we need to take action. In the face of climate crisis we are working together to make positive change.

The range of current EV practice provided models for my creative project, and provided a foundation from which I developed a creative methodology. EV is a new direction for my studio work, though I have long been interested in the visualization of hidden environmental information. My creative project, *Sculpting Corn Production*, is a series of discrete paper sculptures focusing on American corn monoculture farming as a way to engage the climate. The work exemplifies the concepts and information regarding EV artwork as explored in the research investigation in a number of ways, including the strategies and functions as discussed in the Introduction. The creative project was a way for me to attempt to defeat my feelings of solastalgia. Though the research and creative project did not achieve that result, they helped me to understand how working toward a shared cultural environmentalism and sustainable practices will require that all of our emotional, intellectual and practical efforts be directed towards healing ecosystem and human health.

The creative project also presented an opportunity to engage with specific datasets in a physical and visual manner and to demonstrate the broadened definition of EV set forth in the research investigation. For instance, my chosen imagery was driven by predetermined static data

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[142] The US Government is launching a Climate Data Initiative to demonstrate real-world risks of global warming. Data will be made available from the National Oceanic and Atmospheric Administration, NASA, the U.S. Geological Survey, the Department of Defense, and other federal agencies. The first batch of climate data released will focus on coastal flooding and sea-level rise. The first version of the application will not present data visually in ways that are comprehensible to the public. The government is reaching out to researchers and developers to create data-driven simulations. See: Howard, 2014.

sets provided by US Department of Agriculture resources and created with a sense of interpretive complexity. Though the visual elements were guided by data, the resulting imagery underwent an uncoupling of shape from information and is abstract – ultimately its logic may only be available to me. The EV is a point of engagement with the corn industry in the United States; it functions as a way for me to understand our devastated monoculture landscapes and the politics, economics, and related areas of ecology of our food production. *Sculpting Corn Production* is a foundation for future work through the development of concept, the exploration of process, the interpretation / translation of data, and the deployment of information through form.

The research and creative project have been instrumental in the development of new research methodologies, including how to collect data, understand and translate information into form, and look for relevancy and meaning within the data. *Sculpting Corn Production* was foundational for my understanding of the process of visualizing data and choosing a mode of representation. For my future creative research, I am interested in transformative EV works that are beautiful visualizations in tandem with doable actions for environmental support. I look to the methodologies of strategic design for changing the way we engage ecology in urban areas, and will continue to ask informed, sensitive, and interesting questions.

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Vita

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